

such localization of excess fluid behind the failing ventricle may no longer exist. For example, patients with long-standing aortic valve disease or systemic hypertension may have ankle edema, congestive hepatomegaly, and systemic venous distention late in the course of their disease, even though the abnormal hemodynamic burden initially was placed on the left ventricle. This occurs in part because of the secondary pulmonary hypertension and resultant right-sided heart failure but also because of the retention of salt and water characteristic of all forms of heart failure (Chap. 37). The muscle bundles composing both ventricles are continuous, and both ventricles share a common wall, the interventricular septum. Also, biochemical changes that occur in heart failure and that may be involved in the impairment of myocardial function (Chap. 232), such as norepinephrine depletion and alterations in the activity of myosin ATPase, occur in the myocardium of both ventricles, regardless of the specific chamber on which the abnormal hemodynamic burden is placed initially.

BACKWARD VERSUS FORWARD HEART FAILURE For many years a controversy has revolved around the question of the mechanism of the clinical manifestations resulting from heart failure. The concept of *backward heart failure* contends that in heart failure, one or the other ventricle fails to discharge its contents or fails to fill normally. As a consequence, the pressures in the atrium and venous system behind the failing ventricle rise, and retention of sodium and water occurs as a consequence of the elevation of systemic venous and capillary pressures and the resultant transudation of fluid into the interstitial space (Chap. 37). In contrast, the proponents of the *forward heart failure* hypothesis maintain that the clinical manifestations of heart failure result directly from an inadequate discharge of blood into the arterial system. According to this concept, salt and water retention is a consequence of diminished renal perfusion and excessive proximal tubular sodium reabsorption and of excessive distal tubular reabsorption through activation of the renin-angiotensin-aldosterone system.

A rigid distinction between *backward* and *forward* heart failure (like a rigid distinction between right and left heart failure) is artificial, since both mechanisms appear to operate to varying extents in most patients with heart failure. However, the rate of onset of heart failure often influences the clinical manifestations. For example, when a large portion of the left ventricle is suddenly destroyed, as in myocardial infarction, although stroke volume and blood pressure are suddenly reduced (both manifestations of forward failure), the patient may succumb to acute pulmonary edema, a manifestation of backward failure. If the patient survives the acute insult, clinical manifestations resulting from a chronically depressed cardiac output, including the abnormal retention of fluid within the systemic vascular bed, may develop. Similarly, in the case of massive pulmonary embolism, the right ventricle may dilate and the systemic venous pressure may rise to high levels (backward failure), or the patient may develop shock secondary to low cardiac output (forward failure), but this low-output state may have to be maintained for some days before sodium and water retention sufficient to produce peripheral edema occurs.

REDISTRIBUTION OF CARDIAC OUTPUT The redistribution of cardiac output serves as an important compensatory mechanism when cardiac output is reduced. This redistribution is most marked when a patient with heart failure exercises, but as heart failure advances, redistribution occurs even in the basal state. Blood flow is redistributed so that the delivery of oxygen to vital organs, such as the brain and myocardium, is maintained at normal or near-normal levels, while flow to less critical areas, such as the cutaneous and muscular beds and viscera, is reduced. Vasoconstriction mediated by the adrenergic nervous system is largely responsible for this redistribution, which in turn may be responsible for many of the clinical manifestations of heart failure, such as fluid accumulation (reduction of renal flow), low-grade fever (reduction of cutaneous flow), and fatigue (reduction of muscle flow).

SALT AND WATER RETENTION (See also Chap. 37)

When the volume of blood pumped by the left ventricle into the systemic vascular bed is reduced, a complex sequence of adjustments

occurs that ultimately results in the abnormal accumulation of fluid. On the one hand, many of the troubling clinical manifestations of heart failure are secondary to this excessive retention of fluid; on the other, this abnormal fluid accumulation and the expansion of blood volume that accompanies it also constitute an important compensatory mechanism that tends to maintain cardiac output and therefore perfusion of the vital organs. Except in the terminal stages of heart failure, the ventricle operates on an ascending, albeit depressed and flattened, function curve (Fig. 232-6), and the augmented ventricular end-diastolic volume and pressure characteristic of heart failure must be regarded as helping to maintain the reduced cardiac output, despite causing pulmonary and/or systemic venous congestion.

Congestive heart failure is also characterized by a complex series of neurohumoral adjustments. The activation of the adrenergic nervous system is discussed on p. 1285; there is also activation of the renin-angiotensin-aldosterone system and increased release of antidiuretic hormone. These influences elevate systemic vascular resistance and enhance sodium and water retention and potassium excretion. These actions are, to a minor extent, opposed by the release of atrial natriuretic peptide, which also occurs in congestive heart failure. Patients with severe heart failure may exhibit a reduced capacity to excrete a water load, which may result in dilutional hyponatremia. In the presence of heart failure, effective filling of the systemic arterial bed is reduced, a condition that initiates the renal and hormonal changes mentioned above.

The elevation of systemic venous pressure and the alterations of renal and adrenal function characteristic of heart failure vary in their relative importance in the production of edema in different patients with heart failure. The renin-angiotensin-aldosterone axis is activated most intensely by acute heart failure, and its activity tends to decline as heart failure becomes chronic. In patients with tricuspid valve disease or constrictive pericarditis, the elevated venous pressure and the transudation of fluid from systemic capillaries appear to play the dominant role in edema formation. On the other hand, severe edema may be present in patients with ischemic or hypertensive heart disease, in whom systemic venous pressure is within normal limits or is only minimally elevated. In such patients, the retention of salt and water is probably due primarily to a redistribution of cardiac output and a concomitant reduction in renal perfusion, as well as activation of the renin-angiotensin-aldosterone axis. Regardless of the mechanisms involved in fluid retention, untreated patients with chronic congestive heart failure have elevations of total blood volume, interstitial fluid volume, and body sodium. These abnormalities diminish after clinical compensation has been achieved by treatment.

CLINICAL MANIFESTATIONS OF HEART FAILURE

Dyspnea Respiratory distress that occurs as the result of increased effort in breathing is the most common symptom of heart failure (Chap. 32). In early heart failure, dyspnea is observed only during activity, when it may simply represent an aggravation of the breathlessness that occurs normally under these circumstances. As heart failure advances, however, dyspnea appears with progressively less strenuous activity. Ultimately, breathlessness is present even when the patient is at rest. The principal difference between exertional dyspnea in normal persons and in patients with heart failure is the degree of activity necessary to induce the symptom. Cardiac dyspnea is observed most frequently in patients with elevations of pulmonary venous and capillary pressures. Such patients usually have engorged pulmonary vessels and interstitial pulmonary edema, which may be evident on radiologic examination. This reduces the compliance of the lungs and thereby increases the work of the respiratory muscles required to inflate the lungs. The activation of receptors in the lungs results in the rapid, shallow breathing characteristic of cardiac dyspnea. The oxygen cost of breathing is increased by the excessive work of the respiratory muscles. This is coupled with the diminished delivery

of oxygen to these muscles, which occurs as a consequence of the reduced cardiac output and which may contribute to fatigue of the respiratory muscles and the sensation of shortness of breath.

Orthopnea Dyspnea in the recumbent position is usually a later manifestation of heart failure than exertional dyspnea. Orthopnea occurs because of the redistribution of fluid from the abdomen and lower extremities into the chest causing an increase in the pulmonary capillary hydrostatic pressure, as well as elevation of the diaphragm accompanying supine posture. Patients with orthopnea must elevate their heads on several pillows at night and frequently awaken short of breath or coughing (the so-called nocturnal cough) if their heads slip off the pillows. The sensation of breathlessness usually is relieved by sitting upright, since this position reduces venous return and pulmonary capillary pressure, and many patients report that they find relief from sitting in front of an open window. In far-advanced heart failure, orthopnea may become so severe that patients cannot lie down at all and must spend the entire night in a sitting position. On the other hand, in other patients with long-standing, severe left ventricular failure, symptoms of pulmonary congestion may actually diminish with time as the function of the right ventricle becomes impaired.

Paroxysmal (Nocturnal) Dyspnea This term refers to attacks of severe shortness of breath and coughing that generally occur at night, usually awaken the patient from sleep, and may be quite frightening. Though simple orthopnea may be relieved by sitting upright at the side of the bed with legs dependent, in the patient with paroxysmal nocturnal dyspnea, coughing and wheezing often persist even in this position. The depression of the respiratory center during sleep may reduce ventilation sufficiently to lower arterial oxygen tension, particularly in patients with interstitial lung edema and reduced pulmonary compliance. Also, ventricular function may be further impaired at night because of reduced adrenergic stimulation of myocardial function. *Cardiac asthma* is closely related to paroxysmal nocturnal dyspnea and nocturnal cough and is characterized by wheezing secondary to bronchospasm—most prominent at night. *Acute pulmonary edema* (Chap. 32) is a severe form of cardiac asthma due to marked elevation of pulmonary capillary pressure leading to alveolar edema, associated with extreme shortness of breath, rales over the lung fields, and the transudation and expectoration of blood-tinged fluid. If not treated promptly, acute pulmonary edema may be fatal.

Cheyne-Stokes Respiration Also known as *periodic* or *cyclic respiration*, Cheyne-Stokes respiration is characterized by diminished sensitivity of the respiratory center to arterial P_{CO_2} . There is an apneic phase, during which the arterial P_{O_2} falls and the arterial P_{CO_2} rises. These changes in the arterial blood stimulate the depressed respiratory center, resulting in hyperventilation and hypocapnia, followed in turn by recurrence of apnea. Cheyne-Stokes respiration occurs most often in patients with cerebral atherosclerosis and other cerebral lesions, but the prolongation of the circulation time from the lung to the brain that occurs in heart failure, particularly in patients with hypertension and coronary artery disease and associated cerebral vascular disease, also appears to precipitate this form of breathing.

Fatigue, Weakness, and Abdominal Symptoms These nonspecific but common symptoms of heart failure are related to the reduction of perfusion of skeletal muscle. Exercise capacity is reduced by the limited ability of the failing heart to increase its output and deliver oxygen to the exercising muscle. Anorexia and nausea associated with abdominal pain and fullness are frequent complaints and may be related to the congested liver and portal venous system.

Cerebral Symptoms In severe heart failure, particularly in elderly patients with accompanying cerebral arteriosclerosis, reduced cerebral perfusion, and arterial hypoxemia, there may be alterations in the mental state characterized by confusion, difficulty in concentration, impairment of memory, headache, insomnia, and anxiety. *Nocturia* is common in heart failure and may contribute to insomnia.

PHYSICAL FINDINGS (See Chap. 227) In moderate heart failure, the patient appears to be in no distress at rest except that he

or she may be uncomfortable when lying flat for more than a few minutes. In more severe heart failure, the pulse pressure may be diminished, reflecting a reduction in stroke volume, and occasionally, the diastolic arterial pressure is elevated as a consequence of generalized vasoconstriction. In acute heart failure, hypotension may be prominent. There may be cyanosis of the lips and nail beds and sinus tachycardia, and the patient may insist on sitting upright. *Systemic venous pressure* is often abnormally elevated in heart failure and may be recognized by observing the extent of distention of the jugular veins. In the early stages of heart failure, the venous pressure may be normal at rest but may become abnormally elevated during and immediately after exertion as well as with sustained pressure on the abdomen (positive abdominojugular reflux).

Third and fourth heart sounds are often audible but are not specific for heart failure, and *pulsus alternans*, i.e., a regular rhythm in which there is alternation of strong and weak cardiac contractions and therefore alternation in the strength of the peripheral pulses, may be present. Pulsus alternans, a sign of severe heart failure, may be detected by sphygmomanometry and in more severe instances by palpation; it frequently follows an extrasystole and is observed most commonly in patients with cardiomyopathy or hypertensive or ischemic heart disease.

Pulmonary Rales Moist, inspiratory, crepitant rales and dullness to percussion over the lung bases are common in patients with heart failure and elevated pulmonary venous and capillary pressures. In patients with pulmonary edema, rales may be heard widely over both lung fields; they are frequently coarse and sibilant and may be accompanied by expiratory wheezing. Rales may, however, be caused by many conditions other than left ventricular failure. Some patients with long-standing heart failure have no rales because of increased lymphatic drainage of alveolar fluid.

Cardiac Edema (See Chap. 37) This is usually dependent, occurring in the legs symmetrically, particularly in the pretibial region and ankles in ambulatory patients, in whom it is most prominent in the evening, and in the sacral region of individuals at bed rest. Pitting edema of the arms and face occurs rarely and then only late in the course of heart failure.

Hydrothorax and Ascites Pleural effusion in congestive heart failure results from the elevation of pleural capillary pressure and transudation of fluid into the pleural cavities. Since the pleural veins drain into both the systemic and pulmonary veins, hydrothorax occurs most commonly with marked elevation of pressure in both venous systems but also may be seen with marked elevation of pressure in either venous bed. It is more frequent in the right pleural cavity than in the left. *Ascites* also occurs as a consequence of transudation and results from increased pressure in the hepatic veins and the veins draining the peritoneum (Chap. 46). Marked ascites occurs most frequently in patients with tricuspid valve disease and constrictive pericarditis.

Congestive Hepatomegaly An enlarged, tender, pulsating liver also accompanies systemic venous hypertension and is observed not only in the same conditions in which ascites occurs but also in milder forms of heart failure from any cause. With prolonged, severe hepatomegaly, as in patients with tricuspid valve disease or chronic constrictive pericarditis, enlargement of the spleen, i.e., congestive splenomegaly, also may occur.

Jaundice This is a late finding in congestive heart failure and is associated with elevations of both the direct- and indirect-reacting bilirubin; it results from impairment of hepatic function secondary to hepatic congestion and the hepatocellular hypoxia associated with central lobular atrophy. Serum transaminase concentrations are frequently elevated. If hepatic congestion occurs acutely, the jaundice may be severe and the enzymes strikingly elevated.

Cardiac Cachexia With severe chronic heart failure there may be serious weight loss and cachexia because of (1) elevation of circulating concentrations of tumor necrosis factor; (2) elevation of the metabolic rate, which results in part from the extra work performed by the respiratory muscles, the increased oxygen needs of the hypertrophied heart, and/or the discomfort associated with severe heart failure; (3)

anorexia, nausea, and vomiting due to central causes, to digitalis intoxication, or to congestive hepatomegaly and abdominal fullness; (4) impairment of intestinal absorption due to congestion of the intestinal veins; and (5) rarely, in patients with particularly severe failure of the right side of the heart, protein-losing enteropathy.

Other Manifestations With reduction of blood flow, the extremities may be cold, pale, and diaphoretic. Urine flow is depressed, and the urine contains albumin and has a high specific gravity and a low concentration of sodium. In addition, prerenal azotemia may be present. In patients with long-standing severe heart failure, impotence and depression are common.

ROENTGENOGRAPHIC FINDINGS In addition to the enlargement of the particular chambers characteristic of the lesion responsible for heart failure, distention of pulmonary veins and redistribution to the apices is common in patients with heart failure and elevated pulmonary vascular pressures. Also, pleural effusions may be evident and associated with interlobar effusions.

DIFFERENTIAL DIAGNOSIS The diagnosis of congestive heart failure may be established by observing some combination of the clinical manifestations of heart failure described above, together with the findings characteristic of one of the etiologic forms of heart disease. Table 233-1 shows the Framingham criteria, which are useful in the diagnosis of heart failure. Since chronic heart failure is often associated with cardiac enlargement, the diagnosis should be questioned, but is by no means excluded, when all chambers are normal in size. Two-dimensional echocardiography is particularly useful in assessing the dimensions of each cardiac chamber. Heart failure may be difficult to distinguish from pulmonary disease, and the differential diagnosis is discussed in Chap. 32. Pulmonary embolism also presents many of the manifestations of heart failure, but hemoptysis, pleuritic chest pain, a right ventricular lift, and the characteristic mismatch between ventilation and perfusion on lung scan should point to this diagnosis (see Chap. 261).

Ankle edema may be due to varicose veins, cyclic edema, or gravitational effects (Chap. 37), but in these patients there is no jugular venous hypertension at rest or with pressure over the abdomen. Edema secondary to renal disease can usually be recognized by appropriate renal function tests and urinalysis and is rarely associated with elevation of venous pressure. Enlargement of the liver and ascites occur in patients with hepatic cirrhosis and also may be distinguished from heart failure by normal jugular venous pressure and absence of a positive abdominojugular reflux.

Table 233-1

Framingham Criteria for Diagnosis of Congestive Heart Failure*

MAJOR CRITERIA

- Paroxysmal nocturnal dyspnea
- Neck vein distention
- Rales
- Cardiomegaly
- Acute pulmonary edema
- S₃ gallop
- Increased venous pressure (>16 cmH₂O)
- Positive hepatojugular reflux

MINOR CRITERIA

- Extremity edema
- Night cough
- Dyspnea on exertion
- Hepatomegaly
- Pleural effusion
- Vital capacity reduced by one-third from normal
- Tachycardia (≥120 bpm)

MAJOR OR MINOR

Weight loss ≥4.5 kg over 5 days' treatment

* To establish a clinical diagnosis of congestive heart failure by these criteria, at least one major and two minor criteria are required.

SOURCE: KKL Ho et al, *Circulation* 88:107, 1993.

TREATMENT

The treatment of heart failure may be divided logically into three components: (1) removal of the precipitating cause, (2) correction of the underlying cause, and (3) control of the congestive heart failure state. The first two are discussed in other chapters together with each specific disease entity or complication. An example is the treatment of pneumococcal pneumonia and acute heart failure (removal of the precipitating cause) followed by mitral valvotomy (correction of the underlying cause) in a patient with mitral stenosis. In many instances, surgical treatment will correct or at least alleviate the underlying cause. The third component of the treatment of heart failure, i.e., control of the congestive heart failure state, may, in turn, be divided into three categories: (1) reduction of cardiac work load, including both the preload and the afterload; (2) control of excessive retention of salt and water; and (3) enhancement of myocardial contractility. The vigor with which each of these measures is pursued in any individual patient should depend on the severity of heart failure. Following effective treatment, recurrence of the clinical manifestations of heart failure can often be prevented by continuing those measures that were originally effective.

While a simple rule for the treatment of all patients with heart failure cannot be formulated because of the varied etiologies, hemodynamic features, clinical manifestations, and severity of heart failure, insofar as the treatment of chronic congestive failure is concerned, the administration of an angiotensin-converting enzyme inhibitor (e.g., lisinopril 10 mg q.d.) has been shown to retard the development of heart failure and should be begun early in patients with cardiac dilatation and/or hypertrophy, even if they are asymptomatic. Then, as symptoms develop, simple measures such as moderate restriction of activity and sodium intake should be tried (Fig. 233-1). If these and the ACE inhibitor are insufficient, therapy with a combination of a diuretic, a vasodilator, and usually a digitalis glycoside is then begun. The next step is more rigorous restriction of salt intake and higher doses of loop diuretics, sometimes accompanied by other diuretics. If heart failure persists, hospitalization with rigid salt restriction, bed rest, intravenous vasodilators, and positive inotropic agents comes next. In some patients, the order in which these measures are applied may be altered.

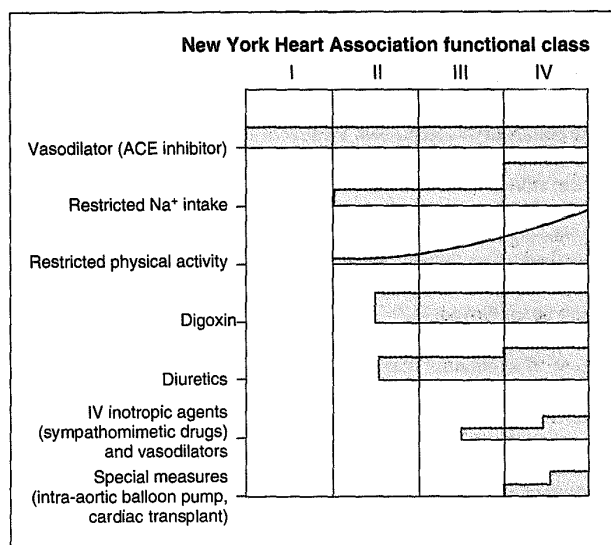


FIGURE 233-1 Overview of the treatment of heart failure. [From RA Kelly, TW Smith: *Treatment of stable heart failure: Digitalis and diuretics, in Heart Failure: Cardiac Function and Dysfunction, in WS Colucci (ed), Atlas of Heart Diseases, vol 4, E Braunwald (series ed), Philadelphia, Current Medicine, 1995.*]

COMPLICATIONS OF MYOCARDIAL INFARCTION AND THEIR TREATMENT

VENTRICULAR DYSFUNCTION Following myocardial infarction, the left ventricle undergoes a series of changes in shape, size, and thickness in both the infarcted and noninfarcted segments. This process is referred to as *ventricular remodeling* and generally precedes the development of clinically evident congestive heart failure in the months to years after infarction. Soon after myocardial infarction, the left ventricle begins to dilate. Acutely, this results from expansion of the infarct (i.e., slippage of muscle bundles, disruption of normal myocardial cells, and tissue loss within the necrotic zone, resulting in disproportionate thinning and elongation of the infarct zone). Later, lengthening of the noninfarcted segments occurs as well. The overall chamber enlargement that occurs is related to the size and location of the infarct, with greater dilation following infarction of the apex of the left ventricle and causing more marked hemodynamic impairment, more frequent heart failure, and a poorer prognosis. Progressive dilation and its clinical consequences may be ameliorated by therapy with ACE inhibitors and other vasodilators (e.g., nitrates) (Fig. 243-2). Thus, in patients with a lowered ejection fraction (less than 40 percent), regardless of whether or not heart failure is present, ACE inhibitors should be prescribed.

HEMODYNAMIC ASSESSMENT Pump failure is now the primary cause of in-hospital death from acute myocardial infarction. The extent of ischemic necrosis correlates well with the degree of pump failure and with mortality, both early (within 10 days of infarction) and later. The most common clinical signs are pulmonary rales and S_3 and S_4 gallop rhythms. Pulmonary congestion is also frequently seen on the chest roentgenogram. Elevation of left ventricular filling pressure and pulmonary artery pressure are the characteristic hemodynamic findings, but it should be appreciated that these findings may result from a reduction of ventricular compliance (diastolic failure) and/or a reduction of stroke volume with secondary cardiac dilation (systolic failure) (Chap. 232).

A classification originally proposed by Killip divides patients into four groups: class I, no signs of pulmonary or venous congestion; class II, moderate heart failure as evidenced by rales at the lung bases, S_3 gallop, tachypnea, or signs of failure of the right side of the heart, including venous and hepatic congestion; class III, severe heart failure, pulmonary edema; and class IV, shock with systolic pressure less than 90 mmHg and evidence of peripheral vasoconstriction, peripheral cyanosis, mental confusion, and oliguria. The expected hospital mortality rate of patients in these clinical classes when this classification was established in 1967 was as follows: class I, 0 to 5 percent; class II, 10 to 20 percent; class III, 35 to 45 percent; and class IV, 85 to 95 percent. With advances in management, the mortality rate has fallen, perhaps by as much as one-third to one-half, in each class.

Hemodynamic evidence of abnormal left ventricular function appears when contraction is seriously impaired in 20 to 25 percent of the left ventricle. Infarction of 40 percent or more of the left ventricle usually results in cardiogenic shock (see below). Positioning of a balloon flotation catheter in the pulmonary artery permits monitoring of left ventricular filling pressure; this technique is useful in patients who exhibit hypotension and/or clinical evidence of heart failure. Cardiac output can also be determined with a pulmonary artery catheter. With the addition of intraarterial pressure monitoring, systemic vascular resistance can be calculated as a guide to adjusting vasopressor and vasodilator therapy. Some patients with acute myocardial infarction have markedly elevated left ventricular filling pressures (>22 mmHg) and normal cardiac indexes [>2.6 and >3.6 L/(min/m²)], while others have relatively low filling pressures (<15 mmHg) and reduced cardiac indexes. The former patients usually benefit from diuresis, while the latter may respond to volume expansion by means of intravenous administration of colloid-containing solutions.

Hypovolemia This is an easily corrected condition that may contribute to the hypotension and vascular collapse associated with myocardial infarction in some patients. Hypovolemia may be secondary to previous diuretic use, to reduced fluid intake during the early stages of the illness, and/or to vomiting associated with pain or medications. Consequently, hypovolemia should be identified and corrected in patients with acute myocardial infarction and hypotension before more vigorous forms of therapy are embarked on. Central venous pressure reflects right rather than left ventricular filling pressure and is an inadequate guide for adjustment of blood volume, since left ventricular function is almost always affected much more adversely than right ventricular function in acute myocardial infarction. The optimal left ventricular filling or pulmonary artery wedge pressure may vary considerably among patients. Each patient's ideal level (generally approximately 20 mmHg) is reached by cautious fluid administration during careful monitoring of oxygenation and cardiac output. Eventually, the cardiac output plateaus and further increases in left ventricular filling pressure only increase congestive symptoms and decrease systemic oxygenation without raising arterial pressure.

Rx TREATMENT

The management of heart failure in association with myocardial infarction is similar to that of acute heart failure secondary to other forms of heart disease (avoidance of hypoxemia, diuresis, afterload reduction, inotropic support) (Chap. 233), except that the benefits of digitalis administration in acute myocardial infarction are unimpressive. On the other hand, diuretic agents are extremely effective, as they diminish pulmonary congestion in the presence of systolic and/or diastolic heart failure. A fall in left ventricular filling pressure and an improvement in orthopnea and dyspnea follow the intravenous administration of furosemide. This drug should be used with caution, however, as it can result in a massive diuresis with associated decrease in plasma volume, cardiac output, systemic blood pressure, and hence coronary perfusion. Nitrates in various forms may be used to decrease preload and congestive symptoms. Oral isosorbide dinitrate, topical nitroglycerin ointment, or intravenous nitroglycerin all have the advantage over a diuretic of lowering preload through venodilation without decreasing the total plasma volume. In addition, nitrates may improve ventricular compliance if ischemia is present, as ischemia causes an elevation of left ventricular filling pressure. The patient with pulmonary edema is treated as described in Chap. 233, but vasodilators must be used with caution to prevent serious hypotension. As noted earlier, ACE inhibitors are an ideal class of drugs for management of ventricular dysfunction following myocardial infarction, especially for the long term.

CARDIOGENIC SHOCK In recent years, efforts to reduce infarct size and prompt treatment of ongoing ischemia and other complications of myocardial infarction appear to have reduced the incidence of cardiogenic shock from 20 percent to about 7 percent. Only 10 percent of patients with this condition present with it on admission, while 90 percent develop it during hospitalization. Typically, patients who develop cardiogenic shock have severe multivessel coronary artery disease with evidence of "piecemeal" necrosis extending outward from the original infarct zone.

It is useful to consider cardiogenic shock as a form of severe left ventricular failure. This syndrome is characterized by marked hypotension with systolic arterial pressure of <80 mmHg and a marked reduction of cardiac index [<1.8 L/(min/m²)] in the face of an elevated left ventricular filling (pulmonary capillary wedge) pressure (>18 mmHg). Hypotension alone is not a basis for the diagnosis of cardiogenic shock, because many patients who make an uneventful recovery will have serious hypotension (systolic pressure of <80 mmHg) for several hours. Such patients often have low left ventricular filling pressures, and their hypotension usually resolves with the administration of intravenous fluids. In contrast to hypovolemic hypotension, cardiogenic shock is generally associated with a mortality rate of >70 percent; however, recent efforts to restore perfusion by coronary

angiop
ity rate
Ri
advanc
sion, &
diabet
consc
angioj
P.
in the
shock
sure,
blood
funct
metal
are t
loop
shoc



Th
the
mo
(a
wi
ne
ct
of
bu
ca
T
b
in
u
(
c
e
(
1

AMERICAN ACADEMY OF PEDIATRICS

Committee on Fetus and Newborn

Use of Inhaled Nitric Oxide

ABSTRACT. Approval of inhaled nitric oxide by the US Food and Drug Administration for hypoxic respiratory failure of the term and near-term newborn provides an important new therapy for this serious condition. This statement addresses the conditions under which inhaled nitric oxide should be administered to the neonate with hypoxic respiratory failure.

ABBREVIATIONS. ECMO, extracorporeal membrane oxygenation; iNO, inhaled nitric oxide; FDA, US Food and Drug Administration.

Hypoxic respiratory failure in neonates born at or near term may be caused by such conditions as primary persistent pulmonary hypertension, respiratory distress syndrome, aspiration syndromes, pneumonia or sepsis, and congenital diaphragmatic hernia. Conventional therapies, which have not been validated by randomized controlled trials, include administration of high concentrations of oxygen, hyperventilation, high-frequency ventilation, the induction of alkalosis, neuromuscular blockade, and sedation.¹ Despite aggressive conventional therapy, neonatal respiratory failure was associated with a high rate of mortality before the development of extracorporeal membrane oxygenation (ECMO).^{2,3} Survival and short-term morbidity rates have been superior in term and near-term infants (≥ 34 weeks' gestation) treated with ECMO compared with conventional therapy⁴; however, questions remain about the long-term safety of ECMO.

Inhaled nitric oxide (iNO) is a selective pulmonary vasodilator for which the mechanism of action involves guanylyl cyclase activation leading to production of cyclic guanosine monophosphate and subsequent smooth muscle relaxation.⁵⁻⁷ Although several studies have suggested that iNO improves oxygenation,⁸⁻¹⁴ the US Food and Drug Administration (FDA) evaluated 2 large randomized multicenter controlled trials of term and near-term neonates with hypoxic respiratory failure that demonstrated improved outcome with iNO therapy. The Neonatal Inhaled Nitric Oxide Study Group trial documented that iNO reduced the need for ECMO¹⁵ without increasing neurodevelopmental, behavioral, or medical abnormalities at 2 years of age.¹⁶ These results were strengthened by the Clinical Inhaled Nitric Oxide Research Group trial, in which iNO reduced the need for ECMO and the incidence of chronic lung

disease.¹⁷ iNO was not effective for infants with congenital diaphragmatic hernia.¹⁸

The limited data to date on hypoxic preterm neonates suggest that low-dose iNO improves oxygenation but does not improve survival.^{14,19} Additional large randomized trials of iNO in premature neonates are required because they may experience more toxic effects than term and near-term infants.^{14,19,20}

It is critical that infants with hypoxic respiratory failure in whom conventional ventilator therapy fails or is predicted to fail be cared for in institutions that have **immediate availability** of personnel, including physicians, nurses, and respiratory therapists, who are qualified to use multiple modes of ventilation and rescue therapies. Radiologic and laboratory support required to manage the broad range of needs of these infants is also essential.

iNO should be administered using FDA-approved devices that are capable of administering iNO in constant concentration ranges in parts per million or less throughout the respiratory cycle. Infants who receive iNO therapy should be monitored according to institutionally derived protocols designed to avoid the potential toxic effects associated with iNO administration. These effects include methemoglobinemia (secondary to excess nitric oxide concentrations), direct pulmonary injury (attributable to excess levels of nitrogen dioxide), and ambient air contamination.

In the trials of iNO therapy reported to date, the indication for use has been failure of ventilatory therapy. ECMO, a therapy of proven efficacy, usually is initiated if iNO therapy fails. Therefore, institutions that offer iNO therapy generally should have ECMO capability; if a center lacks ECMO capability, it should work in collaboration with an ECMO center to prospectively establish appropriate iNO failure criteria and mechanisms for the timely transfer of infants to the collaborating ECMO center. The diversity of geography, climate, and transport capabilities necessitates that the "timely transfer" be dictated by the location-specific transport limitations as well as the severity of the infant's illness. Because hypoxic respiratory failure is often rapidly progressive and abrupt discontinuation of iNO may lead to worsening oxygenation,²¹ the risk of delayed provision of ECMO must be considered carefully when determining the appropriate time of transfer.

Plans for the care and referral of these infants should incorporate the following recommendations.

RECOMMENDATIONS

1. Infants with progressive hypoxic respiratory failure should be cared for in centers with the expertise and

The recommendations in this statement do not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

PEDIATRICS (ISSN 0031 4005). Copyright © 2000 by the American Academy of Pediatrics.

experience to provide multiple modes of ventilatory support and rescue therapies or be transferred in a timely manner to such an institution.

2. iNO therapy should be given using the indications, dosing, administration, and monitoring guidelines outlined on the product label (<http://www.fda.gov>). An echocardiogram to rule out congenital heart disease is recommended. Center-specific criteria for treatment failure should be developed to facilitate timely consideration of alternative therapies.
3. iNO therapy should be directed by physicians qualified by education and experience in its use and offered only at centers that are qualified to provide multisystem support, generally including on-site ECMO capability.
4. Generally, iNO should be initiated in centers with ECMO capability. If iNO is offered by a center without ECMO capability, for geographic or other compelling reasons, mutually acceptable treatment failure criteria and mechanisms for timely transfer of infants to a collaborating ECMO center should be established prospectively. Transfer must be accomplished without interruption of iNO therapy.
5. Centers that provide iNO therapy should provide comprehensive long-term medical and neurodevelopmental follow-up.
6. Centers that provide iNO therapy should establish prospective data collection for treatment time course, toxic effects, treatment failure, use of alternative therapies, and outcomes.
7. Administration of iNO for indications other than those approved by the FDA or in other neonatal populations, including compassionate use, remains experimental. As such, iNO should be administered according to a formal protocol that has been approved by the FDA and the institutional review board and with informed parental consent.

COMMITTEE ON FETUS AND NEWBORN, 1999–2000

James A. Lemons, MD, Chairperson
Lillian R. Blackmon, MD
William P. Kanto, Jr, MD
Hugh M. MacDonald, MD
Carol A. Miller, MD
Warren Rosenfeld, MD
Craig T. Shoemaker, MD
Jane E. Stewart, MD
Michael E. Speer, MD

LIAISON REPRESENTATIVES

Michael F. Greene, MD
American College of Obstetricians and Gynecologists
Patricia Johnson, RN, MS, NNP
American Nurses Association, Association of Women's Health, Obstetric and Neonatal Nurses, National Association of Neonatal Nurses
Arne Ohlsson, MD
Canadian Paediatric Society
Solomon Iyasu, MBBS, MPH
Centers for Disease Control and Prevention
Linda L. Wright, MD
National Institutes of Health

SECTION LIAISONS

Richard Molteni, MD
Section on Perinatal Pediatrics

Jacob C. Langer, MD

Section on Surgery

STAFF

James Couto, MA

REFERENCES

1. Walsh-Sukys MC, Tyson JE, Wright LL, et al. Persistent pulmonary hypertension of the newborn in the era before nitric oxide: practice variation and outcomes. *Pediatrics*. 2000;105:14–20
2. Hageman JR, Adams MA, Gardner TH. Persistent pulmonary hypertension of the newborn. Trends in incidence, diagnosis and management. *Am J Dis Child*. 1984;138:592–595
3. John E, Roberts V, Burnard ED. Persistent pulmonary hypertension of the newborn treated with hyperventilation: clinical features and outcome. *Aust Paediatr J*. 1988;24:357–361
4. UK Collaborative Trial Group. UK collaborative randomized trial of neonatal extracorporeal membrane oxygenation. *Lancet*. 1996;348:75–82
5. Ignarro JJ, Buga GM, Wood KS, Byrns RE, Chaudhuri G. Endothelium-derived relaxing factor produced and released from artery and vein is nitric oxide. *Proc Natl Acad Sci U S A*. 1987;84:9265–9269
6. Palmer RM, Ferrige AG, Moncada S. Nitric oxide release accounts for the biologic activity of endothelium-derived relaxing factor. *Nature*. 1987;327:524–526
7. Frostell C, Fratacci MD, Wain JC, Jones R, Zapol WM. Inhaled nitric oxide. A selective pulmonary vasodilator reversing hypoxic pulmonary vasoconstriction [published correction appears in *Circulation*. 1991;84:2212]. *Circulation*. 1991;83:2038–2047
8. Day RW, Lynch JM, White KS, Ward RM. Acute response to inhaled nitric oxide in newborns in respiratory failure and pulmonary hypertension. *Pediatrics*. 1996;98:698–705
9. Barefield E, Karle VA, Phillips JB III, Carlo WA. Inhaled nitric oxide in term infants with hypoxemic respiratory failure. *J Pediatr*. 1996;129:279–286
10. Roberts JD Jr, Fineman JR, Morin FC III, et al. Inhaled nitric oxide and persistent pulmonary hypertension of the newborn. *N Engl J Med*. 1997;336:605–610
11. Kinsella JP, Truog WE, Walsh WF, et al. Randomized, multicenter trial of inhaled nitric oxide and high-frequency oscillatory ventilation in severe, persistent pulmonary hypertension of the newborn. *J Pediatr*. 1997;131:55–62
12. Wessel DL, Adatia I, Van Marter LJ, et al. Improved oxygenation in a randomized trials of inhaled nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics*. 1997;100(5). Available at <http://www.pediatrics.org/cgi/content/full/100/5/e7>. Accessed May 3, 2000
13. Davidson D, Barefield ES, Kattwinkel J, et al, and the INO/PPHN Study Group. Inhaled nitric oxide for the early treatment of persistent pulmonary hypertension of the term newborn: a randomized, double-masked, placebo-controlled, dose-response, multicenter study. *Pediatrics*. 1998;101:325–334
14. The Franco-Belgium Collaborative NO Trial Group. Early compared with delayed inhaled nitric oxide in moderately hypoxaemic neonates with respiratory failure: a randomized controlled trial. *Lancet*. 1999;354:1066–1071
15. Neonatal Inhaled Nitric Oxide Study Group (NINOS). Inhaled nitric oxide in full-term and nearly full-term infants with hypoxic respiratory failure. *N Engl J Med*. 1997;336:597–604
16. Neonatal Inhaled Nitric Oxide Study Group. Inhaled nitric oxide in term and near-term infants: neurodevelopmental follow-up of the Neonatal Inhaled Nitric Oxide Study Group (NINOS). *J Pediatr*. 2000;136:611–617
17. Clark RH, Kueser TJ, Walker MW, et al. Low-dose nitric oxide therapy for persistent pulmonary hypertension of the newborn. *N Engl J Med*. 2000;342:469–474
18. Neonatal Inhaled Nitric Oxide Study Group (NINOS). Inhaled nitric oxide and hypoxic respiratory failure in infants with congenital diaphragmatic hernia. *Pediatrics*. 1997;99:838–845
19. Kinsella JP, Walsh WF, Bose CL, et al. Inhaled nitric oxide in premature neonates with severe hypoxaemic respiratory failure: a randomized controlled trial. *Lancet*. 1999;354:1061–1065
20. Van Meurs KP, Rhine WD, Asselin JM, Durand DJ. Response of premature infants with severe respiratory failure to inhaled nitric oxide. *Pediatr Pulmonol*. 1997;24:319–323
21. Davidson D, Barefield ES, Kattwinkel J, et al. Safety of withdrawing inhaled nitric oxide therapy in persistent pulmonary hypertension of the newborn. *Pediatrics*. 1999;104:231–236

A statement of reaffirmation for this policy was published on April 1, 2010.

POLICY STATEMENT

PEDIATRICS Vol. 106 No. 2 August 2000, pp. 344-345

AMERICAN ACADEMY OF PEDIATRICS:

Use of Inhaled Nitric Oxide

Committee on Fetus and Newborn

This Article

- ▶ Abstract FREE
- ▶ Full Text (PDF)

Services

- ▶ E-mail this article to
- ▶ Similar articles in this journal
- ▶ Similar articles in PubMed
- ▶ Download to citation manager

Citing Article

- ▶ Citing Articles via HighWire
- ▶ Citing Articles via Google Scholar

Google Scholar

- ▶ Search for Related Content

PubMed

- ▶ PubMed Citation

▶ ABSTRACT

Approval of inhaled nitric oxide by the US Food and Drug Administration for hypoxic respiratory failure of the term and near-term newborn provides an important new therapy for this serious condition. This statement addresses the conditions under which inhaled nitric oxide should be administered to the neonate with hypoxic respiratory failure.

Hypoxic respiratory failure in neonates born at or near term may be caused by such conditions as primary persistent pulmonary hypertension, respiratory distress syndrome, aspiration syndromes, pneumonia or sepsis, and congenital diaphragmatic hernia. Conventional therapies, which have not been validated by randomized controlled trials, include administration of high concentrations of oxygen, hyperventilation, high-frequency ventilation, the induction of alkalosis, neuromuscular blockade, and sedation.¹ Despite aggressive conventional neonatal respiratory failure was associated with a high rate of mortality before the development of extracorporeal membrane oxygenation (ECMO) and short-term morbidity rates have been superior in term and near-term infants (≥ 34 weeks' gestation) treated with ECMO compared with conventional therapy⁴; however, questions remain about the long-term safety of ECMO.

Inhaled nitric oxide (iNO) is a selective pulmonary vasodilator for which the mechanism of action involves guanylyl cyclase activation leading to cyclic guanosine monophosphate and subsequent smooth muscle relaxation.⁵⁻⁷ Although several studies have suggested that iNO improves oxygenation, the US Food and Drug Administration (FDA) evaluated 2 large randomized multicenter controlled trials of term and near-term neonates with hypoxic respiratory failure that demonstrated improved outcome with iNO therapy. The Neonatal Inhaled Nitric Oxide Study Group trial documented that the need for ECMO¹⁵ without increasing neurodevelopmental, behavioral, or medical abnormalities at 2 years of age.¹⁶ These results were similar to the Clinical Inhaled Nitric Oxide Research Group trial, in which iNO reduced the need for ECMO and the incidence of chronic lung disease.¹⁷ iNO is effective for infants with congenital diaphragmatic hernia.¹⁸

The limited data to date on hypoxic preterm neonates suggest that low-dose iNO improves oxygenation but does not improve survival.^{14,19} Additional randomized trials of iNO in premature neonates are required because they may experience more toxic effects than term and near-term infants.¹

It is critical that infants with hypoxic respiratory failure in whom conventional ventilator therapy fails or is predicted to fail be cared for in institutions with **immediate availability** of personnel, including physicians, nurses, and respiratory therapists, who are qualified to use multiple modes of ventilator rescue therapies. Radiologic and laboratory support required to manage the broad range of needs of these infants is also essential.

iNO should be administered using FDA-approved devices that are capable of administering iNO in constant concentration ranges in parts per million throughout the respiratory cycle. Infants who receive iNO therapy should be monitored according to institutionally derived protocols designed to minimize potential toxic effects associated with iNO administration. These effects include methemoglobinemia (secondary to excess nitric oxide concentration), pulmonary injury (attributable to excess levels of nitrogen dioxide), and ambient air contamination.

In the trials of iNO therapy reported to date, the indication for use has been failure of ventilatory therapy. ECMO, a therapy of proven efficacy, is initiated if iNO therapy fails. Therefore, institutions that offer iNO therapy generally should have ECMO capability; if a center lacks ECMO capability, work in collaboration with an ECMO center to prospectively establish appropriate iNO failure criteria and mechanisms for the timely transfer of infants to a collaborating ECMO center. The diversity of geography, climate, and transport capabilities necessitates that the "timely transfer" be dictated by institution-specific transport limitations as well as the severity of the infant's illness. Because hypoxic respiratory failure is often rapidly progressive and abrupt discontinuation of iNO may lead to worsening oxygenation,²¹ the risk of delayed provision of ECMO must be considered carefully when determining appropriate time of transfer.

Plans for the care and referral of these infants should incorporate the following recommendations.

▶ RECOMMENDATIONS

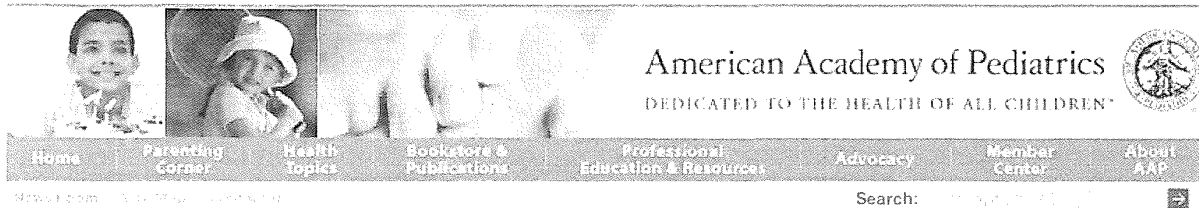
Infants with progressive hypoxic respiratory failure should be cared for in centers with the expertise and experience to provide multiple modes of ventilatory support and rescue therapies or be transferred in a timely manner to such an institution. iNO therapy should be given using the indications, dosing, administration, and monitoring guidelines outlined on the product label (<http://www.fda.gov>). An echocardiogram to rule out congenital heart disease is recommended. Center-specific criteria for treatment failure should be developed to facilitate timely consideration of alternative therapies. iNO therapy should be directed by physicians qualified by education and experience in its use and offered only at centers that are qualified to provide

- ▲ Top
- Abstr.
- ▼ Record
- ▼ Refer

- ▲ Top
- ▲ Abstr.
- Record
- ▼ Refer

2000 © Copyright American Academy of Pediatrics. All rights reserved.
American Academy of Pediatrics, 141 Northwest Point Blvd., Elk Grove Village, IL, 847-434-4000

Contact AAP | Privacy Statement | About



Committee on Fetus and Newborn



cofan

**COFN
2009-2010**

[COFN Roster](#) | [Section on Perinatal Pediatrics](#) | [AAP Committees](#) | [AAP Policy Site](#)

Lu-Ann Papile MD
Chairperson

Members

David H Adamkin MD
Jill E Baley MD
Waldemar A Carlo MD
Praveen Kumar MD
Richard A Polin MD
Rosemarie C Tan MD
Patricia J O'Malley MD
Kristi L Watterberg MD

Section Members

Vinod K Bhutani MD
Section on Perinatal Pediatrics

Kasper S Wang MD FACS
Section on Surgery

Liaisons

Wanda D Barfield MD MPH
Liaison; Centers for Disease Control and Prevention

William H Barth Jr MD
Liaison, American College of Obstetrics and Gynecology (ACOG)

Ann L Jefferies MD
Liaison, Canadian Paediatric Society

Tonse N K Raju MD DCH
Liaison; National Institutes of Health

Rosalie Mainous PhD, ARNP, NNP-BC
Liaison; National Association of Neonatal Nurses and Association of Women's Health, Obstetric and Neonatal Nurses

Staff
Jim Couto
Director

Introduction

The Committee on the Fetus and Newborn studies issues and current advances in fetal and neonatal care; makes recommendations regarding neonatal practice; collaborates with the American College of Obstetricians and Gynecologists (ACOG) to consider perinatal issues on which the practices of obstetrics and pediatrics merge; and works cooperatively with ACOG on new editions of *Guidelines for Perinatal Care*.

Policy Statements

Advanced Practice in Neonatal Nursing
PEDIATRICS Vol. 123 No. 6 June 2009, pp. 1606-1607 (doi:10.1542/peds.2009-0867)
This policy is a revision of the policy posted on June 1, 2003.

Age Terminology During the Perinatal Period
PEDIATRICS Vol. 114 No. 5 November 2004, pp. 1362-1364 (doi:10.1542/peds.2004-1915)
A statement of reaffirmation for this policy was published on January 1, 2009.
A statement of reaffirmation for this policy was published on May 1, 2009.

The Apgar Score
PEDIATRICS Vol. 117 No. 4 April 2006, pp. 1444-1447 (doi:10.1542/peds.2006-0325)
A statement of reaffirmation for this policy was published on May 1, 2009.
This policy is a revision of the policy posted on July 1, 1996.

Apnea, Sudden Infant Death Syndrome, and Home Monitoring
PEDIATRICS Vol. 111 No. 4 April 2003, pp. 914-917
A statement of reaffirmation for this policy was published on September 1, 2007.
This policy is a revision of the policy posted on July 1, 1985.

Controversies Concerning Vitamin K and the Newborn
PEDIATRICS Vol. 112 No. 1 July 2003, pp. 191-192
A statement of reaffirmation for this policy was published on September 1, 2006.
A statement of reaffirmation for this policy was published on August 1, 2009.
This policy is a revision of the policy posted on May 1, 1993.

Hospital Discharge of the High-Risk Neonate--Proposed Guidelines
PEDIATRICS Vol. 122 No. 5 November 2008, pp. 1119-1126 (doi:10.1542/peds.2008-2174)
This policy is a revision of the policy posted on August 1, 1998.

Hospital Stay for Healthy Term Newborns
PEDIATRICS Vol. 113 No. 5 May 2004, pp. 1434-1436
This policy is a revision of the policy posted on October 1, 1995.

CLINICAL REPORT
"Late-Preterm" Infants: A Population Risk
PEDIATRICS Vol. 120 No. 6 December 2007, pp. 1390-1401 (doi:10.1542/peds.2007-2952)

Levels of Neonatal Care
PEDIATRICS Vol. 114 No. 5 November 2004, pp. 1341-1347 (doi:10.1542/peds.2004-1697)

Div of Hospital and Surgical Svcs
847-434-7656
jcouto@aap.org

Noninitiation or Withdrawal of Intensive Care for High-Risk Newborns
PEDIATRICS Vol. 119 No. 2 February 2007, pp. 401-403 (doi:10.1542/peds.2006-3180)
This policy is a revision of the policy posted on August 1, 1995.

CLINICAL REPORT
Perinatal Care at the Threshold of Viability
PEDIATRICS Vol. 110 No. 5 November 2002, pp. 1024-1027
This policy has been revised by the policy posted on July 1, 2009.
This policy is a revision of the policy posted on November 1, 1995.

CLINICAL REPORT
Postdischarge Follow-up of Infants with Congenital Diaphragmatic Hernia
PEDIATRICS Vol. 121 No. 3 March 2008, pp. 627-632 (doi:10.1542/peds.2007-3282)

Postnatal Corticosteroids to Treat or Prevent Chronic Lung Disease in Preterm Infants
PEDIATRICS Vol. 109 No. 2 February 2002, pp. 330-338
A statement of reaffirmation for this policy was published on May 1, 2006.

Prevention and Management of Pain in the Neonate: An Update
PEDIATRICS Vol. 118 No. 5 November 2006, pp. 2231-2241 (doi:10.1542/peds.2006-2277)
This policy is a revision of the policy posted on February 1, 2000.

Revised Guidelines for Prevention of Early-onset Group B Streptococcal (GBS) Infection
PEDIATRICS Vol. 99 No. 3 March 1997, pp. 489-496

CLINICAL REPORT
Safe Transportation of Preterm and Low Birth Weight Infants at Hospital Discharge
PEDIATRICS Vol. 123 No. 5 May 2009, pp. 1424-1429 (doi:10.1542/peds.2009-0559)
This policy is a revision of the policy posted on May 1, 1996.

CLINICAL REPORT
Surfactant-Replacement Therapy for Respiratory Distress in the Preterm and Term Neonate
PEDIATRICS Vol. 121 No. 2 February 2008, pp. 419-432 (doi:10.1542/peds.2007-3283)
This policy is a revision of the policy posted on March 1, 1999.

Use of Inhaled Nitric Oxide
PEDIATRICS Vol. 106 No. 2 August 2000, pp. 344-345

10/09

© COPYRIGHT AMERICAN ACADEMY OF PEDIATRICS. ALL RIGHTS RESERVED
American Academy of Pediatrics, 141 Northwest Point Blvd., Elk Grove Village, IL 60007 847-434-0000

[Site Map](#) | [Contact Us](#) | [Privacy Statement](#) | [About Us](#) | [Home](#)

Ventricular dysfunction clinical research in infants, children and adolescents

Steven E. Lipshultz*

Division of Pediatric Cardiology, University of Rochester Medical Center and Children's Hospital at Strong, and Department of Pediatrics, University of Rochester School of Medicine and Dentistry, 601 Elmwood Avenue, Box 631, Rochester, NY 14642, USA

Abstract

These two issues of *Progress in Pediatric Cardiology* comprehensively illustrate the wealth of currently available information on the pathophysiology of heart failure, age-related myocardial responsiveness, energy metabolism, cardiopulmonary interactions, the pressure-volume relationship, the systemic inflammatory response, the management of heart failure, pediatric pharmacology, the use of heart failure therapies including digoxin, ACE inhibitors, beta-adrenergic blockers, inotropic agents, diuretics, vasodilators, calcium sensitizers, angiotensin and aldosterone receptor blockers, growth hormone, and future gene therapy. The etiology and course of ventricular dysfunction in children is poorly characterized. Furthermore, many changing developmental properties of the pediatric myocardium and differences in the etiologies of ventricular dysfunction in children compared with adults are illustrated in these articles, invalidating the concept that children can safely be considered small adults for the purpose of understanding heart failure pathophysiology and treatment. However, these articles reveal that strikingly little research in children with ventricular dysfunction exists in terms of well-designed large-scale studies of the epidemiology or multicenter controlled clinical therapeutic trials. A future research agenda is proposed to improve understanding etiologies, course and treatment of ventricular dysfunction in children that is based on organized and funded cooperative groups since no one pediatric cardiac center treats enough children with a particular etiology of ventricular dysfunction. In conclusion, significant understanding of basic mechanisms of pediatric ventricular dysfunction and effective therapies for adults with ventricular dysfunction exist. A multicenter pediatric cardiac ventricular dysfunction network would allow improved understanding of diseases and treatments, and result in evidence-based medicine for pediatric patients with ventricular dysfunction. © 2000 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Congestive heart failure; Pediatrics; Ventricular function; Cardiomyopathy; Clinical trials

1. Introduction

The pathophysiology and pharmacologic treatment of ventricular dysfunction in infants, children, and adolescents have been reviewed in these two issues of *Progress in Pediatric Cardiology*. The large amount of work by contributors to highlight pediatric issues demonstrates many unique and potentially important aspects of ventricular dysfunction related to children.

These articles, however, also illustrate how little has been done thus far to understand the pathophysiology and pharmacotherapy of ventricular dysfunction in this population. This summary of where the field of pediatric ventricular dysfunction stands will review unique aspects of pediatric research, challenges in the study of children with ventricular dysfunction, and principles of pediatric ventricular dysfunction. Tremendous opportunities exist to advance our understanding in this area at an unprecedented pace. However, many obstacles need to be overcome, including ourselves. I was recently approached by a respected colleague who explained at great length why he could not participate in an active double-blinded, placebo-

*Tel.: +1-716-275-6096; fax: +1-716-275-7436.

E-mail address: steve_lipshultz@urmc.rochester.edu (S.E. Lipshultz).

controlled clinical trial of therapy for asymptomatic LV dysfunction in children because he just knew, without the benefit of a controlled clinical trial, that this was an effective therapy for his patients. Other pediatric cardiologists have lectured at national meetings stating it is sufficient to study, for example, pharmacologic agents for ventricular dysfunction in adults and, if benefit is found, use the drugs in children with the same illness without clinical trials in this age group. Some of the problems with this approach are that the disease processes resulting in ventricular dysfunction are often different in children than adults. Many pediatric conditions have no close analogies in the adult. Secondly, the effects of the intervention may be unlike those seen in adults. The pharmacokinetics of many drugs vary with age and their beneficial or adverse effects are different in children and adults. Thirdly, children differ from adults. Some therapies may not be tolerated by young children because they are unpalatable or difficult to administer. A final point is that, because the antecedents of many adult diseases are thought to have their origins in early life, studies in very young children, and even antenatally, may identify strategies for preventing diseases which have important public health consequences [1].

Tremendous advances in pediatric cardiology with catheter, surgical, and diagnostic procedures have occurred during the past four decades [2]. Unfortunately, the fields of prevention, therapeutics, and decision analysis based on very limited or biased data for all pediatric ventricular dysfunction have not kept pace. A network of cardiologists willing to participate and adequate funding for an infrastructural network would facilitate research in this area.

2. The current status of clinical research in pediatric ventricular dysfunction

2.1. Reliance on data from studies in adults

In many areas of pediatric practice, therapies have been studied only in adults, and pediatricians must consider whether it is appropriate to generalize from adult to child. Although some pediatric cardiologists have advocated that treatments proved effective for adults with myocardial dysfunction be used in pediatric patients based on data from adults this may not be prudent without further testing.

There appears to be real differences in incidence, implications, expectations, causes, treatment styles, and prevention between children and adults with ventricular dysfunction suggesting that for ventricular dysfunction, children should not be considered 'small adults'. Known ventricular dysfunction occurs fre-

quently in adults and is extremely rare in childhood. Yet, for children there are greater productive years saved by preventing symptomatic ventricular dysfunction. There may be a higher potential for cure from ventricular dysfunction in children than in adults. As a result, the potential goal of pediatric therapy for ventricular dysfunction is more likely to be curative in intent, in contrast to the palliative intent of most adult therapies. Ventricular dysfunction in children is more likely to be due to genetic factors while in adults exogenous exposures predominate. At this time adult causes of ventricular dysfunction may be more amenable to prevention than pediatric causes.

2.2. Reliance on anecdotal experience

The art of learning medicine as a series of clinical anecdotes is important but an over reliance on anecdotal experience, to the exclusion of clinical research, has pitfalls as well [3].

2.3. A lack of appreciation for the need to consider the length of subsequent survival to understand disease process and therapeutic response

The longer a patient remains with LV dysfunction the worse the LV dysfunction becomes. Snapshot studies examining a high-risk population for LV dysfunction at a single point in time are inadequate to state that the population is normal or non-progressive. Natural history studies of LV dysfunction are particularly important in children where we have found that the long length of subsequent survival coupled with the need of the pediatric myocardium to grow in response to increasing somatic growth may result in accelerated progressive LV dysfunction. A small amount of LV dysfunction early in childhood may be particularly problematic later in life [4–40].

2.4. Paucity of data

The risk factors for (e.g. age, sex, ethnic origin and geographic differences) and course of myocardial dysfunction in infants, children, and adolescents have also been studied in a very limited fashion. Consequently, the results of studies to examine the effectiveness of therapies for the prevention, treatment, or beneficial alteration of the subsequent course of pediatric myocardial dysfunction are scarce. This is especially relevant for pediatric congestive heart failure where essentially no prospective multicenter controlled clinical trials have occurred. Yet, the consequences of mild left ventricular dysfunction may be more significant than in adults and due to growth and length of future survival. Heart disease remains the leading cause of death in the United States with

deaths from congestive heart failure on a steadily upward course.

2.5. Lack of evidence-based medicine

The emerging discipline of research synthesis (evidence-based healthcare) has led to greater awareness of the need to evaluate critically what is already known before either making recommendations for clinical practice or embarking on further research [41]. Evidence-based medicine is defined as the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients. By highlighting the strengths and weaknesses of clinical research in different specialties, this process of critical appraisal has shown that, by comparison with situations in adults, research questions relevant to the health of children may have been addressed not at all or only by small, poorly designed studies [42]. Reviews of randomized trials published during a 15-year period in one specialist pediatric journal showed that sample sizes were generally small (less than 20 in approx. one-half of the studies), only a small proportion were multicenter, and reporting of key quality indices was inadequate. When subspecialty areas have been reviewed, the conclusions have been similar. For example, one review characterized recent advances in pediatric cardiology that have led to improved outcomes for surgical repair of complex cardiac malformations to clinical trial-and-error and the common sense and accumulated wisdom of astute clinicians, rather than to basic science or epidemiology [42]. Clinical trial-and-error can occasionally lead to serious errors.

The four steps involved in translating research into practice include: (1) creating evidence through basic science research, phenotype–genotype correlations since different etiologies may lead to different phenotypic outcomes and a heterogeneous population is of limited value, randomized controlled trials, and observational studies; (2) summarizing evidence by published meta-analyses; (3) disseminating evidence by clinical practice guidelines; and (4) implementing evidence by clinical pathways [41].

The clinical effectiveness of therapy comes from randomized controlled trials [43–45]. Observational studies have several advantages over randomized, controlled trials, including lower cost, greater timeliness, and a broader range of patients. Although non-randomized or observational studies have in the past been criticized for bias related to overestimating the true efficacy of a given therapy or leading to erroneous conclusions, recent comparisons to randomized, controlled trials suggest little evidence that estimates of treatment effects in well-designed observational studies (with either a cohort or a case–con-

trol design) are either consistently larger than or qualitatively different from those obtained in randomized, controlled trials [43–45]. These prior concerns led observational studies to be limited in their use to the identification of risk factors and prognostic indicators and to situations in which randomized, controlled trials would be impossible or unethical.

The clinical data for non-therapeutic questions can be derived from observational studies with long follow-up periods to assess prognosis and from large cross-sectional or cohort studies to evaluate the validity and importance of diagnostic tests [41]. The validity of a diagnostic test frequently relies on surrogate endpoints rather than actual patient outcomes and its utility is its ability to meaningfully effect patient outcomes. Diagnostic tests are rarely evaluated in this manner.

Problems encountered in translating research into pediatric practice include a paucity of pediatric clinical trials, underfunding of pediatric research, lack of trained pediatric clinical investigators, frequency of small underpowered studies, heterogeneity of studies, inconsistency between meta-analyses and large randomized, controlled trials, lack of awareness of existing efforts, access to evidence, information overload, format not helpful, labor-intensive, expensive, and waning effectiveness [41].

A schism exists between laboratory-based medical scientists (who attempt to understand the biologic and molecular processes underlying health and disease) and epidemiologists (who try to assess health and disease states [outcomes] in groups of human subjects, exposure to factors that may increase or reduce the likelihood of health or disease, and the causal relationship between these outcomes and exposures), as well as between classical (population-based) and clinical (patient- and clinical intervention-based) epidemiologists [42].

Most pediatric subspecialists, including cardiologists, have not acquired the methodologic skills in research design and statistical analysis required to conduct fundable, hypothesis-driven research. Good science requires focus, depth, and a good question. Rigorous methods should be coupled to substantive expertise to ensure that the hypothesis tested is a useful one. Good epidemiologic science is time-consuming and often quite expensive, especially when it requires long-term follow-up. There are currently 1470 US board-certified pediatric cardiologists with approximately 38 new members each year that trained in the 46 certified US centers [46]. Most centers graduate 1–2 physicians each year and over the past decade the percentage of all pediatric cardiology graduates choosing careers in full-time academic medicine has fallen from nearly 65 to 40%, making it more

concerning whether research in pediatric cardiology will expand in the coming years without an organized research infrastructure [47]. An annual account of research grants funded by the NIH in 1998 showed that the number awarded on topics related to pediatric cardiology to be 117 [48]. Yet, only nine of them involved a pediatric cardiologist as the project's principal investigator [48]. This is occurring at a time when laboratory-based discoveries of new preventive or therapeutic interventions will continue to require demonstration of efficacy and safety in randomized trials. Although more and better epidemiologic studies are needed, so too are laboratory investigations that can confirm or undermine the associations observed in human populations, and explain the biochemical and cellular processes underlying them. Kramer points out that the future of pediatric research will depend on the collaboration of basic scientists and epidemiologists [42]. He cites as an example the use of molecular and other biologic markers that cannot only provide more valid and precise measurements of potentially causal exposures and disease outcomes but can also be used to assess causal mechanisms and pathways [42].

The 1990 US Department of Health and Human Services report entitled 'Healthy People 2000' noted that heart disease was among the five most common causes of death in childhood at any age [49]. An official policy report approved by the Board of Directors of the American Heart Association and written by the Task Force on Children and Youth of the American Heart Association noted that cardiovascular disease occurs more often in children than is generally appreciated [50,51]. More than 600 000 children in the United States have an abnormality of the cardiovascular system, including at least 40 000 whose life expectancy is shortened by an acquired disease such as cardiomyopathy. The annual cost of pediatric cardiovascular disease is >\$8 billion in medical expenses and lost contributions to the gross national product. Cardiomyopathy accounts for an increasing number of the pediatric cardiac transplants. Genetic abnormalities in contractile proteins or energy-producing enzymes, among others, cause cardiomyopathy that becomes manifest in adulthood. Recent advances in genetics allow molecular diagnoses in fetal life. This report acknowledges that cardiomyopathy in children is increasing, and while the prevalence is unknown, 'Eventually more precise classification based on genetic advances will allow detection of people at risk and provide information about the basis of the disease.... With improved understanding of precise etiology, more effective and specific treatment can be developed' [50,51].

Children represent one-third of the United States population, yet they are virtually unrepresented in

cardiovascular research. A paucity of funding for such research, including cardiomyopathy, is related in part to the small number of pediatric cardiovascular scientists. According to the Manpower Advisory and Pediatric Cardiology Committees of the American College of Cardiology, there were < 1000 certified specialists in pediatric cardiology in the United States in 1994, almost all of whom were centered on patient care and diagnostic or interventional techniques [52]. Only a limited number of them devoted a substantial effort to either clinical or basic biomedical research; furthermore, such research was largely retrospective, descriptive, and not controlled. Only 3% of responding certified pediatric cardiologists had completed ≥ 22 months of research training, suggesting that the growth of basic and clinical sciences within the field is limited. This was similar to a prior manpower study of pediatric cardiology that demonstrated that 20 years earlier only 6% of professional activities were devoted to research [53].

Cooperative groups in pediatric cardiology have been helpful at achieving research goals. The Pediatric Cardiomyopathy Registry, for example, has increased the likelihood of collaboration and research, since it allows prospective capture of cases and, in this era of molecular biology, permits new techniques to be applied to the study of pediatric cardiomyopathy [54]. It is hoped that many advances in the prevention, diagnosis, and treatment of cardiomyopathy in the young will be realized by the Registry. The field of pediatric cardiology has always worked well together on multicenter studies and registries. As evidenced by their publications, many of the most important clinical advances in pediatric cardiology have been done in the setting of multicenter studies, such as the New England Regional Infant Cardiac Program, the United States Multicenter Kawasaki Study Group, the Pediatric Cardiac Surgical Registry, the Northern Great Plains Regional Cardiac Program, the Baltimore–Washington Infant Study, the Electrophysiology Study Group, the Valvuloplasty and Angioplasty of Congenital Anomalies Registry, and the Pediatric Heart Transplantation Study Group.

Decoding the human genome will trigger developments that will change our daily lives [55–57]. The finding of genes responsible for diseases will require phenotypically well characterized populations of affected patients to determine patients whose genotypes reveal homogenous defects at high risk of disease and then to test etiology-specific therapies on these populations. Indeed, even at this time single-nucleotide polymorphisms of different genes can be studied by CHIP technology and determine, for example, whether a patient with ventricular dysfunction is likely to decline rapidly on standard drugs for the condition, and hence might need more aggressive treatment.

Dr Francis Collins, director of the Human Genome Research Institute, recently said at the 2000 AAP meeting that understanding the human genome will result in routinely predicting and preventing diseases, and treating patients with highly potent designer drugs tailored to their own genes. Collins said 'It's going to have a profound impact on the practice of medicine and probably nowhere more so than in pediatrics. Virtually all diseases have a genetic component and having the genome will accelerate finding genes for varied diseases.' Collins predicted that by 2010 there will be predictive genetic tests available for at least 10 disorders and treatments to lower risks for several conditions. By 2020 he predicted gene-based designer drugs targeted to the molecular fingerprint of the patient's problem will be available and doctors will be ordering genotype tests on patients before writing prescriptions. By 2030 Collins stated that individualized preventive medicine keyed to a person's genetic profile will be routine, infants will be tested at birth, and gene therapy and gene-based drug therapy will be available.

2.6. Lack of well-designed pharmaceutical industry sponsored studies

Pharmaceutical company placebo-controlled trials have been inadequately performed in children in the past. Prescriptions (25%) in pediatric wards were for drug courses that were either unlicensed or for off-label uses. In neonates, only 35% of prescription episodes were licensed [1]. Industry objectives are frequently more short-term in duration or low cost (e.g. survey data assembly if possible) to meet FDA requirements. However, a large increase in industry-sponsored pediatric drug trials is currently underway due to a new federal law and new FDA regulations that 2 years ago began requiring the pharmaceutical industry to test the effects of many adult products on children (pediatric drug-study proposals filed with FDA, 1999–2000: 184, expected number completed: 150). In December 2000 the FDA will require pedi-

atric study of any adult disease-fighting drug that could be prescribed for children with the same disease. This is expected to increase the number of US children in clinical drug trials from < 1000 in 1990 to 18 000 by 2002. Prior to this legislation there were very few pediatric drug-study proposals filed with the FDA (1991–1997: 70, number completed: 11) [58–62].

3. The necessary clinical research agenda in pediatric ventricular dysfunction

3.1. Understanding heterogeneous etiologies in children

When trying to understand the proper therapy for children with ventricular dysfunction it is usually important not to view the child as a small adult and extrapolate the effects of ventricular dysfunction therapy for adult ischemia or post-infarction patients to the child where a multitude of non-ischemic, non-post-infarction etiologies exist. For example, in the article on angiotensin-converting enzyme inhibitors in this issue we reviewed the effects of this therapy based on the pathophysiology of the condition and found different reported effects of this therapy [63]. A goal is to have effective individualized, etiology-specific therapeutics. An individualized therapeutic approach, based on the etiology of ventricular dysfunction and possibly other factors, such as drug levels or the levels of neurohormones, could result in major progress in treating these patients. We have examined the effect of growth hormone replacement therapy in pediatric LV dysfunction following anthracycline therapy over a 10-year period and found that, unlike adults with LV dysfunction from other etiologies, there was not an improvement in LV dysfunction on growth hormone therapy compared to controls [64]. This suggests that the etiology is extremely important in determining whether the therapy will work. Similar to etiology-specific therapies for children with ventricular dysfunction we have utilized a similar etiology-specific preventive approach for pediatric

Table 1
Detection of doxorubicin cardiotoxicity during therapy by cause and comparison to late cardiotoxicity

Cause of cardiotoxicity	During therapy echocardiogram	During therapy serum cTnT ^a	Late echocardiogram
Depressed energetic (mitochondrial)	–2	0	±
Cytokine myocardial depressant	–2	0	–
Apoptosis	±	±	–1
Free radical injury	–1	≥ +1	≥ –1
Myocarditis	–2	+2	≥ –1

^acTnT, cardiac troponin T.

patients about to receive multiagent chemotherapy that includes doxorubicin. Current protocols employ multiagent cardioprotection targeted against specific etiologies of cardiotoxicity with the goal of no cardiac injury (Table 1).

Although dilated cardiomyopathy (DCM) may be caused by > 75 different disorders, the etiology in most cases is unknown (idiopathic). The course of DCM, almost regardless of etiology, is usually progressive (Fig. 1), with approximately 75% of these children dying within 5 years after the onset of symptoms. Most reports give 1- and 2-year mortality estimates of 25 and 40%, respectively. The cause of death in approximately 80% of cases is evenly divided between sudden cardiac death and congestive heart failure (CHF). Some authors believe that adults who survive more than 2 or 3 years have relatively good long-term survival, but no data have been reported in children. However, the natural history of incidentally discovered, asymptomatic DCM in adults cannot be considered a benign diagnosis, with a 7-year mortality

rate approaching 50%, suggesting that an aggressive approach to the diagnosis and treatment of asymptomatic patients with DCM is clearly warranted (Fig. 1). Small single center series of pediatric DCM ranging from 24 to 81 children have suggested 14 factors predictive of poor outcomes: decreased LV systolic performance at presentation, persistent decreased LV systolic performance, a more spherical LV shape, an elevated LV end-diastolic pressure, increased LV mass, increased cardiothoracic ratio on chest radiograph, mural thrombi, age > 2 years, no LV hypertrophy by electrocardiogram (EKG), endocardial fibroelastosis, complex atrial or ventricular arrhythmias, persistent CHF, ST and T wave changes on EKG, a family history of cardiomyopathy. Most of these factors varied or were in conflict between these different studies making it impossible to understand risk factors for a poor prognosis in children with cardiomyopathy at this time. A report of 137 children with cardiomyopathy in Turkey from 1984 to 1989 noted that DCM improved or normalized for 38.5%,

Stages in The Course of Pediatric Ventricular Dysfunction

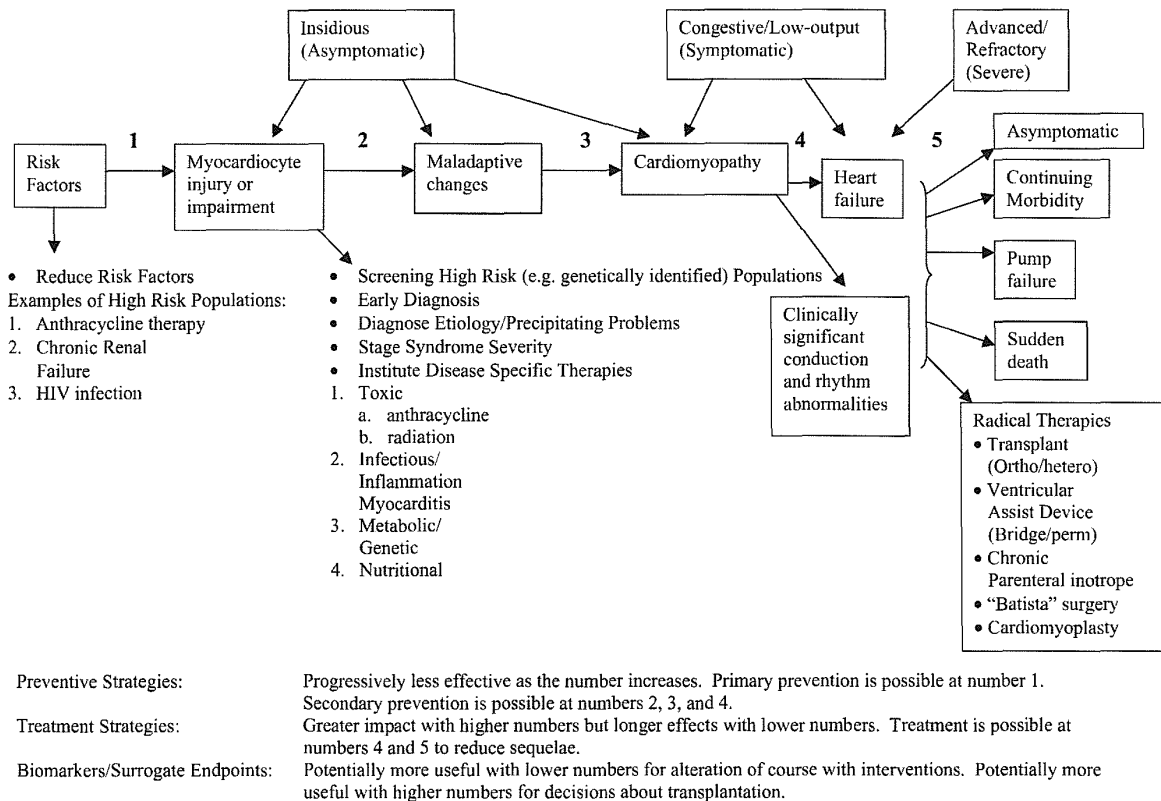


Fig. 1. Stages in the course of pediatric ventricular dysfunction. The identification of risk factors and high risk populations for ventricular dysfunction are highlighted where their use may lead to preventive or early therapeutic strategies. The determination of etiology may lead to etiology-specific therapies. The numbers 1–5 indicate stage-related points of intervention for preventive and therapeutic strategies and where biomarkers and surrogate markers may be used.

DCM remained stable or worsened for 50%, and 11.5% of children died; numbers that are virtually identical to the mean values for these parameters from all studies from more developed countries such as the United States, Canada, and England during similar time periods. This suggests that the enormous intensive and invasive resources spent on the treatment of children with DCM in more developed nations may not have had a significant impact on the morbidity or mortality of pediatric DCM, mandating the need to more completely understand the course, causes, factors predictive of adverse clinical outcomes, and newer etiology-specific therapeutics.

We have found that, in spite of large resources and advanced technology, the prognosis of DCM in developed nations is no better than in developing nations [65]. Furthermore, there has not been a significant improvement in outcome for DCM in children in published studies over the past four decades. We have been involved with studies of the myocardium from children with idiopathic dilated cardiomyopathy that specifically investigated disturbed myocardial energetics. We found a high percentage of these patients had abnormal mitochondrial enzyme function, mitochondrial deletions, or mitochondrial mutations [66,67]. This suggests that treating all children with symptomatic ventricular dysfunction in a similar fashion, regardless of etiology, may be detrimental since inotropes, for example, may not be the most efficacious therapy for a child with disturbed myocardial energetics from mitochondrial genetic or environmental abnormalities.

3.2. Understanding developmental differences in pharmacokinetics

Little is known about cardiovascular drug metabolism in children and this has implications for predicting clinically important drug interactions with the potential for either excessive drug exposure, effect, and toxicity or decreased drug exposure and loss of drug effect [58–62]. Historically this has been due to ethical, economic, regulatory, and technical issues. Dosing children by scaling adult doses based on body weight or surface area does not account for developmental changes that affect drug disposition (pharmacokinetics) or tissue/organ sensitivity to a drug (pharmacodynamics). The pharmacologic impact of these developmental changes is uncovered when unexpected or severe toxicity leads to pharmacologic studies [68,69]. Children metabolize drugs differently than adults. Therefore, drugs must be assessed in children in terms of increased risk of toxicity and reduced efficacy because they may act differently in children than in adults. We need earlier evaluation of

drugs and approaches to make access available as soon as possible. In oncology, for example, in the past 20 years there have been 34 new drugs approved for use in adult cancers, but only one new drug approved to treat cancer in children [58]. Most FDA-approved drugs simply state ‘safety and effectiveness in pediatric patients have not been established.’

Some of the goals of using combination therapy in children with ventricular dysfunction include: (1) To reduce morbidity and mortality with improved quality-of-life; (2) To treat different mechanisms contributing to ventricular dysfunction; (3) To treat for different effects (e.g. drugs to prevent functional deterioration, drugs to reduce mortality, and drugs to control symptoms); (4) To decrease underlying disease complications; (5) To reduce treatment toxicity by using lower doses; (6) To increase patient compliance; (7) To reduce drug dosage or dosing interval; and (8) To provide rational prescriptions (fewest drugs, fewest side effects, maximal compliance, and minimal cost).

3.3. Understanding unique aspects of pediatric recruitment, retention, compliance, and adherence with clinical studies

Children and their families have many unique issues regarding compliance, recruitment, and retention that have been challenging in pediatric studies of LV dysfunction [70–75]. Specific pediatric trial strategies for compliance, recruitment and retention must be developed. Some areas in need of further development and understanding to improve recruitment, retention, compliance, and adherence with clinical studies of ventricular dysfunction include supportive care, adolescent/young adult special issues, when the intention is not curative to stress the participation of the patient and family in the decision-making process, strategies to facilitate return to normal life, improve health-related quality-of-life and self esteem, quantity of life vs. quality of life tradeoffs, end-of-life care issues, minority affairs, underserved populations, alternative therapies, understanding, motivations, expectations, coping, fatigue, self-help, caregiver demands and level of burden, family financial burden, dietary factors, strategies to improve access to state-of-the-art therapy, diffusion into the community of knowledge in this area, develop rational surveillance and monitoring schedules for survivors of pediatric heart failure (determine effectiveness and cost-effectiveness), transition of care from pediatric cardiology to adult cardiology, greater understanding of health service outcome issues such as patient volume, payer differences, academic vs. other settings of care, protocol vs. no protocol care, race and ethnic issues and cultural factors.

3.4. Development of risk factors for pediatric ventricular dysfunction

Fig. 1 shows that the identification of risk factors for cardiomyopathy can help identify high risk populations that through screening may lead to: (1) early diagnosis, institution of disease-specific therapies, and alteration of the course of the disease and to; (2) primary prevention of disease by targeted strategies. Fig. 2 demonstrates independent risk factors identified in multivariable analyses of childhood anthracycline recipients [6,12,14,30]. Fig. 2 illustrates that similarities exist between risk factors for early cardiotoxicity during anthracycline therapy [14,30] and risk factors for late cardiotoxicity in anthracycline-treated long-term survivors of childhood cancer [6,12]. The importance of long-term longitudinal follow-up of high risk populations such as this to determine independent risk factors for late clinically significant outcomes cannot be overstated.

3.5. Development of clinically significant surrogate endpoints

Methodological difficulties that relate specifically to research in children include measuring clinically relevant outcomes. Where death is unlikely, or where research is done in the hope that it will benefit the

participants, outcomes which may be surrogate markers for death are frequently used. The importance of identifying high-risk groups that may be detected early by validated biomarkers and surrogate endpoints cannot be overstated. Examples are p24 antigen and CD4 counts in HIV infection. These surrogate markers have many flaws and their ability to predict death has generally been established only in adults and the associations may be different in children. We have found that subclinical myocardial injury measured by serum cardiac troponin indicates that a low level of injury during doxorubicin treatment frequently translates to considerable echocardiographic abnormalities later in life (Table 1 and Fig. 3) [20,26,28,36,76–84].

Surrogate biomarkers have been useful for drug development and clinical safety assessment. A plethora of technological and conceptual advances in molecular biology and medicine, genetics and genomics, and related research has opened significant opportunities for development of an abundance of new therapies. These opportunities provide a challenge to the assessment of the safety and efficacy of these new candidate therapies. The current status of toxicology biomarkers in pediatric heart failure drug development and clinical safety assessments is in its very early development. A surrogate biomarker is defined as a reliable tool or measure that allows one to monitor and predict that exposure to a drug or

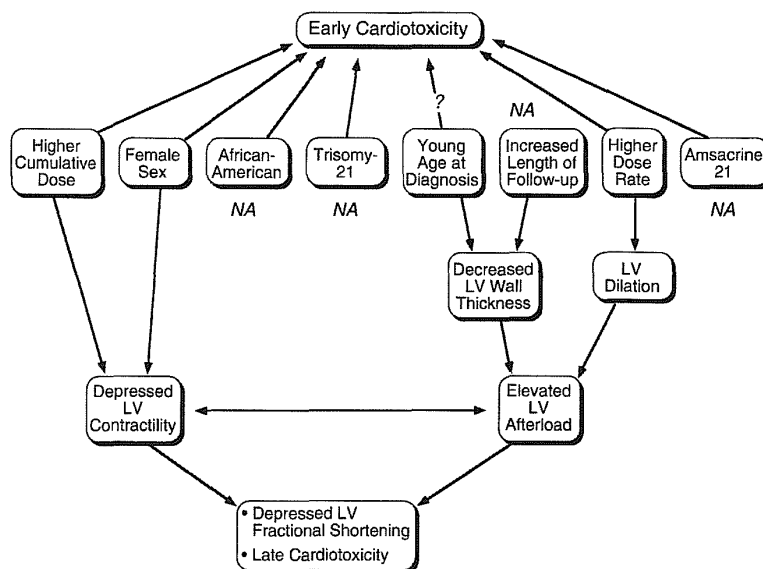


Fig. 2. Risk factors for the development of anthracycline-associated pediatric ventricular dysfunction. The upper part of the figure summarizes independent risk factors identified in multivariable analyses for early clinical cardiotoxicity developing during or in the first year following anthracycline therapy in > 6000 children treated on Pediatric Oncology Group protocols from 1974 to 1990 [14,30]. The lower part of the figure demonstrates the independent risk factors for late cardiotoxicity developing ≥ 2 years after the completion of anthracycline therapy in children treated for ALL or osteosarcoma. Median follow-up was 8 years [12]. The relation of these risk factors from late cardiotoxicity to the echocardiographic abnormalities found in these patients is illustrated and suggests two independent mechanisms of injury, each with distinct risk factors [12].

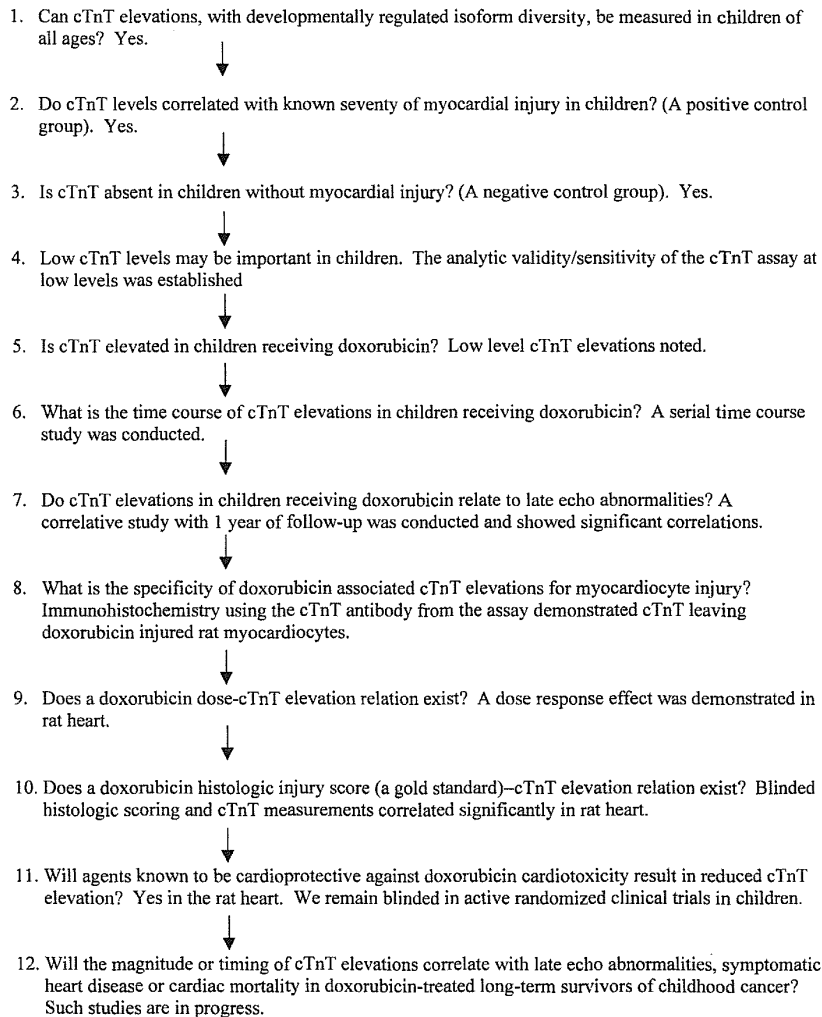


Fig. 3. Stages in the validation of serum cardiac troponin T as a biomarker of doxorubicin cardiotoxicity during therapy and as a surrogate endpoint for late doxorubicin cardiotoxicity in long-term survivors of childhood cancer. This figure illustrates the 12 stages we have undertaken during the past 6 years to determine whether elevations of serum cardiac troponin T represent doxorubicin myocardiocyte injury during therapy and whether these elevations during therapy can predict which children will have late doxorubicin cardiotoxicity. If that is found then cardiac troponin T would be validated as a surrogate endpoint for late doxorubicin cardiotoxicity. A multidisciplinary multispecies approach has been utilized [20,26,28,36,76–84].

environmental chemical may result in harm, illness, or pathology. Particular emphasis is on the demonstration that biomarkers can serve as early predictors of adverse effects and on the development of technological approaches to find more and better toxicology biomarkers.

High throughput technologies are enabling production of large numbers of new chemical entities to be evaluated as target-specific candidate therapies. Improved safety evaluation methods are needed to provide preclinical and clinical toxicity testing in an efficient and timely fashion. The use of biological markers, or biomarkers, defined as characteristics that are objectively measured and evaluated as indicators of

normal biologic processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention, is one approach to enhance toxicity testing.

Mass spectroscopy, cDNA microarray, protein expression, and imaging technologies are examples of basic discovery tools that may serve as platforms to evaluate predictive biomarkers of toxicity. These fundamental research discovery tools now provide opportunities to develop highly efficient assay systems to establish specific and sensitive indicators of cellular and molecular injury. For example, biomarkers may represent components of cell signaling pathways for apoptosis, growth factors, cytokines, and chemokines, and xenobiotic metabolic pathways. Establishment of

the linkage of biomarkers to clinical features of toxicity is critical to their application in drug safety testing.

Harnessing new technologies for toxicology testing will be expedited by cooperative efforts among government, universities, and private industry partners. These interactions will facilitate the development of a technology and information-based infrastructure that will support the standardization of testing methods, validation of assay systems, establishment of databases, and development of statistical analyses that are needed to better characterize toxicity biomarkers and establish linkage of biomarkers to clinical features of toxicity. These are critical to their application for drug safety testing.

The validation of a biomarker as a surrogate endpoint for children at risk of developing ventricular dysfunction is a long and consuming process. We have employed a multispecies, multidisciplinary approach to determine whether measurement of serum cardiac troponin T during doxorubicin therapy for childhood cancer can be considered a surrogate endpoint for the late echocardiographic abnormalities found in these patients when they become long-term survivors (Fig. 3) [20,26,28,36,76–84]. Not all cardiac abnormalities measured during therapy would be expected to relate to late echocardiographic abnormalities in this population (Table 1).

The use of biomarkers to tailor therapy based on mechanisms of injury for an individual child with unexpected new onset symptomatic ventricular dysfunction is a useful goal. Elevated serum cardiac troponin T indicates active myocardocyte injury. In this setting such injury most likely represents infectious or inflammatory causes resulting in myocarditis. Recent work by Towbin and colleagues suggests that a positive PCR viral panel predicts subsequent adverse clinical outcomes following pediatric heart or lung transplantation [85–87]. Table 2 shows an example of a testable treatment strategy based on the presence or absence of active myocardocyte injury, as measured by serum troponin, and the presence or absence of viral myocardial genome, as measured by PCR. This strategy, and others like it, may allow pediatric cardiologists to focus research efforts on whether etiology-specific therapies offer an advantage in outcome over anticongestive therapy alone.

The use of a biomarker for myocardocyte injury, like serum cardiac troponin T, that may become a validated surrogate endpoint, allows for the identification of high-risk populations where subsequent LV dysfunction is likely to occur. We have found that 8% of young children presenting with acute, presumed viral, illnesses had evidence of active myocardial injury [88]. Similarly, we found that children with chronic renal failure frequently have active myocardial injury that relates to potentially modifiable factors [89,90]. Recently, we found that pediatric heart transplant recipients have myocardocyte injury that does not necessarily correlate with histologic rejection [37]. Terbutaline cardiotoxicity for childhood asthma was found by us to be less cardiotoxic than previously thought by using serum cardiac troponin T [38].

The stages of biomarker development as a valid surrogate endpoint in pediatric patients at risk for ventricular dysfunction is illustrated in Fig. 3. The validation of a single biomarker, cardiac troponin T, as a surrogate endpoint for late doxorubicin cardiotoxicity has been a long and involved process [20,26,28,36,76–84].

Myocardocyte injury may occur from disease or during therapy of childhood cancer. Injury should be detectable by screening for cardiac troponin-T, a myocardocyte-specific contractile protein not normally present in serum except with myocardocyte injury. Myocardocyte injury in children with ALL relates not only to doxorubicin, but to other factors as well [79,80]. Low-level myocardial injury occurred in nearly 29% of doxorubicin-treated patients [79,80]. For patients with higher cardiac troponin T elevations, chronically active myocardocyte injury over weeks to months was frequently noted [79,80]. Strategies to prevent or reduce cardiac injury during treatment for childhood cancer may be targeted, including individualized interventions, based on cardiac troponin T elevations.

Normal LV function does not indicate a lack of myocardial injury or damage (Table 1). The use of surrogate markers of subclinical disease is helpful since large sample sizes are needed to achieve endpoints of heart failure or death resulting in problems with recruitment and retention to conduct a placebo-controlled trial. Standard definitions of abnormal surrogate endpoints are imperative if they are to be

Table 2
Testable treatment strategies for children presenting with congestive heart failure

Viral polymerase chain reaction panel	+	+	-	-
Serum cardiac troponin	+	-	+	-
1. Immunomodulatory therapy	+	-	+	-
2. Anti-infective therapy	+	+	-	-
3. Anti-congestive or anti-remodeling therapy	+	+	+	+

adopted on a global basis. The pharmacokinetics of therapy and its pharmacodynamic outcome are important to consider when evaluating surrogate endpoints. Dose–response, add-on, sequential dose-escalation, or cross-over study designs may be useful in studies employing surrogate markers if the underlying disease or condition is stable (and often it is not in this population). Multi-arm and factorial study designs might explore dose and duration of tested therapies and the exploration of trends might be useful when surrogate markers are used. The use of a tiered approach to assess both the surrogate outcomes and a cluster of clinical related outcomes may also be helpful. The surrogate endpoints considered many times reflect the mechanism of action of the study drug. Studies that use clusters or composites of clinically-unproven outcomes for this patient population that are perhaps biologically related and may be affected by the same mechanism of action of the study drug are not acceptable. Unless the surrogate outcomes used are clearly reliable it becomes necessary to interpret results with extreme caution unless consistent results are observed on a range of related outcomes and even then the size of the treatment effect may be substantially overestimated. It is unclear whether in children with ventricular dysfunction, where there are multiple hormonal, nutritional, neurologic, and cardiovascular effects, among others, whether surrogate endpoints that have been validated in adults with ventricular dysfunction are also valid. Changes in surrogate markers should reflect changes in clinically meaningful endpoints such as heart failure or death for the surrogate marker to be valid. Surrogate endpoints that assess health-related quality-of-life are important. For example, if the use of a experimental therapy for pediatric ventricular dysfunction reduces non-fatal endpoints or events such as symptoms, decreases recurrent hospitalizations, or increases functional status, and that may be the only achievable goals for many of these patients, then the therapy's overall benefit to the patient may exceed its effects on objective surrogate markers of clinically significant outcomes.

3.6. Investigate the course of evolving disease processes

Fig. 1 reviews the stages in the course of pediatric ventricular dysfunction. The course is often followed by echocardiographic measurements of LV structure and function. The careful use of these measurements have enabled us to understand the mechanical mechanisms of developing ventricular dysfunction in different affected pediatric populations [11]. In children with HIV infection we have found that there are abnormalities of fractional shortening and contractil-

ity that independently predict mortality years before it occurs [39]. In this same population we found that inappropriately increased ventricular wall thickness or mass were also independent long-term predictors of mortality by different mechanisms [39]. This is in sharp contrast to anthracycline-treated long-term survivors of childhood cancer where we observed that inappropriately reduced ventricular wall thickness was the leading cause of late ventricular dysfunction by increasing ventricular afterload (Fig. 2) [6,12]. In children with chronic renal failure, ventricular dysfunction appears related in part to increased sympathetic cardiac tone [89,90]. Understanding the significance of measurements of ventricular structure and function is enhanced by considering a number of pediatric-specific issues including the normalization of echocardiographic measurements to age, body surface area, sex, and race/ethnic origin [12,91]. It becomes important to understand the effects of mechanical load and its potential implications for treatment options. Testable treatment strategies include whether all children with ventricular dysfunction should be treated similarly or whether afterload reducing strategies may be more beneficial for a child with ventricular dysfunction on the basis of elevated afterload with normal contractility and whether contractility enhancing strategies may be most appropriate for a child with ventricular dysfunction due to depressed contractility but normal loading conditions. We have found that in long-term survivors of childhood cancer treated with mediastinal radiation that many cardiac abnormalities are present including diastolic dysfunction with a restrictive cardiomyopathy [92]. Studies that have limited their assessment to global LV systolic performance have concluded that this is a population free of late dysfunction. The importance of understanding the comprehensive cardiovascular status of this high-risk population is clear and is the only way the patient's cardiac health will be accurately assessed.

3.7. Understanding that serious disability or death as endpoints are rare with intermediate follow-up

Genetic disorders that may lead to serious disability or death in childhood are rare and therefore there is difficulty in using objective clinical outcomes in pediatric research studies. Death is objective and has the advantage of being dichotomous but for most childhood illnesses death is unusual so very large sample sizes would be required.

3.8. Understanding what congestive heart failure is

For childhood congestive heart failure the diagnosis is often subjective or confounded by being linked to measurements of ventricular systolic function which

poses problems when establishing selection criteria or endpoints for clinical trials.

3.9. Understanding functional status and quality of life

There are few validated age-appropriate instruments. Quality-of-life assessment should be an important outcome in clinical trials. A recent review of nine quality-of-life measures developed for children found them to be insufficiently child-centered or family-focused, and few had been adequately validated or subjected to tests for reliability or responsiveness to change [1]. In one study we conducted of patient-perceived functional status of long-term survivors of childhood cancer treated with anthracyclines, we observed that the patients who had received the highest cumulative doses of anthracyclines and, as a result, had the worst ventricular function complained the least of decreased functional status but were the most impaired [6]. This is a complex and important area that needs more development. It is also important that as new therapies are tested in asymptomatic patients that quality-of-life be assessed to ensure that experimental therapies focused on treating ventricular dysfunction do not adversely affect overall quality-of-life.

3.10. Understanding development and progression of disease

It is only by studying the long term course of children with, or at risk for, ventricular dysfunction that we will be able to identify the genetic variations and environmental factors that predispose individuals to the development of heart disease and their subsequent modification [34]. We have found that even the fetal maternal environment may exert strong and lasting adverse effects on ventricular structure and function in infants and children, suggesting that long follow-up of at-risk populations should not only be thought of at the time of diagnosis of ventricular dysfunction, but also during the preceding time interval [17,93–96].

3.11. Proposed research in pediatric ventricular dysfunction

The relation of future research in pediatric ventricular dysfunction to existing guidelines in this area from the literature will be explored in this section. In addition, the ability of the NHLBI-supported Pediatric Cardiomyopathy Registry to facilitate these research objectives is listed [54].

The NHLBI Report of the Task Force on Research in Heart Failure published in May 1994 specifically suggests the formation of a national cardiomyopathy registry to encourage the establishment of working

groups of scientists to: (1) investigate the genetics of cardiomyopathy by exchanging patient material, developing new genetic probes for candidate genes, and organizing a central center for data analysis; (2) integrate basic and clinical studies by using the availability of human cardiac tissue to elucidate the natural history of the biochemical and physiological changes that occur during the progression to heart failure and utilize this to monitor therapeutic interventions; and (3) create a national myocardial tissue bank to coordinate the distribution of tissue to facilitate studies of the pathophysiology of clinical heart disease. The report states that heart failure is a major and growing health problem in the United States; yet, scientists are at the brink of making major advances that could control this condition and reduce the toll of heart failure. The conclusion of the executive summary specifically calls for research on the genetic and cellular causes of heart failure and the development of a preventative strategy that includes identifying patients at risk of heart failure, both of which should be accelerated by the Pediatric Cardiomyopathy Registry [54]. Some of the specific recommendations noted throughout the report that are addressed by the Registry include the following:

- Use specific gene mutations associated with, and presumed responsible for, different cases of cardiomyopathy to allow for the genetic diagnosis of cardiomyopathy and to point the way to treating affected individuals in an early, 'preclinical' stage of disease in the hope of preventing heart failure.
- Efforts to elucidate the fundamental genetic abnormalities in idiopathic dilated cardiomyopathy are encouraged to yield information on the fundamental cause of heart failure and new methods of prevention.
- A major long-range goal that has potential for preventing and treating heart failure is the correction of abnormal cardiac gene expression by the introduction of foreign genes into the heart and by the restoration of myocyte cell division.
- To determine the causes of heart failure in different geographic locations and socioeconomic strata of a population.
- Identify candidate genes for familial forms of idiopathic dilated cardiomyopathy and other forms of hereditary heart disease that can lead to heart failure.
- To determine the relationship between the molecular abnormalities responsible for the synthesis of abnormal proteins and the abnormal clinical phenotype in the cardiomyopathies.
- Investigate potential infectious mechanisms of cardiac damage and cardiomyopathy.
- Determine whether development, race or gender

is a factor in the development or progression of ventricular hypertrophy or cardiomyopathy, and if so then what are gender, racial, and developmental-specific risk factors.

- Develop sensitive, reliable, and reproducible methods for early detection of functional, metabolic, and structural changes of the myocardium.
- Determine the factors that accelerate the progression of cardiac damage, and define the genetic and phenotypic characteristics that contribute to progression and regression of cardiac damage.
- Define the effectiveness of early therapeutic interventions, including their limitations and side effects, and determine ways in which to reduce the risks of early interventions.
- Develop and perfect simple, cost-effective, and yet accurate and reproducible non-invasive techniques suitable for patient care and epidemiological studies. These techniques should be improved sufficiently so that the need for expensive, invasive examinations can be greatly reduced.
- Define factors that constitute a high-risk profile among asymptomatic or mildly symptomatic patients with LV dysfunction.
- Determine how patients with LV dysfunction and heart failure who are at increased risk of sudden death can best be identified.
- Identify factors responsible for progression or lack of progression to symptomatic heart failure in individuals with asymptomatic abnormalities in cardiac structure or function. Clarify the interactions among predisposing factors, aging, and structural or functional cardiac abnormalities in increasing the risk of developing heart failure.
- Validate simplified, non-invasive imaging and cardiac function assessment methods for detecting abnormalities of cardiac structure and function. Evaluate the sensitivity of these methods for monitoring the progression of cardiac dysfunction.
- Identify markers in asymptomatic individuals with left ventricular dysfunction that are predictive of early morbidity and that therefore enable selection of patients who are more likely to benefit from aggressive therapy.
- Assess the relative importance of the relief of symptoms and disability vs. the increased risk of mortality in patients with end-stage heart failure.
- Define the role of cardiac transplantation in children with end-stage dilated cardiomyopathy and determine the risk factors that minimize long-term survival, including graft rejection, pulmonary vascular resistance, premature atherosclerosis, and ventricular diastolic dysfunction.

The NHLBI Report of the Expert Panel on Ge-

netic Strategies for Heart, Lung and Blood Diseases predicts that many of the mutations causing disease will be identified in the next 10–20 years. Registries will allow that to happen for pediatric cardiomyopathy. The Registry should lead to an understanding of the pathogenesis of these disorders and offers the hope of having a major impact on the clinical practice of medicine in this area [54]. In reference to cardiomyopathy, the report notes ‘a paucity of cardiovascular investigators and clinicians who are familiar with genetic principles and methodologies. Similarly, there are few molecular geneticists studying these vascular and myocardial diseases. It is therefore crucial to increase genetic expertise among cardiovascular investigators and to concurrently encourage the involvement of geneticists in this area.’ These research priorities are some of the goals of the registry.

- Establish a disease-specific coordinated network to foster genetic studies among many investigators.
- Provide an infrastructure and ways to interact.
- Have the ability to share data and resources among network members.
- Develop and maintain appropriate databases.
- Provide a uniform, robust, and meaningful definition of the phenotype of cardiomyopathy.
- Have adequate facilities to store data.
- Have sufficient statistical and analytical expertise and resources.
- Result in the establishment of appropriate collections of patients and families of diverse ethnic and racial backgrounds.
- Provide detailed knowledge of relevant physiology to increase the power of genetic studies.

In June 1991, the NHLBI convened a Workshop on the Prevalence and Etiology of Idiopathic Dilated Cardiomyopathy (IDCM) (*Am J Cardiol* 1992; 69:1458–1466), in large part because there was limited information on pathogenesis and prognosis, few population-based estimates of incidence and prevalence were available, and few geographic areas were represented in previous publications. It was noted that IDCM was difficult to study owing to the relatively low prevalence, its potential pluricausal nature, and the fact that it is often a diagnosis of exclusion. The report summarized existing data on established IDCM, which notes 1-year survival rates of 48–77%, 2-year rates of 31–66%, and 3-year rates of 24–53% among more than 2000 adult patients. Because the mechanism of myocardial damage and the related etiologic and prognostic factors are virtually unknown, the workshop felt that it presented a significant challenge to the cardiovascular community. The workshop concluded by recommending several areas for future

observational and interventional studies of IDCM, all of which the Pediatric Cardiomyopathy Registry [54] will facilitate:

- Standardized diagnostic criteria should be developed.
- Population-based registries were given the highest priority among etiologic study designs to understand cardiomyopathy better. The workshop felt that this was an appropriate study design for tracking incidence and prevalence and to identify representative cases to study potential etiologic factors in subsequent case-control studies. Observational studies were recommended that would be able to address non-modifiable factors (e.g. age, sex, race or ethnicity, and genetic predisposition) and modifiable factors (e.g. viruses, diet, socioeconomic status, metabolic conditions, drugs, toxic or occupational exposure, obesity, and hypertension).
- Suggested measurements to be included in population-based studies in IDCM were stated. These included DNA polymorphisms and candidate genes, cardiac structure defined by echocardiography, immunologic markers, and neurohumoral factors). Echocardiography was recommended as the principal method of detection, diagnosis, and follow-up for population-based studies.

In May 1996 the NHLBI convened a Special Emphasis Panel on Research in Heart Failure whose suggestions included a number of areas applicable to clinical studies of children with ventricular dysfunction, some of which are highlighted below [97].

- ‘More focused clinical trials in which the patient population is more homogenous. Although this approach may yield data that are viewed to be less broadly applicable, new understanding of a mechanism in a clearly defined subset of patients with heart failure may well be applicable to a larger population.’
- ‘Future trials of heart failure treatments should plan to consider arrangements for ancillary basic studies and obtain blood, tissue, or other measurements to elucidate mechanisms of the disease and its progression. This information would form the origins of a database that would meet a critical need to establish the phenotypes and genotypes of the normal and failing hearts.’
- ‘Large-scale clinical trials provide a rich population of patients with LV dysfunction that are monitored over time in a well-defined, standardized protocol. The opportunity to identify molecular, cellular, structural, neurohormonal, electrophysiological, bioenergetic, circulatory, or clinical mark-

ers of the progression of the ventricular dysfunction and of its response to the therapeutic interventions should not be lost.’

The list of clinical research studies in this area is large, in part because so little has been done so far. In general, research is needed to find the optimal therapy for correcting both systolic and diastolic ventricular dysfunction and left ventricular hypertrophy before irreversible changes ensue. In addition, more research is needed to find the means to combat the sudden death-promoting dysrhythmias of heart failure. It is also extremely important to consider the efficacy of preventive measures in heart failure candidates with normal systolic function. In adults improved heart failure treatment has resulted in improved outcomes but more work needs to occur to understand the physiological bases for potential sex, race, and age differences [98,99]. Clinical trials need to be designed out of need rather than expediency. Healthcare processes that deliver cost-effective treatments in a more uniform manner need to be implemented.

4. Obstacles to achieving clinical research goals in pediatric ventricular dysfunction

4.1. Smaller population

For many chronic diseases which affect both adults and children the number of patients in the adult population is much greater. This may lead to difficulties in obtaining statistical power to detect an effect of treatment.

4.2. IRBs may not allow pediatric studies where adult data exist

Institutional review boards have rejected pediatric proposals where the study has been done in adults. The same therapy may have different effects depending on the stage in the disease process that is used. Children receive special protection under federal regulations for biomedical research that require the potential for direct benefit to the child participating in a drug study. This limits participation since initial pharmacokinetic and safety testing in normal pediatric subjects is more difficult to obtain informed consent on than with adult studies.

4.3. Need for long-term follow-up to understand natural history and to examine subclinical drug effects

Studies in children are of particular interest where the drug may affect the natural history of a disease.

This is the case for many emerging therapies (i.e. gene therapy). Trials to determine safety and efficacy are initially important. However, the real outcomes of interest, such as rates of decline in function, should be examined over years, rather than months, and are of particular interest in patients with mild disease who may not yet have developed irreversible organ damage. The importance of maintaining cohorts of rare diseases to understand the natural history and response to therapy in children is clear [100,101]. The field of adult congenital heart disease is too narrowly focused on structural cardiovascular malformations and should include adults with onset of ventricular dysfunction in childhood either from genetic or environmental causes. In order to help these populations of patients more and better understand their diseases it becomes important to follow cohorts with specific rare diseases differently and a unified clinic is an ideal way to facilitate this. We found that using cross-sectional data at a single point in time demonstrated a significant correlation between immune dysfunction and ventricular dysfunction in HIV-infected children [23]. However, when we followed these children long-term and examined longitudinal correlations we found that there was not a significant correlation between immune and ventricular dysfunction [23]. Having been able to examine trends over time in this population at high risk for ventricular dysfunction enabled us to determine the truth.

4.4. FDA review and approval of pediatric ventricular dysfunction therapeutic studies utilizing death as the sole acceptable endpoint is not reasonable

The development of validated surrogate endpoints must be a priority. Mortality is not always an indicator of good or poor outcome in heart failure and may be the inevitable consequence of a long illness for which the patient may have received excellent care and had a good pharmacologic response to therapy. Suffering associated with this condition may be substantial, and health status measures may be as important as survival rates.

The FDA has made major changes to increase awareness and compliance with testing new drugs in children to develop pediatric dosing recommendations at an earlier stage in the development process and to improve the safety of new agents in children. Pediatric cardiologists must now devise more rational methods of selecting which new cardiac drugs to develop for children with ventricular dysfunction and to develop new and more efficient trial designs to evaluate safety, pharmacokinetics, and efficacy of new drugs in children with ventricular dysfunction, as more new drugs become available for testing in children at an earlier stage in the drug development process.

4.5. Participation by pediatric cardiologists is difficult

The Pediatric Cardiomyopathy Registry has > 220 centers that confirmed participation but only 44 have actually participated [54]. The agenda for pediatric cardiology should be to advocate for participation of pediatric cardiologists in clinical research studies because all is not well for us in this area. There was acknowledgement in the pediatric oncology field in the late 1960s that the outcome results were not good enough. We must first get that acknowledgement in pediatric cardiology and then get the buy-in of pediatric cardiologists around the country to participate on clinical trials. Recent drug company-sponsored studies of ACE inhibitors indicate that this can be done in this field [102,103].

Despite these difficulties there can be little progress in the clinical care of children without research in this age group, and the findings of studies in children may also be relevant to adult medicine.

Those concerned with the care of children have a duty to improve that care. One way of achieving that goal is through research. However, for research to be successful and to overcome difficulties pediatricians, parents, and children must all be convinced of its importance.

4.6. Reporting and recall bias by pediatric cardiologists

In several studies we have performed in pediatric ventricular dysfunction we have been surprised to find that the results were not what we would have expected a priori. For example, in 1993 we performed a written and telephone survey of 100 pediatric cardiology program directors to review cases of pediatric cardiomyopathy in their practices. The results of that survey are shown in Table 3. Five years later we presented the results of actual data that had been collected from many of these same programs and found major differences from the conclusions of the survey [98,99]. The actual incidence of pediatric cardiomyopathy and the percentage of children with a known etiology of their cardiomyopathy were both approximately one-half of what the survey had suggested [98,99]. This suggests that surveys of experts in pediatric cardiology may be misleading due to unintentional reporting and recall bias. The details of this survey on children with ventricular dysfunction are reviewed below.

Between September 1992 and June 1993, we conducted a self-administered mail survey of pediatric cardiologists associated with a range of health-care institutions and private practices throughout the United States and Canada. We took the sample of cardiologists from the American Academy of Pediatrics, 1991 Fellowship Directory, Section on Cardi-

Table 3
Results from cardiomyopathy survey (*n* = number of respondents; CM = cardiomyopathy)

Clinic profile	
Number of pediatric cardiologists on staff at responding institutions (<i>n</i> = 94)	538
Number of pediatric cardiology patients yearly (<i>n</i> = 90)	267889
Mean	3189
S.D.	1658
<i>Race, ethnicity (n = 74)</i>	
White	63%
Black	22%
Hispanic	10%
Other	5%
<i>Sex (n = 70)</i>	
Male	51%
Female	49%
Cardiomyopathy profile	
Number of patients seen yearly for CM (excluding Kawasaki disease and rheumatic fever) (<i>n</i> = 84)	5205
Mean	62
S.D.	104
<i>Type of CM (n = 82–84)</i>	
Dilated	58%
Hypertrophic	30%
Restrictive	5%
Arrhythmic	5%
<i>Etiology (n = 66–72)</i>	
Known or suspected	
Infectious	17%
Metabolic or genetic	13%
Cancer-related	12%
Immunologic	2%
No known etiology	57%
<i>Cardiac catheterizations on patients with CM (n = 89)</i>	1003
Mean	11
S.D.	12
<i>Biopsies among catheterizations for CM (n = 82)</i>	1075
<i>Heart transplants on patients with CM (n = 92)</i>	212
<i>Deaths among patients with CM (n = 78)</i>	218
<i>Autopsies on patients who died with CM (n = 82)</i>	190
Mean	2

ology. We initially identified 109 cardiologists from the United States and 15 from Canada. These physicians represented 38 large, 27 medium, and 14 small university hospitals in the United States, 30 private-practice settings in the United States, and 15 hospitals in Canada. Of the cardiologists identified from the United States, 1 was not a pediatric cardiologist, 1 was retired, and 1 was deceased. The remaining 121 pediatric cardiologists were eligible to participate in the survey.

We designed the questionnaire to provide estimates on the number of cardiomyopathy cases that might be submitted to a national pediatric registry and the willingness of respondents to participate in such a registry. Specific questions included the number of cardiologists on staff; annual number of pediatric cardiology patients seen by their group or institution; gender and racial distribution of patients; number of

patients with a cardiomyopathy seen yearly; annual number of cardiac catheterizations, biopsies, and transplants performed on these patients; and annual number of deaths and autopsies. In addition, respondents were asked whether they would be willing to participate in a voluntary pediatric cardiomyopathy registry and, if so, what proportion of cases would realistically be reported. The response rate to the survey was 79% (*n* = 96). Twelve pediatric cardiologists from the United States and one from Canada declined to complete the questionnaire and also declined to participate in a voluntary registry on telephone follow-up.

Ninety pediatric cardiologists responded affirmatively to their group or institution participating in a voluntary registry; three respondents reported that they would not participate; and three responses were missing.

The results of this survey suggested a strong nationwide interest in and need for a voluntary registry for pediatric cardiomyopathy. The large number of cases also suggested that the magnitude of the disease is great. Furthermore, the percentage of cases with an unknown etiology and the number likely to be symptomatic (cardiac catheterizations) or to have intractable disease (transplants and deaths) reinforced the need to study this disease and discover common etiologies and disease mechanisms so as to develop appropriate treatments.

4.6.1. Availability of patients and evidence of access to patients

The centers responding to the survey represented a high percentage of pediatric cardiologists in the United States and Canada and encompassed almost all major centers of pediatric cardiology. The responding and participating centers collectively followed 267 889 pediatric cardiology patients. The 1991 Fellowship Directory of the American Academy of Pediatrics listed 580 pediatric cardiologists from the United States and Canada as members. The survey reported here represents the participation of 538 pediatric cardiologists, 95% of the number listed in the academy directory. Survey respondents noted that they refer only 2.5% of cardiomyopathy patients elsewhere for evaluation and management. The respondents stated that realistically, 83% of their pediatric cardiomyopathy patients would be reported to the registry. Therefore, the availability of and access to data from infants and children with cardiomyopathy appears quite strong.

4.6.2. Wide geographic distribution

Participating centers represent 43 states plus the District of Columbia, eight Canadian provinces, and Puerto Rico. These states or provinces encompass 94% of the population. Survey respondents stated that they capture 70% of pediatric cardiology patients in their region, with 80% of new patients having been referred from elsewhere.

4.6.3. Women and minorities

Females represented 49% of all pediatric cardiology patients followed at responding centers. The racial and ethnic composition was 63% white, 22% black, 10% Hispanic, and 5% other.

4.6.4. Importance of the Medical Question

IDCM, or primary myocardial disease, is poorly understood. The annual incidence of IDCM is estimated at 2–8/100 000 in the United States. Overall survival of patients with IDCM is poor (~50–60% at 2 years). As exemplified by the known forms of inherited cardiomyopathy, factors such as age, coexisting

illnesses, diet, and additional genetic loci may play a part in determining the expression of the cardiomyopathy phenotype.

4.6.5. Prevalence of pediatric cardiomyopathy

The mean number of active pediatric cardiomyopathy patients followed at 84 respondents' centers is 62, for a total of 5205 patients, or 1.9% of the mean number of all pediatric cardiology patients followed (3189). This figure is close to the 2.7% prevalence of pediatric cardiomyopathy followed by pediatric cardiologists in the New England Regional Infant Cardiac Program. The actual prevalence of pediatric cardiomyopathy (diagnosed and undiagnosed) is not known.

Cardiomyopathy is functionally classified as hypertrophic, dilated, restrictive, or arrhythmic. The survey noted that DCM was most common (58%), followed by hypertrophic (30%), restrictive (5%), and arrhythmic (5%). In the majority of cases reported here (57%), the etiology was unknown. For those where the etiology was known or suspected, respondents reported that 17% had an infectious etiology, 13% were metabolic or genetic, 12% were related to toxic exposures (e.g. anthracycline chemotherapy or irradiation), and 2% had immunologic causes.

4.6.6. Incidence of pediatric cardiomyopathy

The annual number of new cases of pediatric cardiomyopathy reported by 88 centers was 4098, with a mean of 47. A comparison of 47 with the mean number of total cases per reporting center [62] suggests that the length of follow-up for infants and children with cardiomyopathy is short, approximately 1.4 years. Other studies on cardiomyopathy have suggested that the 1-year survival rate for infants and children is 20–80% and the 5-year survival rate for adults is 25%, supporting the possibility that short survival is likely. Other factors that may have contributed to the similarity between prevalence and incidence could be patient improvement and discharge from follow-up, patients lost to follow-up, and the methods for data collection used in this survey.

This survey suggests that the incidence of cardiomyopathy based on 60 million children \leq 18 years of age is 0.9/10 000 children (4512/60 million). This compares closely with the 1/10 000 incidence noted in the first year of life in the Baltimore-Washington study. This suggests that a steady number of new cases of cardiomyopathy continues throughout childhood to keep the incidence constant.

4.6.7. Severity of pediatric cardiomyopathy

Children with clinically symptomatic cardiomyopathy usually undergo cardiac catheterization with endomyocardial biopsy. The 90 centers reported 1075

cardiac catheterizations for cardiomyopathy in the preceding year, excluding post-transplants, suggesting that 24% of children become clinically symptomatic during the first year after diagnosis of cardiomyopathy. Cardiac catheterizations for cardiomyopathy in children represented 5% of all catheterizations at these centers. Cardiac transplantation, indicating a failure of medical management, was done for 20% of infants and children with symptomatic cardiomyopathy during the first year after presentation. Two hundred eighteen infants and children (20%) died of symptomatic cardiomyopathy in the preceding year at these 90 centers. Together, this suggests that up to 40% (430/1075) of infants and children with symptomatic cardiomyopathy will fail medical or surgical management in the first year following diagnosis.

4.7. What may be intuitive may not be correct

Another prospective study we performed looked at the development of abnormal left ventricular structure or function in children receiving antiretroviral therapy [7,40]. Based on data in animals and adult patients suggesting that cardiac abnormalities may develop in some HIV-infected patients treated with antiretroviral therapy, recommendations were made in children and adults that potentially life-saving antiretroviral therapy be discontinued if ventricular dysfunction develops. When we studied this prospectively in a multicenter design over 10 years we found that unlike animal and adult studies there was no measurable effect of antiretroviral therapy on the myocardium [40].

Another example of where an accepted therapy in adults to reduce the incidence of developing left ventricular dysfunction became the standard-of-care in many pediatric oncology treatment protocols without demonstrating that the therapy resulted in cardioprotection in children was the use of 48 h continuous infusion of anthracycline chemotherapy. We compared continuous infusion therapy with previously conventional bolus anthracycline infusion over less than 1 h duration [104]. To our surprise, after completing a multicenter, prospective randomized blinded study over 5 years duration we concluded that 18 months after the completion of anthracycline chemotherapy there was no difference in left ventricular structure or function between the two groups and that both groups had significantly deteriorated since their initial cardiac assessment [104]. In addition, the continuous infusion cohort had substantially more hospitalization days and other complications [104]. This was unexpected based on adult studies, but was only found by performing a prospective study in children. Knowing the results of this study enabled us to stop giving false hope to our patients with ALL and

their families and allows us to investigate other cardioprotective strategies that may be of benefit. Again, what we have seen many times is that not everything that makes sense biologically, or is based on animal or adult studies, has been useful in the treatment of children.

4.8. Reliability of multicenter pediatric cardiology data

There is a need to know how good your tests are. We determined that locally measured echocardiographic reliability is poor in pediatrics on multicenter studies [105]. There is a need for central remeasurement. Clinical management of children with cardiac disease is frequently based on echocardiographic measurements of LV structure and function. In multicenter pediatric studies of cardiac status associated with experimental treatments or disease processes, the determination of efficacy, toxicity, and course is frequently based on echocardiographic measurements of LV structure and function. Despite the clinical and research importance placed on pediatric echocardiographic measurements, little has been published about the reliability of these measurements.

This may have implications for the planning and conduct of research studies, and as well as for the management of individual patients. The importance of reliable and accurate LV measurements cannot be over-emphasized. For example, expert panel standards of cardiology practice have been used to recommend withholding potentially lifesaving chemotherapy in asymptomatic children with cancer when fractional shortening drops below a specified value [10]. Presenting similar problems, are an increasing number of standard-of-care guidelines that differentiate acceptable from unacceptable care in some settings based on a one percentage point difference in LV function. However, our data show that despite attempts to standardize echocardiographic techniques, the determination of fractional shortening from the same tracing varies considerably among centers [105].

Our study would suggest that these precautions are very important when a single echocardiographic measurement, but not longitudinal changes in z-scores in the same child where any systematic bias in the same child would be subtracted out, are to be used in clinical care [105]. Also, comparing a study sample's data with a data set generated by other researchers may lead to inappropriate normative data for multicenter clinical studies and could result in misleading group averages.

Our study showed that echocardiographic measures of LV structure and function calculated locally are subject to heterogeneity in data acquisition and assessment [105]. Measurements differed so much that a central echocardiographic facility is needed to provide

consistent and reliable data for research studies, and repeat measurements on individual children are recommended to provide clinically meaningful results. To improve inter-institutional agreement, we recommend standardizing how images are acquired and read. Though core laboratories increase the labor and expense of clinical trials, they provide more consistent and probably accurate analysis than do local measurements. Future pediatric clinical trials should arrange for independent evaluations of echocardiographic data.

4.9. Animal models of pediatric ventricular dysfunction

Animal models of pediatric ventricular dysfunction can often augment and expedite controlled clinical trials. For example, the rat model we have used to assess biomarkers for the detection of anthracycline cardiotoxicity enabled us to determine histologic myocardial status in ways not possible in children [20,26,28,36,76–84]. The rat model has allowed us to rapidly test the effectiveness of different anthracycline cardioprotective strategies since we are only able to perform one controlled clinical trial to test an anthracycline cardioprotection strategy in children approximately every 5 years due to accrual and follow-up issues. An animal model has been very helpful for us to identify the most promising strategy to bring to a human clinical trial.

However, it becomes very important to realize that all findings in animal studies are not directly translatable to children. For example, the newborns of pregnant monkeys treated with zidovudine exhibit profound myocardiocyte damage. This resulted in the suggestion that pregnant HIV-infected women should not receive zidovudine to substantially reduce HIV transmission from mother to child. In contrast to the monkey model, when we examined zidovudine cardiotoxicity in infants and children we were unable to demonstrate adverse effects [40]. In this case, human studies are likely to have resulted in many saved lives of uninfected children born to HIV-infected mothers who received zidovudine and who otherwise would have died of HIV infection.

5. How to achieve clinical research goals in pediatric ventricular dysfunction

5.1. Advocacy, representation and participation

Out of frustration with the current voice pediatric cardiology has, a call for an organization devoted entirely to the field of pediatric cardiology has been recommended to provide a 'legitimate body' that can speak out on behalf of pediatric cardiologists [106].

The stated goals would be to create a platform for scientific discussions, propagate knowledge and standards of care, as well as advocate for the advancement of patient care and the professional goals of the medical profession of this field.

Examples of where increased organizational efforts on this field may lead to more attention to the clinical and research needs of children with heart disease are abundant. One example is, on 17 October 2000 the President signed into law the Children's Health Act of 2000 with > \$50 million in FY 2001 earmarked to it. This is a package of provisions related to children's health that promotes additional research on disease and disabilities specific to children, among other topics. Research in many important areas are included such as muscular dystrophy, lead poisoning, infant mortality, traumatic brain injury, autism, fragile X, juvenile arthritis, juvenile diabetes, asthma, hearing loss, childhood cancer, and epilepsy. No mention of pediatric cardiovascular diseases is part of this major federal legislation for children's health.

As another example, NHLBI has had no pediatric cardiology representation on SPARK, Strategic Plan, Epidemiology Task Force, Heart Failure Task Force, Genetics Task Force, Dilated Cardiomyopathy Task Force, Heart Failure Special Emphasis Panel, and very little representation on any NHLBI Study Section listed on the NHLBI web site during the past year, yet this is the major research funding organization for the field of pediatric cardiology in the US. Of the 58 members of the SPARK Working Group, a select group of accomplished scientists convened to assist the NHLBI by identifying research areas that constitute extraordinary opportunities and that would merit substantial increases in resource investment, assembled in May 1998 to formulate a strategic plan for the NHLBI funding the years FY2001-2005 not a single pediatric cardiologist was included.

In spite of this, largely through the efforts of NHLBI internal program staff, an important 2001 initiative was included. This initiative is to 'Investigate diagnostic and therapeutic approaches for congenital and acquired pediatric cardiovascular conditions from fetal life into adulthood. Approximately 32 000 infants are born each year with congenital cardiovascular malformations, one of the leading causes of infant mortality. In addition, acquired pediatric cardiovascular conditions, including arrhythmias, inflammatory conditions, cardiomyopathies, hypertension, and hyperlipidemia affect several million children and adolescents. Treatment of congenital and acquired pediatric cardiovascular disease involves drug and surgical therapies. Yet, most standard therapeutic drugs have not been tested in randomized controlled trials in children. Surgical correction has side effects in children about which much is still unclear. Important

clinical questions remain unanswered. Most treatment decisions concerning pediatric heart disease are not evidence-based. In the past 25 years, fewer than 40 randomized clinical trials have been conducted, of which nearly half dealt with patent ductus arteriosus in preterm infants. The medical, emotional, social and economic consequences of pediatric heart disease are profound. Medical therapy is employed widely to treat pediatric heart disease. Few standard therapy agents, however, have been tested in randomized trials in pediatrics. Agents of choice used in the treatment of adult heart failure are used in children, but have not been studied in a systematic fashion. Emerging adult therapies may benefit children but are virtually untested in them despite their requirement by FDA regulations. A pediatric myocarditis agent has never been evaluated in a prospective randomized trial. A collaborative network of up to six clinical research centers and a data coordinating center will evaluate standard and new diagnostic and therapeutic strategies in pediatric cardiovascular medicine. The network approach can also promote training of investigators in pediatric clinical research and provide a way to ensure rapid dissemination of research findings... The major barriers to clinical studies in pediatric heart disease include the heterogeneity of conditions, the small numbers of individuals with a particular malformation or condition at any one center, differences in treatment approaches to particular problems, the absence of systematic centralized databases, and the lack of resources to provide national coordination of collaborative efforts. Efficiencies will be achieved through a common infrastructure for recruiting, monitoring, and following patients whose conditions will be characterized in a standard fashion' [107]. This is an extremely important landmark advance for pediatric cardiology. Hopefully some of the selected protocols will apply to pediatric ventricular dysfunction.

5.2. Prevention of ventricular dysfunction has to start in childhood

As illustrated in Fig. 1, we should not wait until symptomatic LV function is present to initiate preventive strategies. The studies of Barker and colleagues have demonstrated retrospectively that antenatal events influence morbidity and mortality in adult life (e.g. coronary heart disease and hypertension). The definition of preventive cardiology is too narrow and should include reducing the subsequent risk of developing symptomatic myocardial disease.

For more than 2000 years, cardiac failure has been recognized as a clinical entity, but within the past 15 years it has been identified as a major public health concern [108]. Thus, the national hospital discharge

service estimated that 4.8 million US adults have heart failure and that nearly 500 000 US adults develop it each year, making this condition the leading diagnosis for hospitalization of persons older than 65-years-old. The healthcare expenditure for heart failure in the US in 1993 was \$17.5 billion, which amounts to 11% of the total budget for cardiovascular disease in 1997. Approximately 60% of the healthcare expenditure for heart failure is for hospital care. Heart failure accounts for more than 3 000 000 office visits annually at a cost of \$3 billion yearly for out-of-hospital care. Heart failure is a common chronic condition that impairs quality of life and results in loss of independence.

Kannel has reviewed the prospects for prevention of heart failure in adults that is noted below [108]. Fig. 1 demonstrates how these preventive strategies may be helpful in children at-risk of, or with, ventricular dysfunction. 'The epidemiology and the vital and health statistics concerning heart failure indicate that is a major burden on victims, their families, and the health care system. Evidence indicates that treatment of the overt condition continues to be inadequate because of an unacceptably poor survival rate. Those who may have this condition must be detected and treated while the process is still evolving. Treatment of presymptomatic left ventricular dysfunction, correction of the dysfunctional maladaptive changes of vasoconstriction, increased afterload, and salt and water retention; and timely myocardial revascularization and valve surgery hold great promise for high-risk heart failure candidates. In addition to the proven efficacy of ACE inhibitors, recent growing evidence indicates that beta-blockade can reverse and slow the progression of left ventricular dilatation that characterizes heart failure and reduces all-cause mortality in patients with overt heart failure.

From a population perspective the most cost-effective approach to the problem is to correct the modifiable risk factors as early as possible. The high population-attributable risks imposed by hypertension, diabetes, and coronary disease indicate the priority areas. Detection and control of hypertension and coronary disease have proven efficacy, but these measures are not being fully implemented. Only 45% of hypertensive persons have their blood pressure optimally controlled, and ACE inhibitors, beta-blockers, lipid-correcting therapies, and thrombolytic therapies are far from optimally employed. Major hypertension trials indicate clearly that treating hypertension reduces the risk of heart failure, and a recent meta-analysis indicates that antihypertensive treatment in the elderly can reduce heart failure incidence by 47%, an estimate close to the population-attributable risk estimated by the Framingham study. Although clinical

trials indicate that medical interventions can improve survival in overt heart failure, survival is still poor' [108].

Despite recent innovations in the treatment of predisposing conditions for heart failure, the condition remains highly prevalent and lethal once established in adult patients. Improvements in the treatment of clinically overt heart failure — the end stage of uncontrolled hypertension, myocardial ischemia, and valvular disease — have made only a small improvement in the poor survival in patients with this diagnosis. Therapy introduced at this late stage appears unlikely to substantially prolong life. Preventive measures must be taken before ventricular dysfunction becomes symptomatic and before maladaptive compensatory phenomena ensue. Clues to the methods needed to detect persons vulnerable to heart failure and prevent the progression of conditions predisposing to myocardial decompensation are emerging from recent epidemiologic research.

The goals of preventive strategies for pediatric ventricular dysfunction are: (1) to reduce the incidence of pediatric ventricular dysfunction; (2) to continue basic, clinical and population research into causes of pediatric ventricular dysfunction for interventions; (3) to increase risk factor reduction; (4) to establish data-based interventions; (5) to extend risk reduction to entire populations even though this may be less intensive to individual patients; and (6) to develop systems to monitor surveillance nationally through partnerships and collaborations.

5.3. Network infrastructure

Pediatric oncology is a notable exception to many areas of pediatrics in that high-quality clinical trials (multicenter randomized) are regularly performed [109–114]. Also, some successes have occurred in perinatal medicine where the NICHD Neonatal Research Network was established in 1986 to conduct multi-center clinical trials in neonatal medicine and management that is funded by a cooperative agreement between 14 clinical centers, the data coordinating center, and the NICHD. The neonatal research network has included therapies for sepsis, intracranial hemorrhage, chronic lung disease, and pulmonary hypertension. In addition, the Network has implemented a standardized follow-up program of extremely low birthweight infants and supports a registry of infants less than 1500 g at birth with > 29 000 enrolled babies. Four of the Network centers also support a Maternal Lifestyle Study that investigates the effect of prenatal maternal drug abuse on neonatal and long-term outcomes. The NHLBI has recently established a pediatric asthma clinical network and a

thalassemia clinical research network. In identifying the reasons for the relatively low standard of research in children, it is instructive to examine areas where there has been more success, to try and establish where certain difficulties may not exist or may have more easily been overcome.

Acute lymphoblastic leukemia (ALL) is rare, occurring in 1 in 2000, but the success achieved over the past 30 years in improving survival in ALL has been attributed largely to evaluation of therapy by multicenter trials [109–114]. Over the past 30 years, 5 year event-free survival for high risk ALL has improved from approximately 10% to nearly 90% due to multicenter clinical trials. The small field of pediatric oncology agreed over the past three decades to voluntarily regulate themselves and provide experimental procedures only to patients who participate in valid research. The availability of a pool of test subjects assures that new ideas for treatments are rapidly tested, allowing them to be adopted nationwide if they work, or tossed aside if they prove useless. As a result, the advances in this field have been phenomenal, far outpacing anything seen in adult medicine. In adult oncology for example a giant leap from developmental therapeutics and early underpowered clinical trials to community-wide applications of high-dose therapy for breast cancer circumvented essential scientific scrutiny and the well-intentioned but premature enthusiasm of patients and advocates was used at a time when physicians knew the therapy was toxic, expensive, and experimental [115]. For controlled clinical trials to succeed they must be designed to define the most effective, least morbid, and/or least expensive treatment. The payers must be brought initially into the process to fund the appropriate trials rather than be forced to pay for unproven, perhaps well-intentioned, treatments. The scientific importance of 'approved clinical trials' must be accepted by patients, physicians, and the payers. It must be agreed that the new treatments are unproven and therefore must be a subject for clinical investigation. Patients who are on such approved trials may get better care and closer observation; they should be reassured that they are not receiving a known inferior control therapy. Whether they are the beneficiaries of the experimental therapy is the goal of the trial. If the process can be efficiently undertaken, then resources will be saved. Knowledge, negative or positive, will be accumulated in a timely fashion. Ultimately the patient would be the beneficiary of the progress and not the victim of unproven innovation. This gives further importance to the role of intergroup participation to maximize patient accrual. Small or statistically minute differences in the continuous follow-up may be encountered. There have been few studies comparing the

costs of a clinical trial that defines the correct approach to a particular disease with the consequence of widespread use of an unproven treatment [115].

Advances in childhood cancer therapies have been dramatically aided by the willingness (even eagerness) of parents, children, physicians, nurses, and other health care workers to enroll patients on research studies that attempt to advance knowledge in the field. This degree of cooperation and collaboration among various groups has led to studies that have shown that participation in clinical trials leads to better therapy outcomes than those treated off-protocol using 'the doctor knows what's best' therapy [113]. This has resulted in third party payers reimbursing children on oncology protocols and in some cases not reimbursing those being treated off-protocol. A recent study of adult cancer patients treated at the Kaiser Permanente health maintenance organization demonstrated that participation in cancer clinical trials did not result in substantial increases in the direct costs of medical care [116]. Other costs that were not taken into account include recruiting patients, assuring that treatment protocols are followed, collecting and managing data, and supporting the infrastructure for research. Other benefits to HMOs for participating in clinical trials are enhanced appeal of an HMO to patients and physicians and earlier adoption of new treatments.

Over the past 16 years I have been fortunate to work closely with two oncology groups, the large (> 100 clinical sites) Pediatric Oncology Group (now merged to form the even larger Children's Oncology Group) and the smaller (10 clinical sites) Dana Farber Childhood Leukemia Group. I have observed different strengths of large and small multicenter clinical trials groups. Large groups are able to enroll more patients with quicker accrual and obtain answers sooner, there is often more missing data and less complex protocols, and there is longer protocol development periods to obtain consensus. However, effective therapies more rapidly become standard of care when tested on large group protocols. The smaller groups can perform more complex testing with better quality control and with more frequent testing. Effective therapy on smaller group studies frequently becomes the pilot data for larger group studies.

I have similarly been involved with the care of HIV-infected children during the past 16 years and have been impressed with the major therapeutic advances that have resulted from the NIH sponsored Pediatric AIDS Clinical Trials Group (ACTG). For example, the ACTG protocol 076 demonstrated that transmission from mother to infant could be virtually eliminated by maternal zidovudine use during pregnancy, an amazing result that created life from death.

The value of cooperative group participation in pediatric AIDS speaks for itself.

5.4. Database derived clinical research

Databases derived from clinical trials or registries contain more detailed clinical information than administrative databases but have a selection bias that limit their usefulness in providing a true reflection of ventricular dysfunction across the population. Administrative databases can provide uniform information across a broad population over a long time frame and can track the onset of heart failure within a population [117].

5.5. Registry derived data

Large prospective studies of pediatric cardiomyopathy have not been previously conducted in North America, resulting in little population-based data. The NHLBI-sponsored Pediatric Cardiomyopathy Registry was established to: (1) describe epidemiology and clinical course of cardiomyopathy in patients ≤ 18 years; and (2) to promote the development of etiology-specific treatments [54]. A large database of sociodemographic and clinical information on children with pediatric cardiomyopathy has been established through the cooperative efforts of cardiology centers in North America, allowing precise estimates of the incidence of pediatric cardiomyopathy and a better understanding of the natural history of this disease [98,99].

5.6. Clinical practice guidelines

Practice guidelines have emerged in recent years as an important means of translating the results of clinical trials into specific recommendations for the treatment of patients [118–121]. Such guidelines describe the indications for use of medications and the optimal approach to the management of specific clinical problems. Guidelines help to limit inappropriate care, decrease the magnitude of geographic variations in practice patterns, and enhance the effective use of healthcare resources. In addition, guidelines are an invaluable tool for quality assurance and can assist in the development of coherent plans for inpatient and outpatient treatment. Advances in medicine occur so rapidly that practice guidelines may be out of date shortly after they are issued. Thus, there is a continuing need to update existing recommendations so that recent advances in therapy can be brought to the attention of physicians in a timely fashion. Currently practice guidelines cannot be developed for the pharmacologic management of pediatric patients with

chronic heart failure due to left ventricular systolic dysfunction, the use of surgical approaches or devices or the management of acute heart failure or of heart failure associated with preserved left ventricular systolic function due to the fact that there are virtually no well-controlled studies on the effect of therapy on outcomes in these patients. Practice guidelines are very popular in pediatric cardiology and are useful but potentially dangerous. Guidelines may codify and make rigid algorithmic approaches to the treatment of patients and thereby reduce or even eliminate good clinical judgement or inhibit research [10]. Guidelines can take on a power of their own and have medicolegal ramifications when not followed even if they are based on weak or no data [10]. In adult patients with myocardial infarction critical pathways in hospitals did not have increased use of proven medical therapies, shorter lengths of stay, or reductions in mortality compared with other hospitals that commonly used alternative approaches to quality improvement [122]. A recent survey of general pediatricians found that most use practice guidelines, but no specific guidelines, except those for asthma, are used by > 27% of pediatricians [118]. The results of this survey suggested that practice guidelines are most likely to be followed if they are simple (practical and feasible), flexible to allow for clinical judgement, rigorously tested and shown to improve outcome, not used punitively, and are motivated by desires to improve quality, not reduce costs.

Guidelines are not performance measures. Guidelines are written to suggest diagnostic or therapeutic interventions for most patients in most circumstances. Performance measures are standards of care that imply that physicians are in error if they do not care for patients according to these standards. Performance measures define how to practically identify those patients for whom a specific action should be taken.

For adult patients with heart failure four structural measures were recommended as quality indicators [123]. These include: (1) clear, evidence-based guidelines for the care of patients with heart failure; (2) a mechanism to systematically monitor patient care and outcomes; (3) providers should recognize that many require different levels of care and there must be an organizational structure to move patients to the appropriate level of care; and (4) patients would benefit by having specific programs to address the end-of-life needs of many patients with heart failure.

Four process measures were also recommended as quality measures for adult patients with congestive heart failure [123] including: (1) the medical record should document left ventricular systolic function; (2) patients with heart failure, LV systolic dysfunction, and no contraindications to ACE inhibitors should be

prescribed ACE inhibitors; (3) patients hospitalized with heart failure and LV systolic dysfunction should be treated with digoxin; and (4) patients with NYHA class II and III heart failure, LV systolic dysfunction, and no contraindication to beta-blockers should be prescribed beta-blockers. Similar measures cannot be developed for pediatric heart failure at this time due to lack of data.

6. Summary

Heart-muscle disease is an area of pediatric cardiology where we are often unable to help patients with either knowledge or action. These are rare patients, the number of institutions studying them well is small, and among those studied, the great majority have non-specific findings. Thus, to make progress, there is a need to pool case-study information among institutions. Data sharing makes it possible for all users to profit quickly from knowledge, experience, insights, and hypotheses that may be gained from material from other institutions, even though it may be too scanty, unproved, or speculative for publication.

At this point, a multidisciplinary approach is needed to study longitudinally the variety of pathogenic mechanisms in pediatric cardiomyopathy, as well as diagnostic, therapeutic, and preventive approaches. Given that this group of diseases is relatively rare, with a variety of suggested etiologies and new possibilities for diagnosis and treatment, we have felt that the best way to change the past piecemeal approach to a more constructive one is by a cooperative effort. It is for this reason that we helped establish a national registry for pediatric cardiomyopathy [54].

The available literature on pediatric cardiomyopathy lacks good data on incidence and prevalence, survival, and prognostic factors, largely because of variable selection criteria and case definitions, small numbers, inclusion or exclusion of myocarditis, whether clinically asymptomatic cases are included, and the methods used. These inconsistencies mean that little of the natural history (especially survival and prognosis) is really known. The collection of large numbers of cases in the registry can help identify specific rare defects. The Pediatric Cardiomyopathy Registry provides a clearer understanding of the relationship between myocarditis and DCM and may help determine whether cases of cardiomyopathy in adults may have originated as myocarditis in childhood. The Pediatric Cardiomyopathy Registry has the potential of making a large impact on establishing various etiologies of pediatric cardiomyopathy. Molecular biology has brought new understanding of HCM; similar advances should be forthcoming for other types of cardiomyopathy. Eventually, molecular insight into

the multiple causes of cardiomyopathy will facilitate the diagnosis of these conditions. In the absence of molecular biological testing, there is likely to be serious underestimating of the impact of cardiomyopathy. Distinguishing between some of the types of cardiomyopathy and other cardiac problems is a major diagnostic challenge. Because the human body is almost always host to viral infections, it is likely that subclinical viral cardiovascular involvement is common and not limited to histologically documented myocarditis associated with congestive heart failure. As most past research concentrates on symptomatic myocarditis, the best characterized type of viral heart disease, we are left with the frustration that our level of understanding of this field is still quite limited.

The literature illustrates how poor our existing knowledge is of the clinical epidemiology of viral heart involvement. One can only settle for clinically overt heart disease. Viral heart involvement is often incorrectly captured, owing to difficulties in definition and diagnosis, precluding a good understanding of the spectrum and course of viral heart disease. Classic histologic, serologic, and culture techniques for defining viral heart disease have problems with sensitivity, specificity, and positive and negative predictive values. The histologic diagnosis of myocarditis also has many pitfalls. The limited availability of premorbid tissue for diagnostic purposes further hampers our understanding. Unfortunately, newer techniques such as in situ hybridization and PCR may also have problems with sensitivity and specificity [124]. At this time, the isolated finding of a positive PCR for a specific viral probe may not reliably indicate active viral cardiac involvement. In the absence of an understanding as to what constitutes viral cardiac involvement, it is impossible to understand the clinical epidemiology of viral heart involvement and the response to therapy. Thus, whether a continuum exists from viral myocarditis to DCM remains unanswerable. More than 90% of HIV-infected children have echocardiographic abnormalities, yet chronic congestive heart failure occurs in 10%, transient congestive heart failure in another 10%, and cardiac arrest or sudden death in 10% [4,8]. One-third of HIV-infected children who have died did so in the setting of severe ventricular dysfunction [8]. Therefore, just relying on symptomatic heart disease to capture cardiomyopathy underestimates the impact of this problem. The registry provides the opportunity to capture asymptomatic cardiomyopathy [54].

This registry should help establish the usefulness of endomyocardial biopsy in diagnosing pediatric cardiomyopathy and in determining the course and prognosis of the various types of pediatric cardiomyopathy. It should also allow assessment of newer, less invasive diagnostic imaging techniques to determine

whether the diagnosis of specific types of cardiomyopathy can be made without the need for biopsy. The registry should facilitate treatment trials of immunosuppression and immunomodulation for cardiomyopathy, as well as other therapies. The registry could identify cases for inclusion in trials.

The proposed Pediatric Heart Disease Clinical Research Network [107] is a very exciting development in this field that offers a tremendous opportunity to rigorously investigate important clinical questions in pediatric cardiology at a limited number of centers. Hopefully, some of the clinical studies of this network will focus on issues related to pediatric ventricular dysfunction. Future planning should focus on expanding this network to more completely allow the participation of more pediatric cardiology providers in the US. The tremendous successes in pediatric oncology and pediatric HIV are benchmarks that such efforts are invaluable in improving outcomes for affected children and their families.

The articles in these two issues of *Progress in Pediatric Cardiology* on pediatric heart failure demonstrate how much has been learned to allow us to conclude that the pathophysiology, pharmacology, etiologies, and clinical course of pediatric heart failure differs from adults with heart failure in many ways. The pediatric literature reviewed in these issues has been largely observational studies that support the next steps to embark on multicenter controlled clinical trials, natural history studies, and translational studies to advance this field further.

It is extremely difficult to accept children failing medical management for ventricular dysfunction in the year 2000 and to be able to say to their families that we have done everything possible when, in fact, there have been virtually no controlled clinical trials that have been performed in this area. For the good of our patients, for our personal integrity, and for the future of our subspecialty, the time for active multicenter clinical research in pediatric ventricular dysfunction is now.

Acknowledgements

Supported in part by grants from the National Institutes of Health, Bethesda, MD (HL53392, HL59837, HL07937, HR96041, CA79060, CA68484, RR02172).

References

- [1] Smyth RL, Weindling AM. Research in children: ethical and scientific aspects. *Lancet* 1999;354(suppl II):21–24.
- [2] Gutgesell HP, Lindsey JH. Major advances in pediatric cardiology in the 20th century: I. Diagnostics. *J Pediatr* 2000;137:431–433.

- [3] Borgstein J. The end of the clinical anecdote. *Lancet* 1999;354:2151–2152.
- [4] Lipshultz S, Chanock S, Sanders SP, Colan SD, McIntosh K. Cardiovascular manifestations of human immunodeficiency infection in infants and children. *Am J Cardiol* 1989; 63:1489–1497.
- [5] Goorin AM, Chauvenet AR, Perez-Atayde AR, Cruz J, McKone R, Lipshultz SE. Initial congestive heart failure, six to ten years after doxorubicin chemotherapy for childhood cancer. *J Pediatr* 1990;116:144–147.
- [6] Lipshultz SE, Colan SD, Gelber RD, Perez-Atayde AR, Sallan SE, Sanders SP. Late cardiac effects of doxorubicin in childhood acute lymphoblastic leukemia. *N Engl J Med* 1991;324:808–815.
- [7] Lipshultz SE, Orav EJ, Sanders SP, Rubin A, McIntosh K, Colan SD. Abnormalities of cardiac structure and function in HIV-infected children treated with zidovudine. *N Engl J Med* 1992;327:1260–1265.
- [8] Luginbuhl LM, Orav EJ, McIntosh K, Lipshultz SE. Cardiac morbidity and related mortality in children with symptomatic HIV infection. *J Am Med Assoc* 1993;269:2869–2875.
- [9] Lipshultz SE, Sallan SE. Cardiovascular abnormalities in long-term survivors of childhood cancer. *J Clin Oncol* 1993;11:1199–1203.
- [10] Lipshultz SE, Sanders SP, Goorin A, Krischer JP, Sallan SE, Colan SD. Monitoring for anthracycline cardiotoxicity. *Pediatrics* 1994;93:433–437.
- [11] Lipshultz SE, Orav EJ, Sanders SP, McIntosh K, Colan SD. Limitations of fractional shortening as an index of contractility in HIV-infected children. *J Pediatr* 1994;125:563–570.
- [12] Lipshultz SE, Lipsitz S, Goorin AM et al. Female sex and higher drug dose as risk factors for late cardiotoxic effects of doxorubicin therapy for childhood cancer. *N Engl J Med* 1995;332:1738–1743.
- [13] Lipshultz SE, Orav EJ, Sanders SP, Colan SD. Immunoglobulins and cardiac structure and function in HIV-infected children. *Circulation* 1995;92:2220–2225.
- [14] Krischer JP, Epstein S, Cuthbertson DD, Goorin AM, Epstein ML, Lipshultz SE. Clinical cardiotoxicity following anthracycline treatment for childhood cancer: the pediatric oncology group experience. *J Clin Oncol* 1997;15:1544–1552.
- [15] Schwartz ML, Cox GF, Lin AE et al. Clinical approach to genetic cardiomyopathy in children. *Circulation* 1996;94: 2021–2038.
- [16] Lipshultz SE. Dexrazoxane for protection against cardiotoxic effects of anthracyclines in children. *J Clin Oncol* 1996;14:328–331.
- [17] Hornberger LK, Lipshultz SE, Easley KA et al. for the P²C² Study Group. Cardiac structure and function in fetuses of mothers infected with HIV: The prospective P²C²HIV multicenter study. *Am Heart J* 2000;140:575–584.
- [18] Nysom K, Holm K, Lipsitz SR et al. The relation between cumulative anthracycline dose and late cardiotoxicity in survivors of childhood leukemia. *J Clin Oncol* 1998;16:545–550.
- [19] Miller TL, Orav EJ, Colan SD, Lipshultz SE. Nutritional status and cardiac mass and function in children infected with the human immunodeficiency virus. *Am J Clin Nutr* 1997;66:660–664.
- [20] Lipshultz SE, Rifai N, Sallan SE et al. Predictive value of cardiac troponin T in pediatric patients at risk for myocardial injury. *Circulation* 1997;96:2641–2648.
- [21] Lipshultz SE, Grenier M. Left ventricular function in infants and children infected with the human immunodeficiency virus. *Prog Pediatr Cardiol* 1997;7:33–43.
- [22] Grenier MA, Lipshultz SE. Epidemiology of anthracycline cardiotoxicity in children and adults. *Semin Oncol* 1998;25(suppl 10):72–85.
- [23] Lipshultz SE, Easley KA, Orav EJ et al. for the Pediatric Pulmonary and Cardiovascular Complications of Vertically Transmitted HIV Infection Study Group. Cardiac structure and function in children infected with human immunodeficiency virus. The prospective P²C² HIV multicenter study. *Circulation* 1998;97:1246–1256.
- [24] Lai WW, Lipshultz SE, Easley K et al. for the P²C² Study Group. Prevalence of cardiovascular malformations in children of HIV-infected mothers: The prospective P²C² HIV multicenter study. *J Am Coll Cardiol* 1998;32:1749–1755.
- [25] Giantris A, Abdurrahman L, Hinkle A, Asselin B, Lipshultz SE. Anthracycline induced cardiotoxicity. *Crit Rev Oncol/Hematol* 1998;27:53–68.
- [26] Herman EH, Lipshultz SE, Rifai N et al. Cardiac troponin T: elevated serum levels and loss from cardiac myocytes in doxorubicin toxicity. *Cancer Res* 1998;58:195–197.
- [27] Starc T.J., Lipshultz S.E., Kaplan S., et al., for the P²C² HIV study group. Cardiac complications in children with human immunodeficiency virus infection. *Pediatrics* 1999;104:e14 (9 pages, URL: <http://www.pediatrics.org/cgi/content/full/104/2/e14>; HIV, cardiac disease, pediatrics).
- [28] Ottlinger M, Pearsall L, Rifai N, Lipshultz SE. New developments in the biochemical assessment of myocardial injury in children: troponin T and I as highly sensitive and specific markers of myocardial injury. *Prog Pediatr Cardiol* 1998;8:71–81.
- [29] Nysom K, Colan SD, Lipshultz SE. Late cardiotoxicity following anthracycline therapy for childhood cancer. *Prog Pediatr Cardiol* 1998;8:121–138.
- [30] Krischer JP, Epstein S, Cuthbertson DD, Goorin AM, Epstein ML, Lipshultz SE. Risk factors for early anthracycline cardiotoxicity in children: the pediatric oncology group experience. *Prog Pediatr Cardiol* 1998;8:83–90.
- [31] Cameron EH, Lipshultz SE, Tarbell NJ, Mauck PM. Cardiovascular disease in long-term survivors of pediatric Hodgkin's disease. *Prog Pediatr Cardiol* 1998;8:139–144.
- [32] Bowles NE, Kearney D, Ni J et al. The detection of viral genomes by polymerase chain reaction in the myocardium of pediatric patients with advanced HIV disease. *J Am Coll Cardiol* 1999;34:857–865.
- [33] Shearer W.T., Lipshultz S.E., Easley K., et al., P²C² Study Group. Alterations in cardiac and pulmonary function in pediatric rapid human immunodeficiency virus type 1 disease progressors. *Pediatrics* 2000;105(1):1–8. URL: <http://www.pediatrics.org/cgi/contents/full/105/1/e9>
- [34] Towbin JA, Lipshultz SE. Genetics of neonatal cardiomyopathy. *Curr Opin Cardiol* 1999;14:250–262.
- [35] Lipshultz SE. Dilated cardiomyopathy in HIV-infected patients. *N Engl J Med* 1998;339:1153–1155.
- [36] Herman E.H., Zhang J., Lipshultz S.E., et al. Correlation between serum levels of cardiac troponin-T and the severity of chronic cardiomyopathy induced by doxorubicin. *J Clin Oncol* 1999 17 2237–2243.
- [37] Moran AM, Lipshultz S, Rifai N et al. Non-invasive assessment of rejection in pediatric heart transplant patients: serologic and echocardiographic prediction of biopsy proven myocardial rejection. *J Heart Lung Transplant* 2000; 19:756–764.
- [38] Chiang VW, Burns JP, Rifai N, Lipshultz SE, Adams MJ, Weiner DL. Cardiac toxicity of intravenous terbutaline for the treatment of severe asthma in children: a prospective assessment. *J Pediatr* 2000;137:73–77.

- [39] Lipshultz SE, Easley KA, Orav EJ et al. for the Pediatric Pulmonary and Cardiovascular Complications of Vertically Transmitted HIV Infection Study Group. Cardiac dysfunction and mortality in HIV-infected children. The prospective P²C² HIV multicenter study. *Circulation* 2000;102:1542–1548.
- [40] Lipshultz SE, Easley KA, Orav EJ et al. Absence of cardiac toxicity of zidovudine in infants. *N Engl J Med* 2000;343:759–766.
- [41] Christakis DA, Davis R, Rivara FP. Pediatric evidence-based medicine: past, present, and future. *J Pediatr* 2000;136:383–389.
- [42] Kramer MS. A comparison of laboratory and epidemiologic approaches to pediatric research. *Pediatr Res* 1998;43:711–718.
- [43] Benson K, Hartz AJ. A comparison of observational studies and randomized controlled trials. *N Eng J Med* 2000;342:1878–1886.
- [44] Concato J, Shah N, Horwitz RI. Randomized, controlled trials, observational studies and the hierarchy of research designs. *N Eng J Med* 2000;342:1887–1892.
- [45] Pocock SJ, Elbourne DR. Randomized trials or observational tribulations? *N Eng J Med* 2000;342:1907–1909.
- [46] Abdulla R. Teaching pediatric cardiology. *Pediatr Cardiol* 2000;21:187–188.
- [47] Stockman III JA. Issues related to subspecialty education: weasel words in action. *J Pediatr* 1999;135:669–674.
- [48] Myers JH. Design and redesign of the heart. *Chaser News* 1998;4:13.
- [49] US Department of Health and Human Service. Healthy people 2000. DHHs Publication No. (PHS) 91-50212. 1990.
- [50] Moller JH, Taubert KA, Allen HD, Clark EB, Lauer RM. Cardiovascular health and disease in children: current status. *Circulation* 1994;89:923–930.
- [51] Moller JH, Allen HD, Clark EB et al. Report of the task force on children and youth. *Circulation* 1993;88:2479–2486.
- [52] Williams RG, Kennedy TL, Moller JH. Pediatric cardiology in the 1990s. *J Am Coll Cardiol* 1994;23:977–980.
- [53] Adams FH, Blumenthal S, DuShane JW et al. Manpower and training requirements in pediatric cardiology 1973;51:813–821.
- [54] Grenier MA, Osganian SK, Cox GF et al. Design and implementation of the north american pediatric cardiomyopathy registry. *Am Heart J* 2000;139:S86–S95.
- [55] Lenfant C. NHLBI genomics initiatives. Looking beyond the human genome project. *Circulation* 2000;101:468–469.
- [56] Ponder KP. Systemic gene therapy for cardiovascular disease. *Trends Cardiovasc Med* 1999;9:158–162.
- [57] Smaha LA. From bench to bedside: the future is now. *Circulation* 2000;101:942–945.
- [58] Balis F.M. Clinical trials in childhood cancers. *The Oncologist* 2000;5:xii.
- [59] Blumer JL. Off-label uses of drugs in children. *Pediatrics* 1999;104:598–602.
- [60] Christensen ML, Helms RA, Chesney RW. Is pediatric labeling really necessary? *Pediatrics* 1999;104:593–597.
- [61] Llewellyn S.T. Academy encourages clinical trials for pediatric cancer drugs. *AAP News* April 2000:4.
- [62] Nugent T. Pediatricians should weigh drug trial risks. *AAP News* 133 2000;17:140.
- [63] Grenier M.A., Fioravanti J., Truesdale S.C., Mendelsohn A.M., Vermilion R.P., Lipshultz S.E. Angiotensin converting inhibitor therapy for ventricular dysfunction in infants, children and adolescents: a review. *Prog Ped Cardiol* 2000;12:91–111.
- [64] Vlach SA, Lipsitz SR, Sallan SE, Colan SD, Lipshultz SE. Growth hormone therapy for LV dysfunction: a 10-year experience. *Pediatr Res* 1999;45:32A.
- [65] Kumar K, Thatai D, Saxena A et al. Pediatric dilated cardiomyopathy: prognosis in a developing nation is comparable to developed nations. *J Am Coll Cardiol* 1995;27:187A.
- [66] Marin-Garcia J, Goldenthal MJ, Ananthkrishnan R et al. Specific mitochondrial DNA deletions in idiopathic dilated cardiomyopathy. *Cardiovasc Res* 1996;31:306–313.
- [67] Marin-Garcia J, Goldenthal MJ, Ananthkrishnan R et al. Mitochondrial function in children with idiopathic dilated cardiomyopathy. *J Inherited Metab Dis* 1996;19:309–312.
- [68] Chanock S, Luginbuhl LM, McIntosh K, Lipshultz SE. Life-threatening reactions to trimethaprim–sulfamethoxazole in children with HIV infection. *Pediatrics* 1994;93:519–521.
- [69] Wong J, Lipshultz SE. Cardiovascular complications of pharmacotherapeutic agents (excluding the antiretrovirals) in pediatric HIV infection. In: Lipshultz SE, editor. *Cardiology in AIDS*. New York: Chapman and Hall, pages, 1998:331–344.
- [70] Hunt JR, White E. Retaining and tracking cohort study members. *Epidemiol Rev* 1998;20:57–70.
- [71] Diness R, Greenbaum N, Auletto R, Ross S, Lewis K. Nursing, quality of life, and social issues in HIV-infected patients. In: Lipshultz SE, editor. *Cardiology in AIDS*. New York: Chapman and Hall, 1998:437–454.
- [72] Lane-McAuliffe EA, Lipshultz SE. Cardiovascular manifestations of pediatric HIV infection. *Nurs Clin N Am*. 1995;30:291–316.
- [73] Kattan M, Beck G, Kaplan S et al. The pediatric pulmonary and cardiovascular complications of vertically transmitted human immunodeficiency virus (P²C² HIV) infection study: design and methods. *J Clin Epidemiol* 1996;49:1285–1294.
- [74] Cohen H, Carp D, Davis L, Geromanos K, Hunter J, Sunkle S. P²C² HIV Study Group. Coordinating the large multicentered HIV research project. *J Assoc Nurs AIDS Care* 1997;8:41–50.
- [75] Xanthos G, Carp D, Geromanos K. P²C² HIV Study Group. Recognizing nurses' contributions to the clinical research process. *J Assoc Nurs AIDS Care* 1998;9:39–48.
- [76] Ottlinger M, Sallan SE, Rifai N, Sacks D, Lipshultz SE. The use of serum cardiac troponin-T to detect myocardial damage during doxorubicin therapy. *Am Soc Clin Oncol* 1995;14:345.
- [77] Lipshultz SE, Ottlinger M, Sallan SE et al. The predictive value of serum cardiac troponin T in children with myocardial damage. *J Am Coll Cardiol* 1997;29:429A.
- [78] Herman EH, Lipshultz SE, Rifai N et al. Cardiac troponin T: elevated serum levels and loss from cardiac myocytes in doxorubicin toxicity. *Circulation I* 1996;94:85.
- [79] Lipshultz S.E., Sallan S.E., Dalton V., Arslanian S., Rifai N. Chronically active cardiac injury during doxorubicin therapy for childhood ALL: Serum cardiac troponin-T on DFCI 95-001. Proc NCI workshop on research issues in cancer survivorship (abstract P-36, page 64) (1998).
- [80] Lipshultz SE, Sallan SE, Dalton V et al. Elevated serum cardiac troponin-T as a marker for active cardiac injury during therapy for childhood acute lymphoblastic leukemia. *Proc ASCO* 1999;18:568A.
- [81] Herman E, Zhang J, Lipshultz S et al. Cardiac troponin T (cTnT) as a biomarker for monitoring chronic doxorubicin (dxr) cardiomyopathy. *J Am Coll Cardiol* 1999;33:171A.
- [82] Herman E., Zhang J., Chadwick D., et al. A comparison of the cardioprotective effects of dexrazoxane (DZR) against the cardiotoxicity induced by doxorubicin (DXR) and mitox-

- antrone (MTX) in spontaneously hypertensive rats (SHR). Proc AACR (in press) (2000).
- [83] Lipshultz SE. Determination of serum cardiac troponin-T as a biomarker of anthracycline cardiotoxicity. *Toxicologist* 2000;54:355–356.
- [84] Herman E., Zhang J., Rifai N., Lipshultz S., Sistare F. Serum cardiac troponin T is a sensitive biomarker of anthracycline-induced myocardial damage and dexrazoxane cardioprotection. *The Toxicologist* (in press) (2000).
- [85] Schowengerdt KO, Ni J, Denfield SW et al. Diagnosis, surveillance and epidemiologic evaluation of viral infections in pediatric cardiac transplant recipients with the use of the polymerase chain reaction. *J Heart Lung Transplant* 1996;15:111–123.
- [86] Akhtar N, Ni J, Stromberg D, Towbin JA. Tracheal aspirate as a substrate for PCR detection of viral genome in childhood pneumonia and myocarditis. *Circulation* 1999;99:2011–2018.
- [87] Bridges ND, Spray TL, Collins M, Bowles NE, Towbin JA. Adenovirus infection predicts graft failure after pediatric lung transplantation. *J Thorac Cardiovasc Surg* 1998;116:617–623.
- [88] Wong JCL, Rifai N, Lipsitz SR, Galpachian V, Lipshultz SE. Clinically unsuspected myocardial injury in children. *Pediatr Res* 1997;41:101A.
- [89] Jabs K, Rifai N, Colan SD, Galpachian V, Lipshultz SE. Elevations of serum troponin T and I levels and cardiac abnormalities in children with chronic renal failure. *J Am Soc Nephrol* 1996;9:1320.
- [90] Lipshultz SE, Somers MJG, Lipsitz SR, Colan SD, Jabs K, Rifai N. Cardiovascular abnormalities in children with chronic renal failure. *Pediatr Res* 1999;45:26A.
- [91] Lipshultz SE, Colan SD. The use of echocardiography and Holter monitoring in the assessment of anthracycline-treated patients. In: Bricker JT, Green DM, D'Angio GJ, editors. Long term complications of treatment of children and adolescents for cancer New York: Wiley-Liss, 1993:45–62.
- [92] Adams MJ, Constine L, Lipshultz SE. Radiation effects on the heart. In: Crawford M, DiMarco T, editors. International textbook of cardiology. London: Mosby International, 2000.
- [93] Lipshultz SE, Easley K, Kaplan S et al. P²C² Study Group. Abnormal left ventricular structure and function shortly after birth in infants of HIV-infected mothers — the prospective NHLBI P²C² study. *Circulation* 1995;92:1–581.
- [94] Lipshultz SE, Frassica JJ, Orav EJ. Cardiovascular abnormalities in infants prenatally exposed to cocaine. *J Pediatr* 1991;118:44–52.
- [95] Frassica JJ, Orav EJ, Walsh EP, Lipshultz SE. Arrhythmias in children prenatally exposed to cocaine. *Arch Pediatr Adol Med* 1994;148:1163–1169.
- [96] Gillman M.W., Link C.L., Rich-Edwards J.W., Lieberman E.S., Lipshultz S.E. Maternal age and newborn blood pressure. *Circulation* (abstract – in press) (2000).
- [97] Cohn JN, Bristow MR, Chien KR et al. Report of the National Heart, Lung, and Blood Institute special emphasis panel on Heart Failure Research. *Circulation* 1997;95:766–770.
- [98] Lipshultz SE, Towbin JA, Grenier MA et al. Etiology and family history of pediatric cardiomyopathy: the early pediatric cardiomyopathy registry (PCMR) experience. *J Am Coll Cardiol* 1998;31:30a.
- [99] Lipshultz SE, Grenier MA, Colan SD et al. The incidence of pediatric cardiomyopathy in the NHLBI pediatric cardiomyopathy registry. *Pediatr Res* 1999;45:26A.
- [100] Lipshultz SE, Lipsitz SR, Sallan SE, Mone SM, Gelber RD, Colan SD. Is enalapril beneficial in doxorubicin-treated long-term survivors of childhood cancer? *Circulation* 1997;96:1–436.
- [101] Lipshultz SE, Lipsitz SR, Sallan SE et al. Chronic progressive LV systolic dysfunction and afterload excess years after doxorubicin therapy for childhood acute lymphoblastic leukemia. *Circulation* 1999;100:1–530.
- [102] Soffer BA, Shahinfar Sm Shaw WC, Zhang Z, Herrera P, Frame V, Wells TG. for the Merck Pediatric Enalapril Investigator Group. Effects of the ace inhibitor, enalapril, in children age 6–16 with hypertension. *Pediatr Res* 2000;47:452A.
- [103] Shahnaz S, Rippley R, Hogg R et al. for the Merck Pediatric Enalapril Investigator Group. Multicenter study of enalapril pharmacokinetics in hypertensive children and infants. *Pediatr Res* 2000;47:473A.
- [104] Lipshultz SE, Sallan SE, Giantris A, Lipsitz SR. for the Dana-Farber Childhood Leukemia Consortium Investigators. 48 hour continuous doxorubicin infusion is not cardioprotective in children assessed 18 months later. *Proc Am Soc Clin Oncol* 1998;17:528a.
- [105] Lipshultz SE, Starc T, Easley K et al. P²C² HIV Study Group. The reliability of multicenter pediatric echocardiographic measurements of LV structure and function — the prospective NHLBI P²C² study. *Circulation* 1998;98:480.
- [106] Abdulla R. The American academy of child cardiology. *Pediatr Cardiol* 2000;21:297–298.
- [107] National Heart, Lung and Blood Institute RFA HL-00-013: Pediatric Heart Disease Clinical Research Network. 2000.
- [108] Kannel WB. Current status of the epidemiology of heart failure. *Curr Cardiol Rep* 1999;1:11–19.
- [109] Kolata G., Eichenwald K. Business thrives on unproven care, leaving science behind. *The New York Times*. October 3, 1999. Page 1.
- [110] Kolata G., Eichenwald K. In pediatrics, a lesson in making use of experimental procedures. *The New York Times*. October 3, 1999. Page 40.
- [111] Lantos JD. The 'inclusion benefit' in clinical trials. *J Pediatr* 1999;134:130–131.
- [112] Murphy S. The national impact of clinical cooperative group trials for pediatric cancer. *Med Pediatr Oncol* 1995;24:279–280.
- [113] Kersey JH. Fifty years of studies of the biology and therapy of childhood leukemia. *Blood* 1997;90:4243–4251.
- [114] Murphy S.B. Pediatric patients benefit from inclusion in clinical trials. *POG Perspect* 1998;4:2.
- [115] Canellos GP. Clinical research saves money: reflections on high-dose therapy of breast cancer. *J Clin Oncol* 1999;17:1965–1966.
- [116] Fireman BH, Fehrenbacher L, Gruskin EP, Ray GT. Cost of care for patients in cancer clinical trials. *J Natl Cancer Inst* 2000;92:136–142.
- [117] Black N. High-quality clinical databases: breaking down barriers. *Lancet* 1999;353:1205–1206.
- [118] Flores G, Lee M, Bauchner H, Kastner B. Pediatricians attitudes, beliefs, and practices regarding clinical practice guidelines: a national survey. *Pediatrics* 2000;105:496–501.
- [119] Grilli R, Magrini N, Penna A, Mura G, Liberati A. Practice guidelines developed by specialty societies: the need for a critical appraisal. *Lancet* 2000;355:103–106.
- [120] Miller J, Petrie J. Development of practice guidelines. *Lancet* 2000;355:82–83.
- [121] Woolf SH, Grol R, Hutchinson A, Eccles M, Grimshaw J.

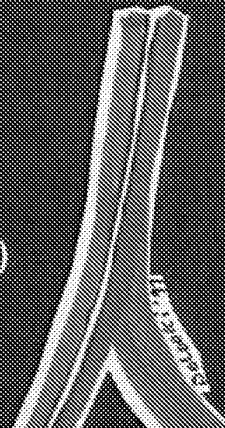
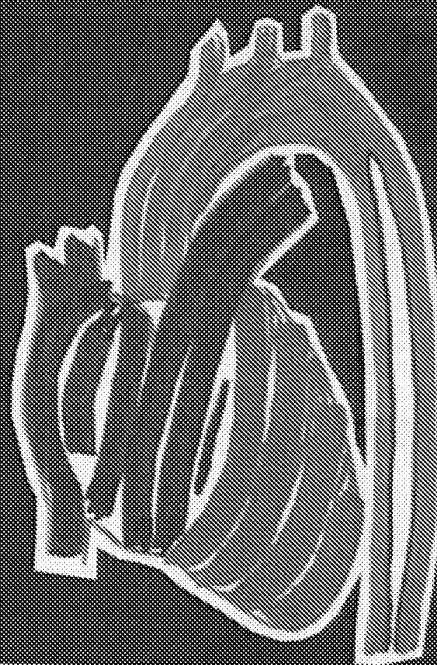
- Potential benefits, limitations, and harms of clinical guidelines. *Br Med J* 1999;318:527–530.
- [122] Holmboe ES, Meehan TP, Radford MJ, Wang Y, Marciniak TA, Krumholz HM. Use of critical pathways to improve the care of patients with acute myocardial infarction. *Am J Med* 1999;107:324–331.
- [123] Quality of care and outcomes research in CVD and stroke working groups. Measuring and improving quality of care. A report from the American Heart Association/American College of Cardiology First Scientific Forum on Assessment of Healthcare Quality in Cardiovascular Disease and Stroke. *Circulation* 2000;101:1483-1493.
- [124] Lipshultz SE, Fox CH, Perez-Atayde AR et al. Identification of human immunodeficiency virus-1 RNA and DNA in the heart of a child with cardiovascular abnormalities and congenital acquired immune deficiency syndrome. *Am J Cardiol* 1990;66:246–250.

CLINICAL
APPLICATION
OF THE

INTRA-AORTIC BALLOON PUMP

Third Revised Edition

By
Hooshang Bolooki, MD, FRCS(C)



Library of Congress Cataloging-in-Publication Data

Bolocki, Hooshang, 1937—
Clinical application of intra-aortic balloon pump / by Hooshang
Bolocki.—3rd rev. ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-87993-401-8
1. Intra-aortic balloon counterpulsation. I. Title.
[DNLM: 1. Intra-Aortic Balloon Pumping. WB 168 B693c 1998]
RC684.I58855 1998
617.8'13—dc21
DNLM/DLC
for Library of Congress

98-6276
CIP

Copyright © 1998
Futura Publishing Company, Inc.

Published by
Futura Publishing Company, Inc.
135 Bedford Road
Armonk, New York 10504

LC#: 98-6276
ISBN#: 0-87993-401-8

Every effort has been made to ensure that the information in this book is up to date and accurate at the time of publication. However, because of the constant developments in medicine, neither the authors, nor the editor, nor the publisher can accept any legal or any other responsibility for any errors or omissions that may occur.

All rights reserved.

No part of this book may be translated or reproduced in any form without written permission of the publisher.

Printed in the United States of America

Printed on acid-free paper.

252 > CLINICAL APPLICATION OF INTRA-AORTIC BALLOON PUMP

loids. Colloids include blood transfusion, plasma, and plasmanate®. Output volume includes gastric drainage, urinary output, amount or number of times of bowel movements, and any evidence of excessive insensible loss (sweating, hyperventilation, etc.).

9) Laboratory studies are done on a daily basis or as ordered. Blood gas analysis and serum potassium levels are measured more frequently.

Prolonged Intra-Aortic Balloon Pump for Chronic Left Ventricular Dysfunction

In these patients, nursing care is somewhat different because of the slow process of recovery. Here, attention is directed mainly to improving the patient's cardiac function through various therapeutic interventions and to preventing major complications such as leg ischemia and balloon rupture. Working toward these goals, it becomes clear that care of the monitoring lines is the prime function of the nurse who also ensures accurate measurement of hemodynamic data. These patients are cared for in an ICU for days or weeks.

After 7 to 10 days when patients are stable, but still are balloon dependent and are awaiting implantation of a cardiac assist device or heart transplantation, radial artery pressure monitoring by pressure cuff may be sufficient. At this stage, they may have a peripheral intravenous line. These patients may ambulate around their bed with the nurse's assistance if there is sufficient improvement of cardiac function in conjunction with IABP assist.

Intra-Aortic Balloon Pump for Reversal of Acute Coronary Ischemia

In these patients, intra-aortic balloon pumping frequently is done for one or a combination of the following indications:

- 1) To decrease the episodes of angina pectoris that are unresponsive to nitroglycerin infusion.
- 2) To suppress and control malignant ventricular arrhythmias that are unresponsive to drug therapy.
- 3) To improve and reverse the acute LV dysfunction due to oxygen supply/demand imbalance.

The main purpose is to *reduce myocardial oxygen consumption and to redistribute the coronary blood flow*. Here, hemodynamic monitoring is of academic interest. The nurse should observe the balloon augmentation curves and record the number and severity of episodes of angina, as well as their duration and response to therapy. The type and frequency of ventricular arrhythmia are also recorded. Since the conditions may alleviate quickly with IABP, psychologic support becomes an important task for the nurse. In contrast to patients who are in chronic LV failure, patients with acute ischemia are awake and alert and are very inquisitive of their condition and prognosis. They are psychologically depressed because of chest discomfort or ventricular arrhythmia which interrupts their rest and may occur unheralded. Frequent discussion with the patient and the family plays an important role. These patients should be sedated more frequently than patients in chronic congestive heart failure where sedation is rarely needed and at times contraindicated.

In these situations, measurement of pulmonary artery pressure and cardiac output should be done at the start of each nursing shift. Once cardiovascular stability is achieved, IABP should be discontinued. The average assist time in these patients is less than 3 days. Pharmacologic therapy includes drugs that increase myocardial oxygen

supply by coronary vasodilatation (calcium channel blockers and nitroglycerin) and drugs that decrease myocardial oxygen consumption (propranolol, ACE inhibitors, and nitroprusside). Since most patients are fully alert and may not be respirator dependent, they generally require less exhaustive nursing care. Nursing care of patients with preinfarction or postinfarction angina in whom LV function is minimally depressed, becomes difficult if distal leg ischemia develops. Ischemic leg pain requires frequent administration of strong sedatives and prompt surgical intervention. A change in the balloon catheter to the opposite leg or a decision to discontinue balloon pumping or to proceed with cardiac surgery may be required. The period of balloon pumping in these patients frequently is short and a decision toward cardiac catheterization and surgical intervention is reached quickly.

Duncan J. Macrae
David Field
Jean-Christophe Mercier
Jens Møller
Tom Stiris
Paolo Biban
Paul Cornick
Allan Goldman
Sylvia Göthberg
Lars E. Gustafsson
Jürg Hammer
Per-Arne Lönnqvist
Manuel Sanchez-Luna
Gunnar Sedin
Nim Subhedar

Inhaled nitric oxide therapy in neonates and children: reaching a European consensus

Received: 8 May 2003
Accepted: 1 December 2003
Published online: 13 January 2004
© Springer-Verlag 2004

Electronic Supplementary Material
Supplementary material is available in the
online version of this article at
<http://dx.doi.org/10.1007/s00134-003-2122-3>

D. J. Macrae (✉)
Royal Brompton Hospital,
Sydney Street,
SW3 6NP London, U.K.
e-mail: d.macrae@rbh.nthames.nhs.uk
Tel.: +44-20-73528121
Fax: +44-20-73518360

D. Field · P. Cornick
Department of Child Health,
Leicester Royal Infirmary,
LE1 5WW Leicester, U.K.

J.-C. Mercier
Hôpital Robert Debré,
48 Boulevard Sérurier,
75935 Paris Cedex 19, France

J. Møller
Klinikum Saarbrücken,
Winterberg 1, 66119 Saarbrücken,
Germany

T. Stiris
Barn. Afd. Ullevål sykehus,
0407, Norway

P. Biban
Neonatal and Paediatric Intensive Care Unit,
Major City Hospital,
Piazzale Stefania, 37126 Verona, Italy

A. Goldman
Great Ormond Street Children's Hospital,
Great Ormond Street,
WC1 N 3JH London, U.K.

S. Göthberg
Drottning Silvias Barnsjukhus,
Sahlgrenska University Hospital,
41685 Gothenburg, Sweden

L. E. Gustafsson
Department of Physiology
and Pharmacology,
Karolinska Institutet,
17177 Stockholm, Sweden

J. Hammer
Kinderspital, Roemerstrasse 8, 4005 Basel,
Switzerland

P.-A. Lönnqvist
Department of Paediatric Anaesthesia
and Intensive Care,
Astrid Lindgren Children's Hospital,
Karolinska Institutet,
17176 Stockholm, Sweden

M. Sanchez-Luna
Servicio de Neonatología,
Hospital General Universitario
Gregorio Marañón,
Dr. Esquerdo 46, 28009 Madrid, Spain

G. Sedin
Akademiska sjukhuset,
75185 Uppsala, Sweden

N. Subhedar
Neonatal Unit,
Liverpool Women's Hospital,
Crown Street, L8 7SS Liverpool, U.K.

Abstract Inhaled nitric oxide (iNO) was first used in neonatal practice in 1992 and has subsequently been used extensively in the management of neonates and children with cardiorespiratory failure. This paper assesses evidence for the use of iNO in this population as presented to a consensus meeting jointly organised by the European Society of Paediatric and Neonatal Intensive Care, the European Society of Paediatric Research and the European Society of Neonatology. Consensus Guidelines on the Use of iNO in Neonates and Children were produced following discussion of the evidence at the consensus meeting.

Keywords Inhaled nitric oxide · Pulmonary hypertension · Persistent pulmonary hypertension of the newborn · Extracorporeal membrane oxygenation · Vasodilator · Pulmonary

Introduction

Inhaled nitric oxide (iNO) has been used in Europe to treat a variety of conditions in neonates and children since 1992, foremost in persistent pulmonary hypertension of the newborn (PPHN), which has remained a major therapeutic challenge in the NICU [1, 2]. Introduction of iNO into clinical use was virtually unregulated in Europe, where supplies of industrially produced gas were freely available. Subsequently clinical trials have established roles for iNO therapy in the treatment of term neonates with severe respiratory failure and a pharmaceutical quality product has recently become available in Europe and the United States. The high cost of the licensed product, compared to previous industrial supplies, and the narrow scope of the drug's licensed indications suggested to our group that a consensus should be established on the use of iNO therapy in neonates and children covering both its approved and potential indications.

Methods

An Advisory Board was established under the auspices of the European Society of Neonatal and Paediatric Intensive Care to co-ordinate the scientific programme of the meeting. The board consisted of experts with proven scientific or clinical expertise relevant to the clinical use of iNO. The board identified a further panel of experts who were invited to act as section leaders whose role was to review the literature in their designated subject area. Section leaders were asked to produce written summaries of their subject area, which were then circulated to delegates prior to the meeting and which formed the basis of the evidence presented to delegates at the consensus meeting itself.

A further panel of opinion leaders were invited to attend the meeting on the basis of their known interest in the use of iNO or their status as opinion leaders in the field of neonatal and paediatric intensive care. The European Society of Paediatric Research and the European Society of Neonatology were officially represented at the meeting. At the consensus meeting each subject area was presented in summary by the section leader(s), following which open discussion led to the composition of draft consensus statements. These were then edited and re-presented to delegates with further discussion leading to final agreement on the individual consensus statements.

Results

Inhaled nitric oxide in term and near-term neonates

Neonatal hypoxaemia may result from *intra-pulmonary shunting*, from *extra-pulmonary shunting* (so-called PPHN) or from cyanotic congenital heart disease. The presence of interstitial pulmonary infiltrates or a low volume lung (<6–7 ribs) on chest X-ray strongly suggests parenchymal lung disease. Alveolar recruitment has been shown to render babies with severe hypoxaemic respiratory failure responsive to iNO, when they were previously

unresponsive [2]. Exogenous surfactant and ventilatory manoeuvres [3] should therefore be deployed to optimise lung volume before iNO is introduced. If cyanosis persists after any necessary lung recruitment manoeuvres have been applied, an echocardiogram should be obtained to confirm or exclude the presence of congenital heart disease or pulmonary hypertension as causes of cyanosis. Inhaled NO is most likely to benefit babies with PPHN with recruited lung volume and is unlikely to benefit babies with cyanotic heart disease.

The recent Cochrane Review was used as a framework in this discussion [4]. The review, last updated in December 2000, included 12 relevant trials in its analysis, all of which used random allocation [5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]. One further on-going study received limited analysis since, at the time of review, it was on-going and published only as an abstract [16]. A literature search up to October 2003 failed to reveal any new randomised, controlled trials not already included in the Cochrane review.

The limitations of the studies presented within the Cochrane review were highlighted. Of major importance, the entry criteria differed markedly between trials as did dosage and ventilatory strategies, there being a suggestion that high frequency oscillatory ventilation (HFOV) appears beneficial in achieving a response to iNO [10]. Eight of the 12 clinical trials studied the effect of iNO on the overall clinical course of the babies included and, in particular, whether the need for extracorporeal membrane oxygenation (ECMO) was reduced. Only six trials did not allow crossover [6, 7, 8, 11, 12, 13]. Of the six studies which did not allow crossover, three [6, 11, 12] found a statistically significant reduction in the combined outcome of death or requirement for ECMO in the NO group. A meta-analysis of all six studies found that iNO treatment resulted in a reduction in the incidence of death or requirement for ECMO (relative risk 0.65) [4].

Inhaled nitric oxide therefore appears to improve outcome in hypoxaemic term and near-term infants. The improvement is due mainly to a reduction in the need for ECMO, since mortality was not reduced. The two largest studies [6, 11] included infants with congenital diaphragmatic hernia as sub-groups. A separate analysis has been presented from one of these studies [17]. There was no evidence that outcome was improved in these babies through the use of iNO, even if short-term improvements in oxygenation did occur. It is important to note that whilst iNO reduced the need for ECMO, the majority of mature babies in these studies went on to ECMO.

Only one study has considered long-term follow-up as a primary or secondary hypothesis. In this study, the incidence of disability, the incidence of deafness and infant development scores were all similar between tested survivors who received NO and those who did not [18].

The major randomised, controlled trials of iNO in term or near-term babies have used echocardiography to

exclude congenital heart disease as a cause of hypoxaemia prior to exposure to iNO. Babies with such lesions are at best unlikely to benefit from iNO, as cyanosis is due to extra-pulmonary shunting. Inhaled NO exposure may even be harmful in some babies with congenital heart disease, such as those with obstructed total anomalous pulmonary venous drainage or severe left ventricular dysfunction with right-to-left ductal shunting [19], in whom pulmonary arteriolar vasoconstriction may be clinically beneficial by reducing left heart filling.

Dosage and response to inhaled nitric oxide treatment in term and near-term neonates

Decisions regarding continued use of iNO therapy cannot be based on the primary end points used in the pivotal studies, such as reduced mortality or 'avoidance' of ECMO. Instead clinicians must use surrogate physiological end points in order to establish whether an initial test exposure to iNO is effective. Improvement in oxygenation of approximately 20% over baseline values at 30–60 min has been used in many studies as an indicator of early response to iNO including six of the studies in the Cochrane review [5, 6, 7, 9, 11, 12].

Four published studies have reported dose-response data for this group of babies [7, 20, 21, 22]. All four studies suggest that a maximal beneficial effect of iNO is already seen at concentrations of less than 30 ppm. Further increases of iNO (to 80–100 ppm) do not appear to result in further improvement of oxygenation above that achieved at 20–30 ppm. The large NINOS study [11] used initial doses of 20 ppm iNO, but exposed 'partial responders' to 80 ppm. Only 6% of these partial responders were converted to full response by 80 ppm iNO.

In the small study published by Tworetzky et al. a maximum reduction of pulmonary artery pressure was observed at 20 ppm NO, whereas maximal improvement in oxygenation occurred at 5 ppm [23]. Response to the introduction of iNO usually occurs rapidly in 'responders'. Some investigators attribute clinical improvements seen several hours later to iNO administration [24]. However it was the expert group's view that there is a serious danger that babies with very severe hypoxaemia could be harmed if ECMO referral were to be delayed whilst waiting for a 'late' response.

If no substantial effect has been achieved during a trial of iNO, treatment with iNO should be rapidly discontinued or the baby transferred on iNO to a level 3 or tertiary neonatal unit. This should occur as soon as the clinician is convinced that iNO is not inducing a beneficial effect judged by improving oxygenation. The trial to improve oxygenation with NO should not last longer than 4 h. The reason not to prolong NO therapy unnecessarily is that NO synthase is down-regulated, with suppression of

endogenous NO production. Down-regulation of endogenous NO synthase by the use of iNO has been suggested [25, 26, 27].

We were unable to identify studies establishing the optimal regime for maintenance of iNO therapy once an initial response has been established. It is, however, logical in clinical practice to seek to minimise iNO exposure by lowering the iNO dose, provided the beneficial effects on oxygenation and general clinical stability are maintained. This approach was described by Kinsella et al. [28] in the early stages of the clinical exploration of iNO therapy and further validated by Clark et al. [6].

Discontinuation and weaning

Some information is available on strategies for weaning patients from iNO as clinical improvement occurs. In a prospective study, Demirakca et al. evaluated the clinical response to iNO in neonates and children with acute respiratory distress syndrome (ARDS) [21]. Attempts to discontinue iNO were made as soon as a stable respiratory status (PEEP < 6 cmH₂O, inspiration/expiration ratio of 1:2, FiO₂ < 0.8 and an iNO concentration of 5 ppm) had been achieved. Oxygenation index (OI) values of less than 5 predicted successful withdrawal with a sensitivity of 75%, a specificity of 89%, a positive predicted value of 69% and a negative predictive value of 91% [21].

Aly et al. [29] adopted a weaning strategy for babies with PPHN which included step-wise 5 ppm decrements of iNO doses. Discontinuation of iNO was performed as soon as the patient was stable with an FiO₂ less than 0.5. Weaning was successful at the first attempt in 9 out of 16 patients. In the remaining seven neonates, major signs of deterioration (oxygen saturation drop > 10% or below 85%) prompted a reinstatement of iNO treatment for 30 min. Subsequently, FiO₂ was raised by 0.4 and a successful withdrawal of iNO was then obtained. Interestingly, FiO₂ could be returned to the pre-weaning value in a few hours. Sokol et al. [30] noted that significant deterioration of PaO₂ occurred in some babies even when weaned from 1 to 0 ppm, suggesting that iNO is physiologically active even at very low concentrations. There may be a role for other vasodilators such as epoprostenol, iloprost, endothelin antagonists or selective phosphodiesterase inhibitors [31] when weaning babies from iNO after treatment courses of sufficient duration to down-regulate NO synthase.

Toxicity

Nitric oxide reacts with oxygen to form nitrogen dioxide (NO₂) where the reaction rate is proportional to the square of the NO concentration and directly proportional to the

oxygen concentration. Whilst NO itself is a relatively reactive molecule, NO₂ is demonstrably more reactive and toxic and is a radical (it has an unpaired electron). Due to the fact that NO is usually administered in combination with high inhaled oxygen concentrations and that NO₂ in animal experiments is damaging to the lungs already at low concentrations when administered with other oxidants, the main toxicological concern should be focused on NO₂ exposure and this should be kept to a minimum. In long-term exposure lung damage may occur at 0.5 ppm NO₂ and acute lethal effects are seen from 100 ppm. Human subjects inhaling 2–3 ppm NO₂ for 5 h demonstrated reductions in antioxidant defences and an increase in alveolar permeability [32]. Reactive species such as peroxynitrite formed from NO₂, as well as being implicated in short-term toxicity, have the potential to cause damage to DNA, raising the possibility of mutagenic or carcinogenic effects. However, the concentrations of iNO and NO₂ to which patients are exposed clinically are largely within the permitted limits for occupational exposure [33]. There is as yet no evidence that inhalation of NO has any lasting adverse effects. Long-term follow-up of children exposed to iNO therapy will be required to establish any late adverse effect.

When NO reacts with haemoglobin, methaemoglobin (metHb) is formed. MetHb is not directly toxic, but is unable to carry oxygen. If metHb is allowed to accumulate it can significantly reduce the oxygen-carrying capacity of blood. The monitoring and management of metHb during clinical iNO therapy is discussed below.

Inhalation of NO has been shown by some investigators [34], but not by others [35], to inhibit platelet function. The randomised controlled neonatal trials have, however, not shown any difference in bleeding complications between groups administered iNO or control gas [4].

Delivery and monitoring

Nitric oxide administration systems should deliver constant concentrations of iNO within the respiratory gas mixture independent of ventilator mode or settings, ensure a rapid mixing and minimise contact time between NO and oxygen, thereby reducing the possibility of generating high NO₂ levels [36, 37, 38]. The delivery system should display the pressure within the NO cylinder to permit timely cylinder changes to be undertaken without loss of gas supply. The system should ideally encompass a backup power supply for use in the event of mains failure or during intra-hospital transport. A manual backup or 'hand bagging' facility must be provided for use in the event of ventilator failure or other indications for hand ventilation, as sudden discontinuation of iNO therapy can be life-threatening [36, 37, 39].

The safest approach to iNO delivery is probably to use only pharmaceutical grade NO stored in cylinders and at concentrations and conditions approved by drug regulatory bodies and delivered by devices tested and approved according to the appropriate medical device legislation.

In the clinical setting, measurement of iNO and NO₂ concentrations can be undertaken using chemiluminescence or electrochemical devices. There are a number of practical disadvantages of chemiluminescence analysers in the clinical setting, including their high cost, their need for relatively high sample volumes, noise, their need for regular calibration and their relative inaccuracy in measuring NO₂ due to the "quenching" effect [37]. Electrochemical analysers use two separate fuel cell sensors for NO and for NO₂, placed either in the gas mainstream or side stream of the ventilatory circuit. Electrochemical devices do not underestimate NO₂ levels, are inexpensive, silent, easy to calibrate and require very low gas sample volumes. Most devices are portable. Electrochemical analysers are, however, relatively insensitive (resolution 0.5 ppm) and their measurements may be affected by temperature, pressure, humidity and the presence of other gases in the environment [37]. Although many early studies of iNO delivery systems were constructed by investigators for their own studies, a number of delivery and monitoring systems have been developed for clinical use and are commercially available [39, 40].

Inhaled NO₂ concentrations should be kept to a minimum. Clinical and experimental evidence show that it is possible to administer 20 ppm iNO whilst generating NO₂ concentrations of less than 0.2 ppm [38]. Direct comparisons with tolerable environmental NO₂ concentrations should take into account that the awake person inhaling NO₂ is exposed to at least 50% lower NO₂ concentrations in their trachea due to efficient scavenging of NO₂ in the upper airways.

Nitric oxide has been supplied for clinical use by a number of suppliers as a compressed gas diluted in a balance of nitrogen with final NO concentrations of between 100 and 1000 ppm. The gas is supplied in aluminium cylinders filled to pressures of 150–200 bar. Very concentrated preparations may be difficult to deliver accurately whilst mixtures with low NO concentrations can reduce FiO₂ excessively [41]. The final choice of cylinder NO concentration will, therefore, depend on the characteristics of the delivery system in use and the required FiO₂ and FiNO. The future availability of iNO as a pharmaceutical within Europe may encourage standardisation.

Environmental safety

The US National Institute for Occupational Safety and Health (NIOSH) suggest a "Permitted Exposure Limit" for

NO₂ of 5 ppm and NO 25 ppm over an 8-h period for these potentially toxic substances [33]. Several European countries have regulated maximal occupational exposure to 2 ppm NO₂. Extrapolating this to the ICU in which iNO would be administered for a 24-h period, it would be prudent to aim for environmental levels of NO₂ in the ICU below 1.5 ppm. Environmental NO contamination can occur from two sources during iNO administration: dumped waste ventilator gas and accidental leakage of concentrated gas from a delivery system or cylinder. The US Food and Drug Administration state, in their specification for medical delivery of NO, that such delivery “does not individually or cumulatively have a significant effect on the human environment. Therefore, neither an environmental assessment nor an environmental impact statement is required” [42]. A similar ruling is applied by the UK National Health Service, which states that scavenging of waste NO is unnecessary provided that ventilation in the ICU meets required standards [43]. Several studies confirm that this advice is sound [44, 45]. There must, however, be a small risk of high environmental levels occurring from uncontrolled release of a large volume of concentrated gas from a cylinder in the event of a serious error or accident. For this reason, the consensus group suggest that it is reasonable to measure environmental levels of NO₂ continuously.

Transport

In 30–50% of babies given a trial of iNO the therapy does not result in a sustained positive oxygenation response [4]. Most babies who fail to respond to iNO are potential ECMO candidates. Since acute withdrawal of iNO may be associated with severe rebound hypoxaemia, even in babies who apparently respond poorly [46, 47], arrangements must be in place for these babies to be transferred to an ECMO centre without interruption of iNO delivery. Occasionally non-neonates may require transport within or between hospital whilst receiving iNO.

Apart from the ability to deliver iNO safely to the baby during transport, consideration must also be given to safety of the staff and crew within the transport vehicle, and compliance with any regulations governing such use. Kinsella et al. recently reported concentrations of NO and NO₂ in the cabin environment of various transport vehicles during iNO use and confirmed them to be negligible. Furthermore, they calculated the effects of uncontrolled release of a full US D-type NO cylinder containing 350 l NO gas. In this “worst case scenario” environmental NO levels were unlikely to reach dangerous levels (maximum 40 ppm fixed wing aircraft, 34 ppm ground ambulance, 94 ppm small helicopter) [48].

The expert group recommend that equipment for delivery and monitoring of iNO during transport should comply with standards for medical devices and the safety

and test requirements of the specific aircraft or other transport vehicle used. Several delivery systems have been used during transport and at least two portable systems are commercially available, one of which is specifically designed as a transport system [48].

Staff training

Clinical use of iNO involves potential hazards for both staff and patients, mainly from the risk of exposure to toxic levels of NO and NO₂, but also issues such as safe handling of gas cylinders. The safe and appropriate use of medical equipment requires adequate preparation and training. Regulatory authorities frequently recommend standards for training in the use of medical equipment, typically stating that training should include both theoretical and practical instruction [49]. US guidelines for neonatal use recommend physician training [50] and some nursing authors have discussed the need for training [51]. It has also been recommended that protocols or guidelines should be compiled by hospitals using iNO, covering all aspects of its use including responsibility for off-label prescription. Such protocols should aim to help staff deliver iNO therapy that is both safe and effective [52].

Use of inhaled nitric oxide in preterm neonates

For the purposes of this paper, ‘preterm’ neonates are defined as those babies too premature to be considered for ECMO should their condition require it, i.e. babies less than 34 weeks completed gestation [53].

Inhaled NO may improve oxygenation in preterm neonates with hypoxaemic respiratory failure in one of two ways: (1) it may reverse extra-pulmonary shunting by selectively decreasing pulmonary vascular resistance (PVR) and (2) it may reduce intra-pulmonary shunting (and/or V/Q mismatch) by redistributing pulmonary blood flow. The former mechanism is likely to be the most important in infants with primary or secondary PPHN, whereas the latter will be more important in the majority of preterm infants who have parenchymal lung disease as the primary cause of their hypoxaemic respiratory failure.

There are three published, randomised, controlled trials (RCTs) of iNO therapy in preterm infants [14, 54, 55], overviews of which have been reported in the form of two systematic reviews [53, 56]. A total of 207 infants have been studied in these RCTs. Other RCTs (such as the UK INNOVO trial, NICHD Preemie iNO trial and other US trials) are either on-going or have only just completed recruiting and results are not yet available. One small RCT has reported the long-term neurodevelopmental outcome following iNO therapy [57].

A Cochrane Review has summarised the results of the three RCTs in preterm infants [53]. The study of Kinsella

et al. [55] is the single most useful trial in that it recruited neonates with hypoxaemic respiratory failure early in the course of their respiratory disease, the intervention was masked, an important primary outcome (mortality) was chosen, there was no crossover treatment with iNO and infants were carefully evaluated for intraventricular haemorrhage (IVH). There is no evidence of an effect of iNO on mortality or chronic lung disease (CLD) at 36 weeks, or on survival without CLD in preterm infants with hypoxaemic respiratory failure. Doses of between 5–20 ppm iNO appear to be effective in improving arterial oxygenation within the first 2 h of treatment. One study showed a reduction in days of ventilation with 5 ppm iNO in survivors [55] whilst another study reported no difference [14].

Sufficient data are lacking for evaluation of the possible effects of iNO on periventricular haemorrhage or on long-term neurodevelopmental outcome. Thus, with the data currently available, the consensus group do not recommend the routine use of iNO in the preterm infant and strongly recommend its use in this indication only within controlled clinical trials. The use of iNO could, however, be justified as rescue therapy in life-threatening hypoxaemia after lung recruitment has been optimised.

Use of inhaled nitric oxide in paediatric acute lung injury and acute respiratory distress syndrome

Acute lung injury (ALI) or acute respiratory distress syndrome (ARDS) may result from many systemic disease processes, and affects people of all ages. No drug therapy has been found to impact substantially on survival in ALI cases. Inhaled NO has been used in this setting principally because of its effect in improving oxygenation as therapy commences, due to improved ventilation-perfusion matching.

The comments in this section are aimed at guiding the clinical use of iNO in paediatric practice. Recommendations on ALI and ARDS had to be formed on a very limited base of information as, apart from case series and anecdotes about children, almost all data on such clinical use of iNO were only available for adult patient populations. Five randomised controlled trials were evaluated (Dellinger [58], Dobyns [59], Lundin [60], Troncy [61], Michael [62]) in a recent Cochrane review [63] assessing 535 patients, with only one trial focused on children [59]. Inhaled NO had no impact on mortality in trials without crossover (relative risk 0.98, 95% confidence intervals 0.66, 1.44) or with crossover of treatment failures to open-label iNO (RR 1.22, 95% CI 0.65, 2.29). Evidence published in one study demonstrated that iNO resulted in a transient improvement in oxygenation in the first 24 h of treatment: the oxygenation index (OI) showed a mean difference of -3 (95% CI -5.354 , -0.646), and $\text{PaO}_2/\text{FiO}_2$ ratio and a mean difference of 35 (95% CI

20.236 – 49.764) [58]. Other clinical indicators of effectiveness, such as duration of hospital and intensive care stay, were inconsistently reported. There were no complications reported to be directly attributable to this treatment.

Based on these data, it appears that iNO has no effect on mortality and only transiently improves oxygenation in ALI/ARDS. There is insufficient data to assess other end points. The authors of the Cochrane review suggest that any further trials of iNO in this indication must stratify for underlying disease, since outcome is thought to be more related to this than to respiratory failure alone.

Use of inhaled nitric oxide in children with cardiac disease

Pulmonary hypertension is an important problem in many children with acquired or congenital heart disease. As a selective pulmonary vasodilator, as in neonatal PPHN, iNO has the potential to improve the management of these patients. Numerous reports of iNO usage in such patients have been published including its use in the assessment of the reversibility of pulmonary hypertension as a diagnostic procedure [64, 65] and in the perioperative management of pulmonary hypertension or RV afterload reduction [66, 67, 68]. Inhaled NO has also been shown to complement standard methods of differentiating reactive from fixed pulmonary vascular disease [64, 65].

Inhaled NO has been shown to be effective in the management of some patients with severe reactive pulmonary hypertensive episodes following cardiac surgery [69, 70]. In these patients, iNO is believed to replace endogenous NO production, which is temporarily impaired due to the effects of cardiopulmonary bypass on the pulmonary endothelium. One randomised, controlled trial [71] reported that the prophylactic administration of 10 ppm iNO was associated with a significant reduction in pulmonary hypertensive events and a reduction in time to meeting extubation criteria. Mortality and length of ICU stay were, however, unaffected. Another similar, but smaller, study failed to demonstrate any benefit from prophylactic iNO [72]. The view of the consensus meeting experts was that data from other clinical trials was required before the routine prophylactic use of iNO could be recommended in children at risk of pulmonary hypertensive events after repair of congenital heart surgery. Inhaled NO has also been shown to improve the haemodynamic status in patients with elevated PVR after the Fontan operation [73] and in those with failing right ventricles [74]. There are no RCT's in this group of patients.

In summary, there are few RCTs on the use of iNO in children with cardiac disease from which to draw evidence-based conclusions. There is insufficient evidence to recommend the routine use of prophylactic

postoperative iNO in congenital heart patients at risk of pulmonary hypertension. The expert group felt that there is, however, sufficient evidence (from large case series) to support a trial of 20 ppm iNO for 10 min, increasing to 40 ppm if no response to the lower dose, in patients with clinically significant pulmonary hypertension complicating their perioperative course. In this setting it is recommended that iNO should only be continued if there is documented evidence of important haemodynamic improvement. After a 30-min trial of iNO at 20 ppm, increasing to 40 ppm, consideration should be given to discontinuing the drug if no clinically significant response has occurred.

Conclusion

These guidelines, "Use of iNO in neonates and children: consensus guidelines from the European Society of Paediatric and Neonatal Intensive Care, the European Society of Paediatric Research and the European Society of Neonatology", (please see ESM), were compiled by a group of practitioners with knowledge of iNO therapy drawn from the majority of European states. The guidelines are designed to allow the safe use of this therapy, within both its permitted and its potential uses. It is hoped that these guidelines will encourage evidence-based

practice and further clinical trials on the use of iNO therapy.

Acknowledgements Performed under the auspices of the European Society of Paediatric and Neonatal Intensive Care in collaboration with the European Society for Paediatric Research and the European Society of Neonatology. Supported by an unrestricted educational grant from iNO Therapeutics.

Members of the Consensus Group

Belgium—B. van Overmeire, Antwerp. Finland—M. Hallman, Oulu; S. Andersson, Helsinki. France—T. Lacaze, Clamart; C. Danan, Creteil; J.-M. Hoscoet, Nancy; J.-C. Roze, Nancy; D. Devictor, Paris. Germany—S. Demirakca, Mannheim; B. Roth, Koln; W. Kachel, Heilbronn; K. Bauer, Berlin. Greece—T. Hatzis, Athens. Italy—F. Mosca, Milan; M. Somaschini, Sierate; D. Trevisanuto, Padova; P. Tagliabue, Monza. Netherlands—D. Tibboel, Rotterdam; J. Latour, Amsterdam. Norway—S. Sponheim, Oslo. Portugal—G. Rodriguez, Lisbon; F. Simoes, Lisbon. Spain—P. Rodriguez, Madrid; J. Figueras-Aloy, Barcelona; A. Valls-I-Soler, Bilbao. Sweden—B. Jonson, Stockholm. Switzerland—J.-F. Tolsa, Lausanne; M. Berner, Geneva. United Kingdom—A. Greenough, London; S. Sinha, Middlesborough; H. Halliday, Belfast. Slovenia—J. Primozic, Ljubljana. USA—D. Wessel, Boston.

References

- Walsh-Sukys MC, Tyson JE, Wright LL, Bauer CR, Korones SB, Stevenson DK, Verter J, Stoll BJ, Lemons JA, Papile LA, Shankaran S, Donovan EF, Oh W, Ehrenkranz RA, Fanaroff AA (2000) Persistent pulmonary hypertension of the newborn in the era before nitric oxide: practice variation and outcomes. *Pediatrics* 105:14-20
- Kinsella JP, Abman SH (1996) Clinical pathophysiology of persistent pulmonary hypertension of the newborn and the role of inhaled nitric oxide therapy. *J Perinatol* 16:S24-27
- Kinsella JP, Abman SH (2000) Clinical approach to inhaled nitric oxide therapy in the newborn with hypoxemia. *J Pediatr* 136:717-726
- Finer NN, Barrington KJ (2000) Nitric oxide for respiratory failure in infants born at or near term. *Cochrane Database Syst Rev* CD000399
- Barefield ES, Karle VA, Phillips JB 3rd, Carlo WA (1996) Inhaled nitric oxide in term infants with hypoxemic respiratory failure. *J Pediatr* 129:279-286
- Clark RH, Kueser TJ, Walker MW, Southgate WM, Huckaby JL, Perez JA, et al. (2000) Low-dose nitric oxide therapy for persistent pulmonary hypertension of the newborn. *Clinical Inhaled Nitric Oxide Research Group. N Engl J Med* 342:469-474
- Davidson D, Barefield ES, Kattwinkel J, Dudell G, Damask M, Straube R, Rhines J, Chang CT (1998) Inhaled nitric oxide for the early treatment of persistent pulmonary hypertension of the newborn: a randomized, double-masked, placebo-controlled, dose-response, multicenter study. *Pediatrics* 101:325-334
- Christou H, Van Marter LJ, Wessel DL, Allred EN, Kane JW, Thompson JE, Stark AR, Kourembanas S (2000) Inhaled nitric oxide reduces the need for extracorporeal membrane oxygenation in infants with persistent pulmonary hypertension of the newborn. *Crit Care Med* 28:3722-3727
- Day RW, Lynch JM, White KS, Ward RM (1996) Acute response to inhaled nitric oxide in newborns with respiratory failure and pulmonary hypertension. *Pediatrics* 98:698-705
- Kinsella JP, Truog WE, Walsh WF, Goldberg RN, Bancalari E, Mayock DE, Redding GJ, de Lemos RA, Sardesai S, McCurnin DC, Moreland SG, Cutter GR, Abman SA (1997) Randomized, multicenter trial of inhaled nitric oxide and high-frequency oscillatory ventilation in severe, persistent pulmonary hypertension of the newborn. *J Pediatr* 131:55-62
- The Neonatal Inhaled Nitric Oxide Study Group (NINOS) (1997) Inhaled nitric oxide in full-term and nearly full-term infants with hypoxic respiratory failure. *N Engl J Med* 336:597-604

12. Roberts JD Jr, Fineman JR, Morin FC 3rd, Shaul PW, Rimar S, Schreiber MD, Polin RA, Zwass MS, Zayek MM, Gross I, Heymann MA, Zapol WM (1997) Inhaled nitric oxide and persistent pulmonary hypertension of the newborn. *The Inhaled Nitric Oxide Study Group*. *N Engl J Med* 336:605–610
13. Wessel DL, Adatia I, Van Marter LJ, Thompson JE, Kane JW, Stark AR, Kourembanas S (1997) Improved oxygenation in a randomized trial of inhaled nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics* 100:E7
14. The Franco-Belgium Collaborative NO Trial Group (1999) Early compared with delayed inhaled nitric oxide in moderately hypoxaemic neonates with respiratory failure: a randomised controlled trial. *Lancet* 354:1066–1071
15. Cornfield DN, Maynard RC, deRegnier RA, Guiang SF 3rd, Barbato JE, Milla CE (1999) Randomized, controlled trial of low-dose inhaled nitric oxide in the treatment of term and near-term infants with respiratory failure and pulmonary hypertension. *Pediatrics* 104:1089–1094
16. Sadiq F (1998) Illinois multicenter trial. Treatment of persistent pulmonary hypertension of the newborn with inhaled nitric oxide: a randomised trial. *Pediatr Res* 43:192A
17. The Neonatal Inhaled Nitric Oxide Study Group (NINOS) (1997) Inhaled nitric oxide and hypoxic respiratory failure in infants with congenital diaphragmatic hernia. *Pediatrics* 99:838–845
18. The Neonatal Inhaled Nitric Oxide Study Group (NINOS) (2000) Inhaled nitric oxide in term and near-term infants: neurodevelopmental follow-up of the neonatal inhaled nitric oxide study group (NINOS). *J Pediatr* 136:611–617
19. Henrichsen T, Goldman AP, Macrae DJ (1996) Inhaled nitric oxide can cause severe systemic hypotension. *J Pediatr* 129:183
20. Finer NN, Etches PC, Kamstra B, Tierney AJ, Peliowski A, Ryan CA (1994) Inhaled nitric oxide in infants referred for extracorporeal membrane oxygenation: dose response. *J Pediatr* 124:302–308
21. Demirakca S, Dotsch J, Knothe C, Magsaam J, Reiter HL, Bauer J, Kuehl PG (1996) Inhaled nitric oxide in neonatal and pediatric acute respiratory distress syndrome: dose response, prolonged inhalation and weaning. *Crit Care Med* 24:1913–1919
22. Lönnqvist PA, Winberg P, Lundell B, Sellden II, Olsson GL (1994) Inhaled nitric oxide in neonates and children with pulmonary hypertension. *Acta Paediatr* 83:1132–1136
23. Tworetzky W, Bristow J, Moore P, Brook MM, Segal MR, Brasch RC, Hawgood S, Fineman JR (2001) Inhaled nitric oxide in neonates with persistent pulmonary hypertension. *Lancet* 357:118–120
24. Goldman AP, Tasker RC, Haworth SG, Sigston PE, Macrae DJ (1996) Four patterns of response to inhaled nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics* 98:706–713
25. Dotsch J, Demirakca S, Zepf K, Hanze J, Parida S, Rascher W (2000) Recovery from withdrawal of inhaled nitric oxide and kinetics of nitric oxide-induced inhibition of nitric oxide synthase activity in vitro. *Intensive Care Med* 26:330–335
26. Black SM, Heidersbach RS, McMullan DM, Bekker JM, Johengen MJ, Fineman JR (1999) Inhaled nitric oxide inhibits NOS activity in lambs: potential mechanism for rebound pulmonary hypertension. *Am J Physiol* 277:H1849–H1856
27. Petros AJ (1994) Down-regulation of endogenous nitric oxide production after prolonged administration. *Lancet* 344: 191
28. Kinsella JP, Neish SR, Shaffer E, Abman SH (1992) Low-dose inhalation nitric oxide in persistent pulmonary hypertension of the newborn. *Lancet* 340: 819–820
29. Aly H, Sahni R, Wung JT (1997) Weaning strategy with inhaled nitric oxide treatment in persistent pulmonary hypertension of the newborn. *Arch Dis Child Fetal Neonatal* Ed 76:F118–F122
30. Sokol GM, Fineberg NS, Wright LL, Ehrenkranz RA (2001) Changes in arterial oxygen tension when weaning neonates from inhaled nitric oxide. *Pediatr Pulmonol* 32:14–19
31. Atz AM, Wessel DL (1999) Sildenafil ameliorates effects of inhaled nitric oxide withdrawal. *Anesthesiology* 91:307–310
32. Rasmussen TR, Kjaergaard SK, Tarp U, Pedersen OF (1992) Delayed effects of NO₂ exposure on alveolar permeability and glutathione peroxidase in healthy humans. *Am Rev Respir Dis* 146:654–659
33. Anonymous (1988) Recommendations for occupational safety and health standards. *MMWR* 37:1–29
34. Gries A, Herr A, Motsch J, Holzmann A, Weimann J, Taut F, Erbe N, Bode C, Martin E (2000) Randomized, placebo-controlled, blinded and cross-matched study on the antiplatelet effect of inhaled nitric oxide in healthy volunteers. *Thromb Haemost* 83:309–315
35. Albert J, Norman M, Wallén NH, Frostell C, Hjemdahl P (1999) Inhaled nitric oxide does not influence bleeding time or platelet function in healthy volunteers. *Eur J Clin Invest* 29:953–959
36. Müller OI, Celermajer DS, Deanfield JE, Macrae DJ (1994) Guidelines for the safe administration of inhaled nitric oxide. *Arch Dis Child* 70:F47–F49
37. Francoe M, Troncy E, Blaise G (1998) Inhaled nitric oxide: technical aspects of administration and monitoring. *Crit Care Med* 26:782–796
38. Schedin U, Frostell CG, Gustafsson LE (1999) Formation of nitrogen dioxide from nitric oxide and their measurement in clinically relevant circumstances. *Br J Anaesth* 82:182–192
39. Kirmse M, Hess D, Fujino Y, Kakmarek RM, Hurford WE (1998) Delivery of inhaled nitric oxide using the INOvent delivery system. *Chest* 113:1650–1657
40. Stenqvist O, Kjelltoft B, Lundin S (1993) Evaluation of a new system for ventilatory administration of nitric oxide. *Acta Anaesth Scand* 37:687–691
41. Lindwall R, Frostell, CG, Lönnqvist PA (2002) Delivery characteristics of a combined nitric oxide continuous positive airway pressure system. *Paediatr Anaesth* 12(6):530–536
42. Anonymous (2000) Classification of nitric oxide administration apparatus, nitric oxide analysers and nitrogen dioxide analysers. H Final Rule. *Fed Regist* 65:11464–11465
43. Squire S (1996) An effective method of scavenging nitric oxide (with personal communication from NHS Estates). *Br J Anaesth* 77:432–434
44. Phillips ML, Hall TA, Sekar K, Tomey JL (1999) Assessment of medical personnel exposure to nitrogen oxides during inhaled nitric oxide treatment of neonatal and pediatric patients. *Pediatrics* 104:1095–1100
45. Goldman AP, Cook PD, Macrae DJ (1995) Exposure of intensive-care staff to nitric oxide and nitrogen dioxide. *Lancet* 345:199–200
46. Kinsella JP, Neish SR, Ivy DD, Shaffer E, Abman SH (1993) Clinical responses to prolonged treatment of persistent pulmonary hypertension of the newborn with low doses of inhaled nitric oxide. *J Pediatr* 123:103–108

47. Kinsella JP, Schmidt JM, Griebel J, Abman SH (1995) Inhaled nitric oxide treatment for stabilization and emergency medical transport of critically ill newborns and infants. *Pediatrics* 95:773-776
48. Kinsella JP, Griebel J, Schmidt JM, Abman SH (2002) Use of inhaled nitric oxide during interhospital transport of newborns with hypoxemic respiratory failure. *Pediatrics* 109:158-161
49. Anonymous (2000) Equipped to care. The safe use of medical devices in the 21st century. Medical Devices Agency, London
50. Anonymous (1999) Use of inhaled nitric oxide. *Pediatrics* 106:344-345
51. Noel S (1999) Nitric oxide at work in the intensive care unit; implications for nursing practice. *Nurs Crit Care* 4:249-255
52. Glynn G (1999) Nitric oxide: a nursing experience. *J Neonatal Nurs* 5:11-14
53. Barrington KJ, Finer NN (2001) Inhaled nitric oxide for respiratory failure in preterm infants (Cochrane Review). *Cochrane Database Syst Rev* 4
54. Subhedar NV, Ryan SW, Shaw NJ (1997) Open randomised controlled trial of inhaled nitric oxide and early dexamethasone in high risk preterm infants. *Arch Dis Child* 77:F185-F190
55. Kinsella JP, Walsh WF, Bose CL, Gerstmann DR, Labella JJ, Sardesai S, Walsh-Sukys MC, McCaffrey MJ, Cornfield DN, Bhutani VK, Cutter GR, Baier M, Abman SA (1999) Inhaled nitric oxide in premature neonates with severe hypoxaemic respiratory failure: a randomised controlled trial. *Lancet* 354:1061-1065
56. Hoehn T, Krause MF, Buhner C (2000) Inhaled nitric oxide in premature infants—a meta-analysis. *J Perinat Med* 28:7-13
57. Bennett AJ, Shaw NJ, Gregg JE, Subhedar NV (2001) Neurodevelopmental outcome in high-risk preterm infants treated with inhaled nitric oxide. *Acta Paediatr* 90:573-576
58. Dellinger RP, Zimmerman JL, Taylor RW, Straube RC, Hauser DL, Criner GJ, Davis K Jr, Hyers TM, Papadakos P (1998) Effects of inhaled nitric oxide in patients with acute respiratory distress syndrome: results of a randomized phase II trial. *Crit Care Med* 26:15-23
59. Dobyns EL, Cornfield DN, Anas NG, Fortenberry JD, Tasker RC, Lynch A, Liu P, Eells PL, Griebel J, Baier M, Kinsella JP, Abman SH (1999) Multi-center randomized-controlled trial of the effects of inhaled nitric oxide therapy on gas exchange in children with acute hypoxaemic respiratory failure. *J Pediatr* 134:406-412
60. Lundin S, Mang H, Smithies M, Stenqvist O, Frostell C (1999) Inhalation of nitric oxide in acute lung injury: results of a European multicentre study. The European Study Group of Inhaled Nitric Oxide. *Intensive Care Med* 25:911-919
61. Troncay E, Collet J-P, Shapiro S, Guimond JG, Blair L, Ducruet T, Francoeur M, Scharbonneau M, Blaise G (1998) Inhaled nitric oxide in acute respiratory distress syndrome: A pilot randomized controlled study. *Am J Respir Crit Care* 157:1483-1488
62. Michael JR, Barton G, Saffle JR, Mone M, Markewitz BA, Hillier K, Elstad MR, Campbell EJ, Troyer BE, Whatley RE, Liou TG, Samuelson WM, Carveth HJ, Hinson DM, Morris SE, Davies BL, Day RW (1998) Inhaled nitric oxide versus conventional therapy: effect on oxygenation in ARDS. *Am J Respir Crit Care* 157:1372-1380
63. Sokol J, Jacobs SE, Bohn D (2000) Inhaled nitric oxide for acute hypoxemic respiratory failure in children and adults. *Cochrane Database Syst Rev* CD002787
64. Wessel DL, Adatia I, Giglia TM, Thompson JE, Kulik TJ (1993) Use of inhaled nitric oxide and acetylcholine in the evaluation of pulmonary hypertension and endothelial function after cardiopulmonary bypass. *Circulation* 88:2128-2138
65. Adatia I, Perry S, Landzberg M, Moore P, Thompson JE, Wessel DL (1995) Inhaled nitric oxide and hemodynamic evaluation of patients with pulmonary hypertension before transplantation. *J Am Coll Cardiol* 25:1656-1664
66. Roberts JD Jr, Lang P, Bigatello LM, Vlahakes GJ, Zapol WM (1993) Inhaled nitric oxide in congenital heart disease. *Circulation* 87:447-453
67. Miller OL, Celermajer DS, Deanfield JE, Macrae DJ (1994) Very-low-dose inhaled nitric oxide: a selective pulmonary vasodilator after operations for congenital heart disease. *J Thorac Cardiovasc Surg* 108:487-494
68. Wessel DL (1993) Inhaled nitric oxide for the treatment of pulmonary hypertension before and after cardiopulmonary bypass. *Crit Care Med* 21:S344-S345
69. Wessel DL, Adatia I, Thompson JE, Hickey PR (1994) Delivery and monitoring of inhaled nitric oxide in patients with pulmonary hypertension. *Crit Care Med* 22:930-938
70. Goldman AP, Delius RE, Deanfield JE, Macrae DJ (1995) Nitric oxide is superior to prostacyclin for pulmonary hypertension after cardiac operations. *Ann Thorac Surg* 60:300-305; discussion 306
71. Miller OL, Tang SF, Keech A, Pigott NB, Beller E, Celermajer DS (2000) Inhaled nitric oxide and prevention of pulmonary hypertension after congenital heart surgery: a randomised double-blind study. *Lancet* 356:1464-1469
72. Day RW, Hawkins JA, McGough EC, Crezee KL, Orsmond GS (2000) Randomized controlled study of inhaled nitric oxide after operation for congenital heart disease. *Ann Thorac Surg* 69:1907-1912; discussion 1913
73. Goldman AP, Delius RE, Deanfield JE, Miller OL, de Leval MR, Sigston PE, Macrae DJ (1996) Pharmacological control of pulmonary blood flow with inhaled nitric oxide after the fenestrated Fontan operation. *Circulation* 94 (9 Suppl):II-44-II-48
74. Schulze-Neick I, Bultmann M, Werner H, Gamillscheg A, Vogel M, Berger F, Rossaint R, Hetzer R, Lange PE (1997) Right ventricular function in patients treated with inhaled nitric oxide after cardiac surgery for congenital heart disease in newborns and children. *Am J Cardiol* 80:360-363

NIH Clinical Center NATIONAL INSTITUTES OF HEALTH			
Home Contact Us Site Map Search	About the Clinical Center	For Researchers And Physicians	Participate in Clinical Studies

Back to: [About the Clinical Center](#) > [Departments and Services](#) > [Critical Care Medicine Department](#)

Critical Care Medicine Department

[CCMD Staff](#)

[Critical Care Services](#)

[Respiratory Care and Therapy Service](#)

[Clinical Simulation Service](#)

[Training Programs](#)

[Career Opportunities](#)

[CCMD Sponsored Meetings](#)

[Publications](#)

[Alumni Reflections](#)

[Contact Us](#)

[Site Map](#)

Critical Care Services

The CCMD provides the following clinical services:

Intensive Care Unit (ICU)

The Intensive Care Unit (ICU) at the NIH is located on the third floor of the Mark O. Hatfield NIH Clinical Center. This is a 12-bed Medical/Surgical ICU with an adjoining 6-bed intermediate care unit. The unit can provide hemodynamic monitoring, diagnostic ultrasound, ventilatory, renal replacement, and cardiovascular support. In addition, all medical patients and some surgical patients with predominantly medical problems are cared for by Critical Care Medicine Department (CCMD) senior physicians and medical fellows. The ICU team physicians, nurses, respiratory therapists, and a pharmacist, nutritionist, and social worker dedicated to the management of CCMD patients. The department also provides a diagnostic pulmonary service for patients with bronchoscopy and elective pulmonary artery catheterization. The CCMD accepts patients from any service within the Clinical Center. Admission of patients for CCMD care can be requested by contacting the CCMD physician on-call via the page operator or by calling (301) 451-0567.

Code Team

"Code Blue" procedures have been established to obtain emergency medical assistance for patients, visitors, and employees. The code team serves as a mobile emergency response team, rendering lifesaving first aid, and making appropriate referrals to any needed services including outside facilities. The Critical Care Medicine Department (CCMD) fellow serves as the team leader. Other members of the code team include the surgery oncology fellow, two intensive care nurses, two respiratory therapists, and the CCMD attending physician. The team responds typically to respiratory and cardiac arrests, anaphylaxis, respiratory distress, severe seizures, and hypotensive/ syncopal episodes.

A Rapid Response Team (RRT) had been established to obtain early access to critical care consultation for any inpatient or outpatient if their condition appears to be deteriorating. This service is provided to improve recognition and response to a change in patient condition and to enhance a culture of safety for the patient. The RRT team consists of the CCMD fellow and the ICU charge nurse. The patient's physician, nurse, or respiratory therapist may call for this assistance whenever needed. Patients and families may also use the service when requested through their health care provider.

Procedures, Vascular Access, and Conscious Sedation (PVCS) Services

The Procedures, Vascular Access, and Conscious Sedation (PVCS) Services are staffed by critical care fellows and the Nursing Service and provides temporary vascular catheters to those patients requiring continuous vascular access for long periods of time.

The service places multilumen jugular, subclavian, and femoral vascular catheters as well as peripherally inserted central catheters. All catheters are placed using ultrasound guidance. This service also provides conscious sedation when necessary for procedures such as vascular access, bronchoscopy, and bone marrow biopsies. Patient care providers may call (301) 451-0336 to make an appointment for their patients to have catheters placed.

Critical Care Therapy and Respiratory Care Section (CTRCS)

The Critical Care Therapy and Respiratory Care Section (CCTRCS) was established, with specially cross-trained respiratory therapists, to provide respiratory critical care and essential support to accomplish specific therapeutic goals. In 1999, the CCTRCS expanded its staff and clinical services to support all areas of the Clinical Center. In addition to our patient care responsibilities, the CCTRCS provides monthly Basic Cardiac Life Support recertification classes to all allied healthcare personnel and has developed a weekly lecture series to foster continued professional growth and development of our staff.

Critical Care Nursing

The critical care nurses provide care to critically ill patients and their families. The nurses provide this highly skilled care in close collaboration with the critical care physicians, critical care respiratory therapists, and other members of the multidisciplinary health care team. The scope of practice for critical care nurses encompasses patients of all ages, from infancy through adulthood, with a variety of potentially life-threatening problems. These nurses provide care for patients on protocols from any of the institutes of the NIH through complex and vigilant assessment and interventions. Although the patient population is widely variable, the nurses are particularly skilled in caring for immunosuppressed patients with life-threatening infections and/or respiratory failure and for patients requiring continuous renal replacement therapy for acute renal failure.

This page last reviewed on 06/18/10



Accessibility | Privacy
Disclaimer | FOIA

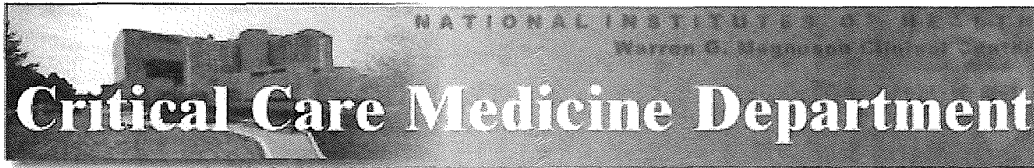


National Institutes
of Health



Department of Health
and Human Services





Critical Care Therapy and Respiratory Care Section

Category:	Clinical
Section:	Ventilator Management
Title:	Standard of Practice: Care of the Mechanically Ventilated Patient
Policy #:	01
Revised:	03/00

1.0 DESCRIPTION

1.1 Definition: Mechanical ventilatory support may be provided to a patient through a wide variety of mechanical, pneumatic, electronic, and microprocessor-driven devices for the purposes of life support during acute respiratory failure, therapeutic support of suboptimal cardiopulmonary function, or therapeutic support of chronic ventilatory failure. Ideally, mechanical ventilatory support should:

- Maintain alveolar ventilation to ensure adequate elimination of carbon dioxide.
- Maintain arterial oxygenation to ensure adequate delivery of oxygen to the tissues.
- Minimize the risk of adverse pressure and volume effects on the lungs (eg, baro-/volutrauma) and cardiovascular system.
- Aim for patient comfort.
- Provide appropriate reconditioning workloads as well as muscle rest during recovery.
- Specific instruction for the use of any of the devices of ventilatory support should be obtained from the Operator's Manuals for the devices. Additionally, specific indications and procedures exist for some devices (see the corresponding procedures in References), and Section policies still apply. The purpose of this Standard of Practice is to provide a *guideline* for proper care of the patient whose medical management includes the use of any of the devices of mechanical ventilatory support.

1.1 Indications

1.1.1 Hypercapnic respiratory failure resulting from:

- 1.1.1.1 Decreased respiratory drive
- 1.1.1.2 Increased dead space
- 1.1.1.3 Right-to-left shunt
- 1.1.1.4 Mechanical failure
- 1.1.1.5 Hypermetabolism with resulting increases in carbon dioxide production

1.1.2 Hypoxic respiratory failure resulting from:

- 1.1.2.1 Right-to-left shunt
- 1.1.2.2 Ventilation-perfusion mismatch

1.1.2.3 Diffusion defect

1.1.2.4 The acute respiratory distress syndrome (ARDS)

1.1.3 Refer to the operator's manual and/or procedure for device-specific indications (see References).

1.2 Contraindications:

1.2.1 Documented refusal to be mechanically ventilated as per an advance directive signed by the patient or an acceptable surrogate

1.2.2 Device-specific contraindications may exist. Refer to the operator's manual and/or procedure

1.3 Potential Complications

1.3.1 Pulmonary barotrauma

1.3.2 Ventilator-associated pneumonia

1.3.3 Cardiovascular compromise

1.3.4 Increased intracranial pressure

1.3.5 Device-specific complications may exist. Refer to the operator's manual and/or procedure.

1.4 Precautions

1.4.1 Mechanical ventilatory devices are highly sophisticated requiring understanding of the technical components of their design, the pathophysiology of the respiratory system, and the patient-ventilator interaction. Personnel who are primarily responsible for implementing mechanical ventilation or associated changes to the parameters of mechanical ventilation must demonstrate competence in:

1.4.1.1 The technical setup and operation of the device

1.4.1.2 Cardiopulmonary physiology and pathophysiology

1.4.1.3 Interpretation of the results of arterial blood gas analysis

1.4.1.4 Assessment of the need for mechanical ventilatory support, therapeutic response, and adverse reactions

1.4.1.5 The ability to respond appropriately to adverse reactions as well as to make recommendations to improve the ventilator plan of care

1.4.1.6 Appropriate application of universal precautions

- 1.4.2 Mechanical ventilatory devices should not be adapted for uses other than those intended by the manufacturer.
- 1.4.3 Any device which fails to perform according to the manufacturer's specifications should not be used for patient care. Refer all equipment failures and malfunctions to appropriate service personnel.

1.5 Adverse Reactions and Interventions

- 1.5.1 If mechanical ventilation results in life-threatening cardiopulmonary compromise, or the mechanically ventilated patient exhibits life-threatening physical signs, appropriate life support measures must be implemented. Specifically, the caregiver must:
 - 1.5.1.1 Ensure that the patient has an adequate airway.
 - 1.5.1.2 Ensure that ventilation is supported via the use of a manual resuscitator.
 - 1.5.1.3 Ensure that oxygenation is optimized.
 - 1.5.1.4 Ensure that steps are taken to preserve cardiac function.
- 1.5.2 If a malfunction of the device is suspected, remove the patient from the device and ensure appropriate oxygenation and ventilation. Do not reinstitute mechanical ventilation with the device until troubleshooting maneuvers prove proper function. Secure an alternate ventilatory device when necessary.
- 1.5.3 Device-specific interventions may exist. Refer to the operator's manual and/or procedure.

2.0 EQUIPMENT AND SUPPLIES

- 2.1 Manual resuscitator and appropriate size mask
- 2.2 Cardiopulmonary monitor and supplies
- 2.3 Pulse oximeter and supplies
- 2.4 Suction equipment and supplies
- 2.5 Intubation equipment and supplies
- 2.6 Stethoscope
- 2.7 Oxygen analyzer

- 2.8 Pressure monitor
- 2.9 Volume monitor
- 2.10 Timepiece
- 2.11 Device-specific humidification system
- 2.12 Device-specific patient interface and circuit including a water trap system capable of closed disposal of condensation (when necessary) **NOTE: Pediatric circuit shall be utilized on pts. weighing < 20kg.**
- 2.13 Test lung
- 2.14 Continuous Ventilation Record
- 2.15 Universal precautions attire
- 2.16 Calibration equipment and preventive maintenance documentation as per the manufacturer's specifications and departmental policy

3.0 PROCEDURE

- 3.1 Assure device readiness for use through evidence of calibration/performance verification.
- 3.2 Assess appropriateness of physician's orders and set ventilatory parameters accordingly. Initial settings as well as changes to ventilatory parameters must be accompanied by physician's orders.
- 3.3 Ensure proper device function with a test lung.
- 3.4 Connect the patient to the device. Assess the patient for tolerance and the patient-ventilator system for good coordination and proper function. Set all applicable alarms including alarms for thermal regulation of the humidification system.
- 3.5 Perform a thorough assessment of the patient-ventilator system according to the CCTRCS Patient Assessment Policy. Document ventilator data (see 5.0. Documentation) as well as cardiopulmonary data according to CCTRCS policy on the Continuous Ventilation Record. Perform repeat patient-ventilator checks as per policy.
- 3.6 Monitor the patient continuously via cardiopulmonary monitor and pulse oximetry. Perform arterial pH and blood gas analysis and/or capnometry or transcutaneous monitoring as necessary and per physician order.

- 3.7 Make recommendations for changes to the ventilatory care plan as appropriate.
- 3.8 Perform suctioning and other airway care interventions as clinically indicated to ensure optimal pulmonary management of the patient.
- 3.9 Perform routine circuit and related equipment changes as per Section policy and whenever required to restore integrity of the circuit or when the circuit is visually soiled.
- 3.10 Ensure that ventilator readiness data are filed according to Section policy.

4.0 POST PROCEDURE

- 4.1 Refer to the operator's manual and/or procedure for specific cleaning instructions.
- 4.2 After appropriate disinfection and reassembly, perform a pre-use functional check according to Section policies.

5.0 DOCUMENTATION

- 5.1 A proper record of ventilator care should include documentation of at least the following every two hours:
 - 5.1.1 Ventilator settings comply with physician orders
 - 5.1.2 The ventilator is functioning properly as evidenced by a check of measured volumes, rates, pressures, and FiO₂
 - 5.1.3 Alarms are appropriately set
 - 5.1.4 Measured inspired gas temperature
 - 5.1.5 Transcutaneous oxygen saturation (SpO₂), carbon dioxide, or end-tidal carbon dioxide values (when available)
 - 5.1.6 The signature or initials of the person performing the patient-ventilator system check and the person's credentials are documented at the time of the check.
- 5.2 A proper record of ventilator care should include documentation of the following, at least every twelve hours:
 - 5.2.1 Alarms are activated and respond appropriately
 - 5.2.2 The patient's artificial airway is secure and positioned as previously documented

- 5.2.3 A manual resuscitator and appropriate size mask are available at the bedside and functional
 - 5.2.4 Physician's orders for ventilator parameters as written are up-to-date
 - 5.2.5 Physical assessment results are documented (see the CCTRCS Patient Assessment Policy).
- 5.3 A proper record of ventilator care should include documentation of the following as needed:
- 5.3.1 Ventilator circuitry and/or manual resuscitation equipment is changed according to policy or as needed when visibly soiled or leaky
 - 5.3.2 Changes to the ventilatory parameters are documented at the time of change, and circled for easy identification
 - 5.3.3 Airway care maneuvers (including suctioning) are documented when performed
 - 5.3.4 Transport parameters, adverse events, weaning parameters, care plan information, etc. are documented as needed to ensure the most complete information on the patient and a good continuity of care.
- 5.4 This documentation shall be made on the patient's Continuous Ventilation Record and/or the nursing flowsheet.
- 5.5 See the CCTRCS Patient Assessment Policy for specific information on the communication and reporting of pertinent patient information to the oncoming shift.

6.0 REFERENCES

- 6.1 CCTRCS Policy "Patient Assessment, Documentation and Communication of Patient Care Information"
- 6.2 CCTRCS Policy "General Standards for Mechanically Ventilated Patients"
- 6.3 AARC Clinical Practice Guideline "Patient-Ventilator System Checks"
- 6.4 AARC Clinical Practice Guideline "Humidification during Mechanical Ventilation"
- 6.5 AARC Clinical Practice Guideline "Ventilator Circuit Changes"

- 6.6 AARC Clinical Practice Guideline “Transport of the Mechanically Ventilated Patient”
- 6.7 Servo Ventilator 900C - Operating Manual
- 6.8 Servo Ventilator 300 - Operating Manual
- 6.9 BiPAP® Ventilatory Support System Clinical Manual
- 6.10 CCTRCS Procedure “Use of the Respironics BiPAP® Ventilatory Support System”
- 6.11 Ambu TransCARE Series Ventilators Operator’s Manual
- 6.12 CCTRCS “TransCARE I Transport Ventilator Procedure”
- 6.13 CCTRCS “Equipment Change Policy”
- 6.14 CCTRCS “Ventilator Weaning Procedure”
- 6.15 CCTRCS “Receiving and Implementing of Physician Orders Policy”
- 6.16 CCTRCS “Infant, Pediatric and Adult Ventilator Circuit Size Guidelines Policy”
- 6.17 CCTRCS “Servo Calibration Policy”
- 6.18 CCMD “Pressure Control Setting Policy”
- 6.19 CCMD “Pressure Support Mode Ventilation Policy”
- 6.20 CCMD “Ventilator Settings Change Policy”
- 6.21 CCTRCS “Compliance Measurements Policy”
- 6.22 CCMD “Physician Section Patient Transport Policy”

SIGNATURE: _____
Assistant Section Chief, CCTRCS, CCMD

DATE: _____

SIGNATURE: _____
Section Chief, CCTRCS, CCMD

DATE: _____

SIGNATURE: _____
Medical Director, CCTRCS, CCMD

DATE: _____

(Orig. 8/97)
(Rev. 3/00)

PEDIATRICS®

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Improved Oxygenation in a Randomized Trial of Inhaled Nitric Oxide for Persistent Pulmonary Hypertension of the Newborn

David L. Wessel, Ian Adata, Linda J. Van Marter, John E. Thompson, Janie W. Kane,
Ann R. Stark and Stella Kourembanas

Pediatrics 1997;100:e7

DOI: 10.1542/peds.100.5.e7

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://www.pediatrics.org/cgi/content/full/100/5/e7>

PEDIATRICS is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since 1948. PEDIATRICS is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 1997 by the American Academy of Pediatrics. All rights reserved. Print ISSN: 0031-4005. Online ISSN: 1098-4275.

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™



Improved Oxygenation in a Randomized Trial of Inhaled Nitric Oxide for Persistent Pulmonary Hypertension of the Newborn

David L. Wessel, MD*‡; Ian Adatia, MBChB*#; Linda J. Van Marter, MD MPH§¶; John E. Thompson, RRT||; Janie W. Kane, RNC¶; Ann R. Stark, MD§¶; and Stella Kourembanas, MD§¶#

ABSTRACT. *Objective.* To determine the effect of inhaled nitric oxide (NO) on clinical outcome in newborns with persistent pulmonary hypertension (PPHN).

Design. A prospective, randomized trial of patients referred to a level 3 nursery in a single large center. Clinicians were not masked to group assignment. Cross-over of patients from control to NO treatment was not permitted.

Methods. We randomized 49 mechanically ventilated newborns, transferred to our center with clinical and echocardiographic evidence of severe PPHN (arterial oxygen tension [P_{aO_2}] <100; fractional inspired oxygen = 1) to treatment with or without NO. Patients with gestational age <34 weeks or with congenital heart disease or diaphragmatic hernia were excluded. High-frequency oscillatory ventilation was used but not allowed concomitantly with NO. Primary outcome variables were oxygenation, mortality, and use of extracorporeal membrane oxygenation (ECMO).

Results. Meconium aspiration syndrome and isolated PPHN were the most common diagnoses (32/49) and were distributed equally between groups. The median age at the time of entry into the study was similar between groups, 25 hours for control patients and 18 hours for NO patients. Median baseline oxygenation index (OI) was similar in 23 control (OI = 29) and 26 NO (OI = 30) patients. Mortality (8%), use of ECMO (33%), median days on mechanical ventilation (9 days), and duration of supplemental oxygen (13 days) were not different between treatment groups. P_{aO_2} , oxygen saturation, and OI improved in the NO group compared with baseline and to control patients at 15 minutes. The median percent change in OI (-31%) in the NO group was significantly different from baseline and from the control group. The difference in oxygenation between treatment groups was still apparent 12 hours after baseline. Before cannulation for ECMO, oxygenation was better in the NO group compared with control patients. Among patients who were placed on ECMO, the median time from baseline to ECMO cannulation was 2.4 hours (range, 1 to 12 hours) among control patients and 3.3 hours (range, 2 to 68 hours) for those randomized to receive NO. There was a tendency to observe fewer adverse neurologic events (seizure and intracranial hemorrhage) in the NO group (4/26 vs 8/23). One child with alveolar capillary dysplasia confirmed by postmortem examination could not be

weaned from 80 parts per million of NO and transiently developed methemoglobinemia (peak methemoglobin level = 17%). No other side effects were observed.

Conclusions. Although mortality and ECMO use were similar for both treatment groups using this study size and design, sustained improvement in oxygenation with NO and better oxygenation at initiation of ECMO may have important clinical benefits. We speculate that modification of treatment to include specific lung expansion strategies with NO treatment and recognition that early improvement of oxygenation may be sustained with NO may lead to reduced use of ECMO in NO treated patients compared with controls. *Pediatrics* 1997; 100(5). URL: <http://www.pediatrics.org/cgi/content/full/100/5/e7>; persistent fetal circulation, extracorporeal membrane oxygenation, high-frequency oscillatory ventilation, alveolar capillary dysplasia, methemoglobin.

ABBREVIATIONS. PPHN, persistent pulmonary hypertension of the newborn; ECMO, extracorporeal membrane oxygenation; NO, nitric oxide; ppm, parts per million; P_{aO_2} , arterial oxygen tension; F_{iO_2} , fractional inspired oxygen; P_{aCO_2} , arterial carbon dioxide tension; OI, oxygenation index; HFOV, high-frequency oscillatory ventilation.

Persistent pulmonary hypertension of the newborn (PPHN) is a syndrome characterized by increased pulmonary vascular resistance, right to left shunting of blood, and severe hypoxemia.¹⁻³ PPHN is frequently associated with pulmonary parenchymal abnormalities, including meconium aspiration, pneumonia, sepsis, lung hypoplasia, and dysplastic alveolar capillary structure. In some instances, there is no evidence of pulmonary parenchymal disease and the etiology is unknown. Treatment strategies, including alkalinization, hyperventilation, and use of intravenous vasodilators are aimed at lowering pulmonary vascular resistance but are associated with adverse effects and are not always successful.⁴ Extracorporeal membrane oxygenation (ECMO) has improved survival for neonates with refractory hypoxemia but may be associated with hemorrhagic, neurologic, and other complications.⁵⁻⁷ Although survival for PPHN has improved, better treatment would further reduce mortality rates and morbid outcomes.

Inhaled nitric oxide (NO) is a selective pulmonary vasodilator.^{8,9} Early investigations suggested that this drug improved oxygenation in patients with PPHN who were administered 6 to 80 parts per million (ppm) of NO with oxygen.^{10,11} Although promising, these initial studies were small case series

From the Departments of *Cardiology, ‡Anesthesia, §Medicine, ||Respiratory Care, and the ¶Joint Program in Neonatology, Children's Hospital, and the #Department of Pediatrics, Harvard Medical School, Boston, Massachusetts.

Received for publication Mar 7, 1997; accepted Jul 2, 1997.

Reprint requests to (D.L.W.) Cardiac ICU Office, Farley 653, Children's Hospital, 300 Longwood Avenue, Boston, MA 02115.

PEDIATRICS (ISSN 0031 4005). Copyright © 1997 by the American Academy of Pediatrics.

with physiologic rather than clinical outcomes and lacked a control group. Subsequent trials were informative but until recently were still limited by lack of controls, extensive treatment crossover designs, or inherent limitations of multicenter trials with varying definitions of standard clinical practice.¹²⁻¹⁷ Although the efficacy of NO in the treatment of PPHN has been recently affirmed in multicenter randomized trials,^{18,19} results of other studies may add to our understanding of this new therapy. We conducted a prospective, randomized trial of NO for treatment of PPHN among patients referred to a single large center. Our objective was to systematically introduce this investigational therapy in a randomized fashion to all patients with PPHN, allowing for an interim analysis and protocol modification, until we or others could demonstrate sustained improvement in oxygenation and superior outcome with NO.²⁰ Our primary hypothesis was that treatment with inhaled NO would improve oxygenation compared with controls and reduce mortality and utilization of ECMO.

METHODS

Patients

We screened all newborns with a clinical diagnosis of PPHN admitted to Children's Hospital between September 1, 1992 and September 1, 1994. Qualifying criteria for enrollment included gestational age ≥ 34 weeks and $\text{PaO}_2 < 100$ mm Hg during mechanical ventilation on $\text{FiO}_2 = 1$ after optimization of ventilatory and pharmacologic strategies. Patients were sedated with narcotic and administered muscle relaxants, with efforts made to achieve moderate hyperventilation ($\text{PaCO}_2 = 30$ to 40 mm Hg). Sodium bicarbonate was infused to correct metabolic acidosis and raise pH to 7.45 to 7.60. Systemic blood pressure was supported with colloid infusions, dopamine, and dobutamine. Intravenous vasodilators such as tolazoline or prostaglandin E1 were not used.

Echocardiographic evidence of pulmonary hypertension was required and included right to left or bidirectional shunting at the ductus arteriosus or foramen ovale. Evidence of systemic pressure in the pulmonary artery was inferred by Doppler assessment of tricuspid regurgitation or by ventricular septal position.

Patients were excluded from study if they had major anomalies including congenital heart disease or congenital diaphragmatic hernia, or if echocardiography demonstrated evidence of low pulmonary vascular resistance (eg, continuous left to right flow through a patent ductus arteriosus or isolated right ventricular dysfunction without pulmonary hypertension). Previous treatment with surfactant therapy or high-frequency oscillatory ventilation (HFOV) at the referring institution was permitted.

Patients were randomly assigned to control or NO treatment. Randomization schemes were developed using a permuted-blocks design with blocks of size 10. Primary outcome variables were oxygenation, mortality, and use of ECMO. The initial study design predicted that a reduction in ECMO utilization from 40% to 15% would require 50 patients in each treatment group to achieve 80% power. For continuous variables [oxygenation index (OI) and PaO_2], a 20% reduction would require 25 patients in each group. Additional outcomes included oxygenation before ECMO, duration of mechanical ventilation, duration of exposure to supplemental oxygen during hospitalization, and need for supplemental oxygen after discharge from the hospital. We recorded and analyzed continuous variables including oxygenation, airway pressures, heart rate, and systemic blood pressure during the 24 hours after baseline measurements were obtained. Measures of oxygenation were: PaO_2 , $\text{PaO}_2/\text{FiO}_2$, OI ($\text{OI} = \text{FiO}_2 \times \text{mean airway pressure} \times 100 \div \text{PaO}_2$), and oxygen saturation by pulse oximetry. For patients who were supported with ECMO, we recorded the last PaO_2 before preparation for ECMO and the last oxygen saturation before initiation of ECMO. The clinical course was also noted for occurrence of seizures treated with anticonvulsants or for abnormalities on head ultrasound described as intracranial hemorrhage

more severe than grade 1. Head ultrasounds were obtained at the discretion of the responsible clinician and for all patients before and after initiation of ECMO.

Protocol

We obtained informed consent from the parents of all patients using a protocol approved by the Clinical Investigation Committee of Children's Hospital with an investigational new drug number assigned by the United States Food and Drug Administration. Patients were randomized either to receive NO or to continue conventional therapy. Patients randomized to receive NO had the FiO_2 reduced to 0.97. After randomization, patients were continued in the study even though the baseline PaO_2 may have exceeded 100 mm Hg. Arterial blood gases, heart rate, blood pressure, pulse oximetry, and all ventilator settings were recorded at baseline and 15 minutes later. During this interval no change in pharmacologic or mechanical support was permitted except as a resuscitative maneuver. All clinical variables were again recorded and analyzed at 1, 2, 6, 12, and 24 hours after baseline and daily thereafter until hospital discharge.

All patient care decisions were made by the clinical care team according to standard practice guidelines and were not altered by the investigators. In both the treated and control groups attempts to wean mean airway pressure and FiO_2 were made after a stable $\text{PaO}_2 > 60$ mm Hg had been achieved. Patients assigned to the NO group received a starting dose of 80 ppm. NO was weaned according to a preset protocol which lowered the NO dose from 80 ppm to 40 ppm after 1 hour. If tolerated, this dose was continued up to 12 hours and dose reductions to 5 ppm were attempted each morning. NO was discontinued when the dose could be successfully reduced to 5 ppm for at least 12 hours while PaO_2 was sustained > 60 mm Hg with an $\text{FiO}_2 \leq 0.5$.

Alternatively, NO was discontinued when a patient was cannulated for ECMO or when the attending physician chose to convert from conventional mechanical ventilation to HFOV. The protocol permitted use of NO only during conventional mechanical ventilation. HFOV was allowed before randomization, or if NO treatment was discontinued in favor of HFOV, or at any time in patients randomized to control. Concomitant treatment with HFOV and NO was not permitted because of early theoretical concerns about toxicity when NO at 80 ppm was combined with HFOV. Criteria for initiation of ECMO included an OI > 40 for at least 1 hour or hemodynamic instability despite inotropic support. If a patient failed to wean from an FiO_2 of 1.0 after persistent attempts during 2 to 3 days, ECMO was then utilized even though the OI was still just below 40.

We have described our NO delivery system previously.^{21,22} We used NO gas (Scott Specialty Gases, Plumsteadville, PA and Ohmeda Pharmaceutical Division, Liberty Corner, NJ) of medical grade quality which conformed to United States Food and Drug Administration standards. The source tank concentration of NO was either 2200 ppm (45 patients) or 800 ppm (4 patients, later in the study). NO, nitrogen dioxide, and inspired oxygen were continuously monitored from a sampling port on the inspiratory limb of the ventilator circuit (Thermoenvironmental Instruments, chemiluminescence model 42H, Franklin, MA). Methemoglobin levels were measured by coximetry (Ciba model 2500) in all patients receiving NO after the first 15 minutes of exposure and then every 12 hours.

Statistical Analysis

Data are represented by median values and ranges along with mean and standard error of the mean where appropriate. After a Friedman's analysis of variance by ranks, a paired nonparametric test (Wilcoxon signed rank test) was used to compare the difference between baseline hemodynamic variables and after 15 minutes of inhaled NO and five subsequent times up to 24 hours with correction for multiple comparisons. Comparison between patients in the control and NO treatment groups was made using the Mann-Whitney test. Binary variables were compared using Fisher's exact test.

RESULTS

We enrolled 51 patients. Two patients were promptly disqualified for study because on review of the echocardiogram shortly after enrollment 1 pa-

tient was noted to have total anomalous pulmonary venous connection; the other patient had an erroneously reported entry Pao₂. Neither patient received treatment under this protocol. Among the remaining 49 patients, 23 randomized to conventional treatment and 26 were assigned to receive NO. There were 3 departures from the intended protocol. One patient in the NO group received only conventional therapy. In 2 patients who randomized to NO, the drug was administered for only 15 minutes; conventional therapy was continued for 12 and 14 hours, respectively, before initiation of ECMO in both patients. Outcomes for these 3 patients were analyzed according to the intention to treat. There were no differences between groups for age at entry, gestational age, weight, or baseline Pao₂ (Table 1).

Associated conditions including meconium aspiration syndrome, isolated PPHN, pneumonia, sepsis, and rare patients with hydrops fetalis, respiratory distress syndrome, or pulmonary hemorrhage were similar between groups (Table 2). Surfactant therapy was permitted at any stage during hospitalization. Four patients received surfactant therapy including 1 after enrollment in the study.

Overall Outcome

Four (8%) of the 49 patients died, 2 in each group. Two had alveolar capillary dysplasia identified at a postmortem examination, and a third patient had clinical features consistent with alveolar capillary dysplasia but we were unable to obtain permission to perform an autopsy of this child. One child who died with alveolar capillary dysplasia while receiving NO had an intracranial (thalamic) hemorrhage which precluded use of ECMO. A fourth patient had poor left ventricular function and a right ventricular dependent circulation with echocardiographic evidence of a small left atrium and left atrial hypertension with continuous right to left ductal flow, but continuous left to right flow across the foramen ovale. Her clinical presentation and echocardiographic assessment were consistent with PPHN. Severe pulmonary hypertensive changes were identified microscopically during the autopsy. NO was administered to this patient for 15 minutes and then discontinued because of clinical deterioration. Hypoxemia and hypotension persisted with conventional therapy and ECMO was initiated. The patient

TABLE 1. Comparative Data at Baseline, Median (Range)

	Control (n = 23)	Nitric Oxide (n = 26)
Age at entry (hours)	25 (3-63)	18 (5-83)
Gestation (weeks)	40 (36-42)	40 (35-42)
Weight (kg)	3.4 (2.2-5.2)	3.5 (2.5-5.0)
Heart rate (beats per min)	165 (139-200)	175 (135-195)
Mean blood pressure (mm Hg)	54 (39-80)	53 (35-76)
Pao ₂ (mm Hg)	64 (27-212)	47 (24-113)
pH	7.48 (7.23-7.62)	7.51 (7.14-7.66)
Paco ₂ (mm Hg)	34 (18-58)	31 (13-75)
Mean airway pressure (cmH ₂ O)	15.2 (8.3-32)	16.3 (10.8-25.6)
Oxygenation index	29.4 (10.5-114)	30.4 (10.4-84.5)

TABLE 2. Diagnostic Categories and Associated Conditions

Diagnosis	All (n = 49)	Control (n = 23)	Nitric Oxide (n = 26)
Meconium aspiration syndrome	22 (45%)	9	13
Persistent pulmonary hypertension of the newborn	11 (23%)	7	4
Pneumonia	8 (16%)	3	5
Sepsis	4 (8%)	3	1
Hydrops fetalis	2 (4%)	1	1
Respiratory distress syndrome	1 (2%)	0	1
Pulmonary hemorrhage	1 (2%)	0	1

died on ECMO with an intracranial hemorrhage 16 hours after baseline.

Sixteen (33%) of the 49 patients required ECMO, one half in each group (relative risk = 1). One-quarter of our patients had either seizures or intracranial hemorrhages more severe than grade 1. No patient was discharged home requiring supplemental oxygen (Table 3).

Differences Between Treatment Groups

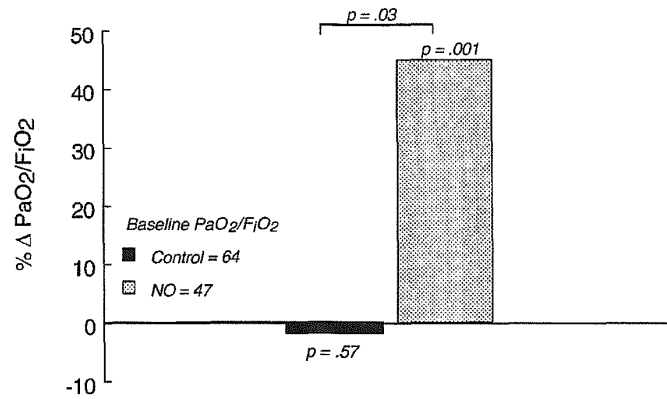
There were no differences between groups with respect to death, use of ECMO, days on mechanical ventilation, or days receiving supplemental oxygen (Table 3). However, measures of oxygenation after baseline were markedly different between the two groups. The median percentage change in Pao₂/Fio₂ at 15 minutes compared with baseline for the control patients (-2%, range -37% to 249%; *P* = .57) compared with patients assigned to NO (+45%, range -33% to 539%; *P* = .001) was significant (*P* = .03 between groups, Fig 1).

Similarly, the percentage change in OI at 15 minutes compared with baseline was significant for the NO group and it had improved compared with control patients (Fig 2). Baseline OI was similar between the two groups but dropped dramatically in the treated NO patients compared with baseline (-31%, range -84 to 38%; *P* = .003) and also compared with the control population (5%, range -71 to 101%; *P* = .39) (*P* = .009 between groups). This observation was related to changes in oxygenation and not mean airway pressure or Fio₂; the median percentage change in Pao₂ was 43% (range, -35 to 539%; *P* = .002) for patients receiving NO and -2% for control patients (range, -37 to 247%; *P* = .57) (*P* = .04 between groups). The median change in mean airway pressure at 15 minutes compared with baseline was zero. Oxygen saturation by pulse oximetry increased by 4% (range, -9% to 21%; *P* = .0003) in NO

TABLE 3. Outcome

	All (n = 49)	Control (n = 23)	Nitric Oxide (n = 26)
Mortality	4 (8%)	2 (9%)	2 (8%)
Extracorporeal membrane oxygenation	16 (33%)	8 (35%)	8 (31%)
Seizure or intracranial hemorrhage	12 (25%)	8 (35%)	4 (15%)
Median days on ventilator	9	10	9
Median days on oxygen	13	12	13
Home oxygen	0	0	0

Fig 1. Median percentage change in P_{aO_2}/F_{iO_2} at 15 minutes compared with baseline for control patients and patients treated with NO. Oxygenation significantly improved in NO patients compared with the control population ($P = .03$).



treated patients and 0 (range, -22 to 41%; $P = .97$) for control patients ($P = .006$ between groups). There was no change in heart rate or blood pressure within groups compared with baseline or between groups.

Fifteen patients who received NO increased their P_{aO_2} at 15 minutes by more than 20% from baseline. Only 2 of these patients were subsequently placed on ECMO. One of these patients, with the diagnosis of pulmonary hemorrhage, saw improvement in P_{aO_2} from 29 to 42 mm Hg at 15 minutes and to 55 mm Hg 2 hours later just before cannulation for ECMO (OI = 49). The second patient had improvement in P_{aO_2} from 43 to 54 mm Hg 15 minutes after NO was started. P_{aO_2} was sustained in the 60s in this patient. However, after 68 hours the F_{iO_2} still could not be weaned from 0.97 without reduction in the P_{aO_2} below 60 mm Hg; the child was placed on ECMO ($P_{aO_2} = 63$ mm Hg, OI = 28). Thus, no child had a positive response (more than 20% change) to NO followed by marked deterioration and need for ECMO.

The improvement in oxygenation among patients treated with NO was sustained. Figure 3 shows the median percentage change in OI for both treatment groups during the first 24 hours of study. The reduction in OI seen at 15 minutes with NO was sustained compared with baseline and was significantly different from controls at later time points. After 12 hours of treatment, the median percentage change in OI among NO treated patients was -50% (range, -86 to 30%; $P = .0007$) compared with control patients'

change of -19% (range, -81 to 97%; $P = .20$) ($P = .03$ between groups). OI was excluded from analysis after patients were placed on ECMO. Because the number of patients treated with ECMO was the same in each group ($n = 8$), and because the number of patients treated with HFOV at any point in their treatment ($n = 18$, controls vs $n = 15$, NO) was not different between groups, the data suggest that the immediate and sustained improvement in oxygenation was attributable to NO inhalation. Analysis of oxygenation data with ECMO patients excluded at all times demonstrates similar findings, as does separate statistical analysis which excludes patients assigned to but not treated with NO. The median time receiving NO was 22.5 hours (range, 0.25 to 137 hours).

For those patients who were placed on ECMO the P_{aO_2} and oxygen saturation were higher in the NO group just before cannulation (Table 4). In control patients, the median value of the last recorded P_{aO_2} was 38 mm Hg, similar to the baseline value. Before ECMO the oxygen saturation by pulse oximetry had fallen from 86% to 82%. In contrast, in NO treated patients the median P_{aO_2} rose from 41 mm Hg at baseline to 55 mm Hg before ECMO ($P = .02$, between groups) and oxygen saturation rose from 87% to 91% ($P = .02$, between groups). The median time from baseline to ECMO cannulation was 2.4 hours (range, 1 to 12 hours; mean = 3.9 ± 1.3 hours) among control patients and for the NO group it was 3.3 hours (range, 2 to 68 hours; mean 17.7 ± 8.9 hours).

Fig 2. Median percentage change in OI at 15 minutes compared with baseline for control patients and for patients treated with NO. In NO treated patients, OI was reduced and was significantly different from control patients ($P = .04$).

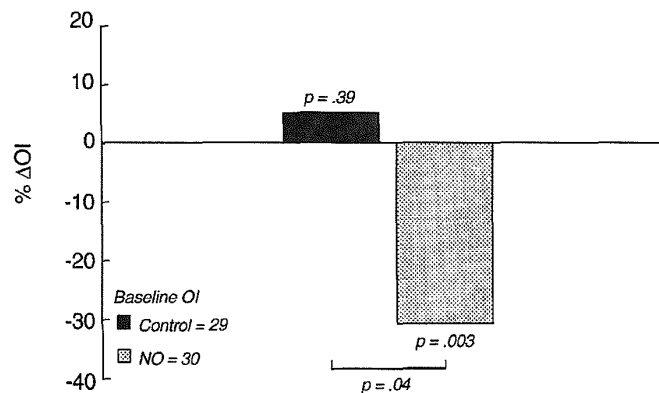
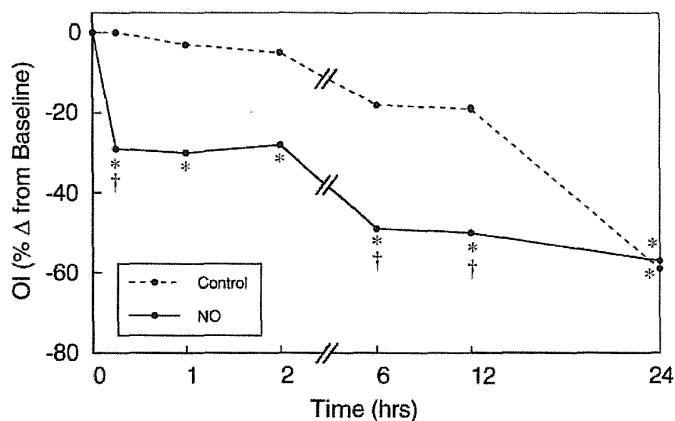


Fig 3. Median percentage change in OI during the first 24 hours of study. The reduction in OI during the first 15 minutes was sustained during subsequent times compared with baseline (*) or to control patients (†) ($P < .05$). OI data were not included in this figure after patients were cannulated for ECMO.



There was a tendency toward fewer neurologic complications in the NO treatment group. Eight of 23 control patients suffered from intracranial hemorrhage or seizures compared with 4 of 26 in the NO group including the incompletely treated patient with left atrial hypertension who died on ECMO ($P = .1$ by Fisher's exact test; Table 4).

Toxicity

The median peak methemoglobin level was 1.7% (range, 0.1 to 17%). One patient with subsequently documented alveolar capillary dysplasia could not be weaned to <80 ppm of NO and developed a peak methemoglobin level of 17% after 25 hours of treatment. The methemoglobin level was reduced below 8.0% with vitamin C therapy and transfusion with packed red blood cells. The patient died suddenly on 80 ppm of NO, 4 days after enrollment with a tension pneumothorax and intracranial hemorrhage.

Peak nitrogen dioxide levels of 1 ppm or less were recorded in 19 out of 26 patients who received NO. One patient had a spurious nitrogen dioxide level of 9 ppm which could not be subsequently confirmed using backup chemiluminescence devices. No other patient had nitrogen dioxide levels that exceeded 5 ppm.

DISCUSSION

This study showed that inhaled NO improved oxygenation in patients with PPHN compared with control patients. This confirms earlier reports from smaller uncontrolled trials of NO and supports the contention that improved oxygenation can be sustained with NO. The OI improved not only during

the first 15 minutes of therapy, but was also reduced compared with control patients at 6 and 12 hours after initiation of therapy. Because the number of patients treated with ECMO or HFOV was not different between groups one cannot attribute these oxygenation differences to drop out of ECMO patients or artifact of mean airway pressure measurements during HFOV compared with conventional therapy.

However, sustained improvement in oxygenation was not sufficient in all cases to avoid treatment with ECMO. Thus, we could not demonstrate any difference in use of ECMO between the two treatment groups. Several possible reasons may account for this finding including: 1) lack of important clinical benefit of the drug, 2) insufficient sample size to detect clinical benefit, 3) poor patient selection for optimal NO effect, 4) physician preference to pursue strategies utilizing ECMO despite clinical improvement with NO, and 5) incomplete utilization of optimal ventilatory strategies to facilitate NO effect.

It seems unlikely that NO has no clinical benefit whatsoever other than a transient effect on PaO_2 . Several studies, including ours, have shown sustained improvement in oxygenation with NO.^{10-12,14} Severe hypoxemia is usually the main indication for ECMO. Along with cardiac output, oxygenation is the primary determinant of oxygen delivery and, therefore, of end organ function and clinical well being. If better oxygenation can be obtained without increased risk, it is likely to be desirable in PPHN. Use of NO did not prolong exposure to mechanical ventilation or supplemental oxygen. We did not increase the risk of intracranial hemorrhage and seizures. In fact, there was a tendency to observe fewer such events in patients treated with NO, although the number of patients affected was too small to predict improvement in neurologic outcome with confidence. We did not observe patients who had favorable transient responses, but then deteriorated to require ECMO support. This circumstance has been described more characteristically in patients with severe pulmonary parenchymal disease or lung hypoplasia rather than those predominantly affected by profound elevation in pulmonary vascular resistance.¹³⁻¹⁶

TABLE 4. Extracorporeal Membrane Oxygenation Patients (n = 16)

	Control (n = 8)		Nitric Oxide (n = 8)	
	Base	Pre-ECMO	Base	Pre-ECMO
PaO_2 (mm Hg)	38	38	41	55*
Oxygen saturations (%)	86	82	87	91*
Time to extracorporeal membrane oxygenation (hours)		2.4		3.3

* $P = .02$ compared to control patients.

Is it possible that within this study design, there was an observable effect on clinical outcome and we enrolled too few patients to reveal this effect? If we exclude patients who were randomized to receive NO, but who were prematurely withdrawn from NO therapy or never received the drug, then the differential use of ECMO (6/23 vs 8/23) still does not reach statistical significance. A 25% reduction in risk of ECMO at this rate of utilization would require 438 patients in each group to achieve a statistical power of 80%. Because many centers are now using NO, such a study design would have little chance of successful completion. It is unrealistic to assume that a larger enrollment with the same study design and clinical algorithms for care would have demonstrated differences in clinical outcome.

Exclusion of patients with congenital diaphragmatic hernia and selection of patients who had clinical and echocardiographic confirmation of high pulmonary vascular resistance should have optimized the likelihood of beneficial response to NO.¹⁴ Nonetheless, this study included patients who retrospectively were thought to be unsuitable candidates for successful use of NO, including those with alveolar capillary dysplasia²³ and a patient with severe left ventricular dysfunction.²⁴ Better selection of patients may further enhance our ability to detect beneficial uses and effects of NO.

It is possible in this early limited experience with NO, clinicians were uncertain about the clinical course with the drug and were inclined to utilize ECMO despite improvement in oxygenation. We observed that the precannulation Pao₂ and oxygen saturation for patients who went to ECMO were better in the NO group. Pao₂ rose to the middle 50s in NO patients as they were directed to ECMO, but stayed between 30 and 40 mm Hg among control patients who went to ECMO. This improvement in oxygenation did not dissuade clinicians from utilizing ECMO during this phase of our NO experience. Our institution has reported a large ECMO experience with low mortality; new therapies may be accepted slowly.²⁵ It may be argued that although patients who were receiving NO and cannulated for ECMO were still receiving an Fio₂ of 0.97, the median Pao₂ of 55 mm Hg before ECMO was adequate to defer cannulation in at least one-half of the patients. This idea is supported by the short time between enrollment and cannulation for those patients who were supported by ECMO. It was also noted that NO patients had a tendency to undergo cannulation for ECMO at a slightly later time but generally within the first 24 hours of life. An aggressive mind set among clinicians toward utilization of ECMO may have hindered our evaluation of the clinical efficacy of NO but may also have accounted for the low incidence of chronic lung disease among our patients; no patient was discharged to home on supplemental oxygen.

It is most likely in our opinion that the study design of this investigation precluded the optimal effect of NO by excluding the concomitant use of HFOV with NO in any patient, including those with findings of pulmonary parenchymal disease and loss

of lung volume on chest radiograph. As has been suggested by Abman and Kinsella²⁶ and others, lung recruitment strategies facilitated by HFOV ventilation may enhance the efficacy of NO. With this in mind, our protocol was reevaluated after 2 years of enrollment when this interim analysis was conducted. NO is now used in conjunction with HFOV when clinically indicated.

Limitations

Some limitations of the study have already been mentioned. The exclusion of HFOV and the low power to detect small differences in clinical outcomes are apparent.

The trial was unmasked which may introduce observer bias. Although it is possible that investigators may be biased toward overstating the benefits of the therapy, the timing of the first hemodynamic record and blood gas sampling was rigidly enforced at 15 minutes and 1 hour and then subsequently left to the execution of the bedside clinicians according to preset times. Thus the measures of oxygenation were objective and less susceptible to bias. On the other hand, the purported rapid onset of action of NO may lead more easily in an unmasked trial to premature and incorrect clinical assumption of treatment failure.^{12,17} Investigators have recently suggested that the clinical benefit of NO may be manifest throughout several hours. An unmasked trial may permit clinicians to condemn slow responders to a category of failure to respond after a few minutes of NO therapy and therefore reinforce the perceived need for ECMO. Although indications for ECMO may be reasonably stated to include a sustained OI >40, many factors play a role in the timing and utilization of this resource.

We did not investigate the dose response relationship for NO nor did we establish the minimum effective dose of this drug. Based on earlier animal and human infant experience, we chose the initial dose of 80 ppm as the likeliest tolerable dose of NO able to achieve maximal pulmonary vasodilation.^{8,27,28}

Methemoglobinemia was observed in 1 patient who was the only patient who could not be weaned from 80 ppm. This patient had postmortem evidence of alveolar capillary dysplasia. All other patients tolerated reduction in NO dose to 40 ppm. Although nitrogen dioxide levels did not exceed 3.5 ppm in any patient, these measurements were performed with chemiluminescence technique before our appreciation that quenching effects in high oxygen environments may contribute to falsely low (or even negative) measurements of nitrogen dioxide.²¹ Modification of chemiluminescence technology for clinical use, along with improvements in electrochemical detection devices may be combined with the use of 40 ppm or lower doses of NO, to minimize toxicity without significant compromise of any potential therapeutic efficacy.²⁹ Nonetheless, the full range of potential toxicity of NO and its metabolites such as peroxynitrite, and the potential effects of adverse interaction with free radical scavenging among normal processes in immature and diseased lungs, have not been fully tested. This will require further study

with randomized trials which implement appropriate follow-up of patients and do not permit crossover of treatment.

Finally, we have seen that mortality for reversible causes of PPHN is low in an ECMO center. At most, 2 and probably only 1 patient in this series died with reversible pulmonary hypertension. This low event rate will make it unlikely that mortality is a realistic outcome variable for single-center randomized trials of the efficacy of NO in PPHN. Considering the potential to achieve zero mortality in this disease, centers without ECMO capability may need to re-evaluate the timing of patient referrals, especially if withdrawal of NO (during transport) may be associated with rebound pulmonary hypertension.³⁰

The improvement in oxygenation and low incidence of identifiable side effects with inhaled NO in this study encouraged us to proceed with continued randomization in a second phase of the trial using lower NO doses and combined therapy with NO and HFOV when indicated. This phase has just been completed and confirms the value of HFOV. These and other studies will be required before one can conclude with certainty whether NO improves outcome in patients with PPHN.

ACKNOWLEDGMENTS

This study was supported by a Clinical Research Grant in Aid Award, Children's Hospital, Boston. Dr. Wessel is supported by a grant from the United States Food and Drug Administration; Dr. Van Marter is supported by a grant from the National Institutes of Health; Dr. Kourembanas is supported by grants from the American Heart Association, the William Randolph Hearst Foundation, and by the National Institutes of Health.

We thank Elizabeth Allred for statistical analysis and Margarita Arroyave for her assistance in preparation of the manuscript.

REFERENCES

- Gersony W, Duc G, Sinclair J. "PFC" syndrome (persistence of the fetal circulation). *Circulation*. 1969;39:III-87
- Siassi B, Goldberg S, Emmanoulides G, Higashino S, Lewis E. Persistent pulmonary vascular obstruction in newborn infants. *J Pediatr*. 1971;78:610-615
- Levin D, Heymann M, Kitterman J, Gregory G, Phibbs R, Rudolph A. Persistent pulmonary hypertension of the newborn infant. *J Pediatr*. 1976;89:626-630
- Roberts JD, Shaul PW. Advances in the treatment of persistent pulmonary hypertension of the newborn. *Pediatr Clin North Am*. 1993;40:983-1004
- Bartlett R, Roloff D, Cornell R, Andrews A, Dillon P, Zwischenberger J. Extracorporeal circulation in neonatal respiratory failure: a prospective randomized study. *Pediatrics*. 1985;76:479-487
- O'Rourke P, Crone R, Vacanti J, et al. Extracorporeal membrane oxygenation and conventional medical therapy in neonates with persistent pulmonary hypertension of the newborn: a prospective randomized study. *Pediatrics*. 1989;84:957-963
- UK Collaborative ECMO Trial Group. UK collaborative randomised trial of neonatal extracorporeal membrane oxygenation. *Lancet*. 1996;348:75-82
- Frostell CG, Fratacci MD, Wain JC, Jones R, Zapol WM. Inhaled nitric oxide: a selective pulmonary vasodilator reversing hypoxic pulmonary vasoconstriction. *Circulation*. 1991;83:2038-2047
- Pepke-Zaba J, Higenbottam TW, Dinh-Xuan AT, Stone D, Wallwork J. Inhaled nitric oxide as a cause of selective pulmonary vasodilatation in pulmonary hypertension. *Lancet*. 1991;338:1173-1174
- Roberts JD, Polaner DM, Lang P, Zapol WM. Inhaled nitric oxide in persistent pulmonary hypertension of the newborn. *Lancet*. 1992;340:818-819
- Kinsella JP, Neish SR, Shaffer E, Abman SH. Low-dose inhalational nitric oxide in persistent pulmonary hypertension of the newborn. *Lancet*. 1992;340:819-820
- Kinsella JP, Neish SR, Ivy DD, Shaffer E, Abman SH. Clinical responses to prolonged treatment of persistent pulmonary hypertension of the newborn with low doses of inhaled nitric oxide. *J Pediatr*. 1993;123:103-108
- Barefield ES, Karle VA, Philips JB, Carlo WA. Inhaled nitric oxide in term infants with hypoxemic respiratory failure. *J Pediatr*. 1996;129:279-286
- Finer NN, Etches PC, Kamstra B, Tierney AJ, Peliowski A, Ryan CA. Inhaled nitric oxide in infants referred for extracorporeal membrane oxygenation: dose response. *J Pediatr*. 1994;124:302-308
- Day R, Lynch J, White K, Ward R. Acute response to inhaled nitric oxide in newborns with respiratory failure and pulmonary hypertension. *Pediatrics*. 1996;98:698-705
- Goldman A, Tasker R, Haworth S, Sigston P, Macrae D. Four patterns of response to inhaled nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics*. 1996;98:706-713
- Turbow R, Waffarn L, Yang L, Sills J, Hallman M. Variable oxygenation response to inhaled nitric oxide in severe persistent pulmonary hypertension of the newborn. *Acta Paediatr*. 1995;84:1305-1308
- The Neonatal Inhaled Nitric Oxide Study Group. Inhaled nitric oxide in full-term and nearly full-term infants with hypoxic respiratory failure. *N Engl J Med*. 1997;336:597-604
- Roberts JD, Fineman JR, Morin FC, et al. Inhaled nitric oxide and persistent pulmonary hypertension of the newborn. *N Engl J Med*. 1997;336:605-610
- Chalmers T. Randomization of the first patient. *Med Clin North Am*. 1975;59:1035-1038
- Wessel DL, Adatia I, Thompson JE, Hickey PR. Delivery and monitoring of inhaled nitric oxide in patients with pulmonary hypertension. *Crit Care Med*. 1994;22:930-938
- Betit P, Adatia I, Benjamin P, Thompson JE, Wessel DL. Inhaled nitric oxide: evaluation of a continuous titration delivery technique developed for infant mechanical ventilation and manual ventilation. *Respir Care*. 1995;40:706-715
- Steinhorn R, Cox P, Fineman J, et al. Inhaled nitric oxide enhances oxygenation but not survival in infants with alveolar capillary dysplasia. *J Pediatr*. 1997;130:417-422
- Henrichsen T, Goldman A, Macrae D. Inhaled nitric oxide can cause severe systemic hypotension. *J Pediatr*. 1996;129:183
- Wilson J, Bower L, Thompson J, Fauza D, Fackler J. ECMO in evolution: the impact of changing patient demographics and alternative therapies on ECMO. *J Pediatr Surg*. 1996;31:1116-1123
- Abman SH, Kinsella JP. Inhaled nitric oxide for persistent pulmonary hypertension of the newborn. The physiology matters! *Pediatrics*. 1995;26:1153-1155
- Roberts JD, Lang P, Bigatello LM, Vlahakes GJ, Zapol WM. Inhaled nitric oxide in congenital heart disease. *Circulation*. 1993;87:447-453
- Wessel DL, Adatia I, Giglia TM, Thompson JE, Kulik TJ. Use of inhaled nitric oxide and acetylcholine in the evaluation of pulmonary hypertension and endothelial function after cardiopulmonary bypass. *Circulation*. 1993;88(part 1):2128-2138
- Betit P, Grenier B, Thompson J, Wessel D. Evaluation of four analyzers used to monitor nitric oxide and nitrogen dioxide concentrations during inhaled nitric oxide administration. *Respir Care*. 1996;41:817-825
- Atz AM, Adatia I, Wessel DL. Rebound pulmonary hypertension after inhalation of nitric oxide. *Ann Thorac Surg*. 1996;62:1759-1764

Improved Oxygenation in a Randomized Trial of Inhaled Nitric Oxide for Persistent Pulmonary Hypertension of the Newborn

David L. Wessel, Ian Adatia, Linda J. Van Marter, John E. Thompson, Janie W. Kane, Ann R. Stark and Stella Kourembanas

Pediatrics 1997;100:e7

DOI: 10.1542/peds.100.5.e7

Updated Information & Services	including high-resolution figures, can be found at: http://www.pediatrics.org/cgi/content/full/100/5/e7
References	This article cites 28 articles, 9 of which you can access for free at: http://www.pediatrics.org/cgi/content/full/100/5/e7#BIBL
Subspecialty Collections	This article, along with others on similar topics, appears in the following collection(s): Premature & Newborn http://www.pediatrics.org/cgi/collection/premature_and_newborn
Permissions & Licensing	Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: http://www.pediatrics.org/misc/Permissions.shtml
Reprints	Information about ordering reprints can be found online: http://www.pediatrics.org/misc/reprints.shtml

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™



Inhaled Nitric Oxide in the Neonate With Cardiac Disease

Andrew M. Atz and David L. Wessel

As a selective pulmonary vasodilator, inhaled nitric oxide is an important diagnostic and therapeutic agent for the treatment of pulmonary hypertension in patients with congenital heart disease. Among 400 patients treated in our center with nitric oxide, 37% were newborns. Hemodynamic benefit was shown in newborns with total anomalous pulmonary venous connection, in those with congenital mitral stenosis, and in postoperative patients with preexisting left to right shunts and other lesions. It can be used to help discriminate anatomic obstruction to pulmonary blood flow from pulmonary vasoconstriction, and it may be used in the treatment or prevention of pulmonary hypertensive crises after cardiopulmonary bypass. However, none of the purported benefits of inhaled nitric oxide in children with congenital heart disease have been studied in a randomized, placebo-controlled manner. Copyright © 1997 by W.B. Saunders Company

Pulmonary Hypertension and Congenital Heart Disease

Prevalence

Among causes of infant mortality in the United States, congenital anomalies account for the largest diagnostic category, and structural heart disease leads the list of congenital malformations.¹ Approximately one third of pediatric intensive care admissions are for children with cardiovascular disorders.² Compared with the number of adults with coronary and rheumatic heart disease, the number of Americans with congenital heart disease is relatively small, but one quarter of this number are sufficiently affected by the disease to require intervention within the first month of life.³ The number of neonates with pulmonary hypertensive disorders further complicating their congenital heart disease is difficult to precisely quantify, but likely represents about 25% of those who require early intervention.⁴ Their severity of illness, demand on resources, and the previously limited success of therapeutic options have focused attention on this population of patients.

Importance

Pulmonary hypertension is often a crucial factor in determining the timing or type of intervention, and has been invoked as the primary determinant of mortality in many lesions.^{5,6} The assessment of pulmonary vascular reactivity forms an important part of the preoperative and postoperative management of patients with congenital

tal heart disease. A fixed elevation in pulmonary vascular resistance may deny them the chance of corrective surgery with the subsequent development of progressive obliterative pulmonary vascular disease and severely reduced life-expectancy. Children with congenital heart disease are frequently cyanotic and have multiple intracardiac shunts, often coexisting with varying degrees of right or left ventricular outflow tract obstruction. Intravenous vasodilators with their attendant risks of hypotension and increased intrapulmonary shunt may be not only hazardous, but yield results that confound analysis of the reactivity of the pulmonary vascular bed.

The Neonate With Congenital Heart Disease

Effects of Cardiopulmonary Bypass

Only a few years ago, it was considered heretical that a child with congenital heart disease should be electively repaired with a single primary pro-

From the Division of Cardiac Intensive Care, Department of Cardiology, Children's Hospital and the Departments of Pediatrics and Anesthesia, Harvard Medical School, Boston, MA.

Supported in part by a grant from the United States Food and Drug Administration, and an award from the National Institutes of Child Health and Human Development and the Research Endowment of Children's Hospital.

Address reprint requests to David L. Wessel, MD, Cardiac ICU Office, Farley 653, Children's Hospital, 300 Longwood Ave, Boston, MA 02115.

*Copyright © 1997 by W.B. Saunders Company
0146-0005/97/2105-0008\$05.00/0*

cedure during the first few days of life using cardiopulmonary bypass. Criticism of this approach focused not only on the technical capabilities of the surgeon, but on the adverse effects of cardiopulmonary bypass on the neonatal myocardium. Furthermore, concerns existed that severe pulmonary hypertension, activated by cardiopulmonary bypass, would compromise postoperative hemodynamic stability. Today, surgical correction of congenital heart disease, in contrast to palliation with shunts or pulmonary artery bands, has been extended to the neonate; surgical correction is emerging as the preferred approach to many defects in most major centers.^{7,8} However, perioperative care of the newborn and infant does require an appreciation of the relative intolerance of the immature myocardium to increased afterload. The right ventricle must face the potential challenges of the transitional pulmonary circulation rendered ischemic and reactive by cardiopulmonary bypass, while simultaneously coping with impaired ventricular function caused by the adverse effects of bypass. Aside from the consequences of cardiopulmonary bypass, aortic cross-clamp time, routine use of deep hypothermia and cardioplegia solutions, many congenital heart defects (eg, tetralogy of Fallot, truncus arteriosus, pulmonary atresia) require a right ventriculotomy as part of the repair. Thus, it is imperative that one minimize right ventricular afterload during the early postoperative hours while the ischemic-reperfusion injury transiently depletes myocardial reserve and cardiac output normally declines.⁹

Causes of Pulmonary Hypertension

The neonatal pulmonary vasculature may be extremely labile. Remodeling of the vessel wall, functional maturation of the endothelial cell, differentiation of the smooth muscle cell, release of vasoactive mediators, and vessel recruitment all contribute to the successful transition from fetal to neonatal pulmonary circulation. The child with congenital heart disease and pulmonary hypertension has abnormal postnatal vessel remodeling.¹⁰ Prolonged exposure to high pulmonary blood flow under conditions of high pressure will accelerate the pathological progression to less reversible states. Thus early surgical repair has been advocated to prevent later pulmonary vascular obstructive disease.^{11,12} Neonatal cardiac surgical repair achieves earlier and

more normal pulmonary vascular maturation. It seems to reduce but not abolish the incidence of problematic postoperative pulmonary hypertension.¹²

Several factors attributable to cardiopulmonary bypass may raise pulmonary vascular resistance: microemboli, platelet aggregation, complement activation, pulmonary leukosequestration, excess thromboxane and endothelin production, atelectasis, and hypoxic pulmonary vasoconstriction among others. Furthermore, prior data would suggest that preoperative conditioning of the pulmonary vascular bed, perioperative vasospastic stimuli, increased postoperative adrenergic tone, along with damage to the pulmonary endothelium likely combine to increase pulmonary vascular resistance after cardiopulmonary bypass. The effect may be insidious, expressed over several hours as low cardiac output and right heart failure, or more acutely as pulmonary hypertensive crises. Pulmonary hypertensive crises are dramatic events that threaten the life of an infant despite a good surgical repair.^{13,14} In such situations, the pulmonary artery pressure increases to systemic or suprasystemic levels, the systemic blood pressure falls and the arterial oxygen saturation decreases. In a report of a series from one large center, half of the postoperative cardiac children who had pulmonary hypertensive crises died during their hospitalization.⁴

Inhaled NO: Measuring the Response

The first investigations of pulmonary vasodilation with NO in adults were quickly followed by several clinical reports of inhaled NO aimed at the transitional circulation of the newborn and children with congenital heart disease. Successful clinical trials of inhaled NO have been conducted among patients with persistent pulmonary hypertension of the newborn (PPHN).^{15,16} However, direct measurement of pulmonary artery pressure is rarely undertaken in patients with PPHN or in other forms of neonatal respiratory failure. Effects of NO treatment on pulmonary hypertension may be inferred from changes in systemic oxygenation only when hypoxia results from right to left shunting across the ductus arteriosus or foramen ovale. Even then, oxygenation is an indirect and ambiguous measure of the effect of treatment on pulmonary vascular resistance. The analysis is further confounded when severe pulmonary parenchymal disease

coexists with pulmonary hypertension. In this setting, systemic oxygenation may improve with inhaled vasodilators by enhancing ventilation-perfusion matching.¹⁷ Pulmonary artery pressure is often monitored directly in the neonate and infant with congenital heart disease. This population affords us a unique opportunity to directly record the hemodynamic effects of initiation and withdrawal of inhaled NO.

Clinical Studies

We will review the current literature regarding the use of inhaled NO in congenital heart disease, focusing on neonates. We first present studies that used nitric oxide as a means to identify endothelial dysfunction resulting from cardiopulmonary bypass and then suggest how NO may benefit cardiac patients with combined problems of pulmonary hypertension and acute respiratory failure. We will review its therapeutic utility in perioperative patients with pulmonary hypertension, and its use as a diagnostic tool to distinguish between neonates with reactive pulmonary vasoconstriction and those with right ventricular hypertension resulting from anatomic obstruction to pulmonary blood flow. We will also explore its use and limitations in patients with single ventricle physiology and discuss potential adverse effects as pertains to cardiac disease. Finally, we will consider the potential benefits of longer-term administration of NO to facilitate growth and remodeling of the abnormal pulmonary vasculature in unusual forms of idiopathic pulmonary hypertension identified in early infancy.

Age Distribution

By 1997, we had studied the clinical response to inhaled NO in more than 400 patients at a single center. Nearly two-thirds of these patients exhibited pulmonary hypertension associated with congenital heart disease. Thirty-seven percent were younger than 1 month of age and the majority were less than 1 year (Fig 1), reflecting the bias toward early surgical repair of congenital heart defects at Children's Hospital, Boston⁷ and the perceived benefit of NO for PPHN.

Endothelial Dysfunction After Cardiopulmonary Bypass

Pulmonary vascular endothelial dysfunction contributes to post-cardiopulmonary bypass pulmo-

nary hypertension. The degree of pulmonary hypertension correlates with the extent of damage to the pulmonary endothelium after cardiopulmonary bypass. Reactivity of the pulmonary vascular bed is related to the presence and degree of preoperative pulmonary hypertension, magnitude of preoperative left to right shunts, and duration of bypass. On cardiopulmonary bypass, pulmonary blood flow is supplied only by the vasovasorum via the bronchial circulation, which may be inadequate to prevent ischemic damage to the endothelium and subsequently compromise endogenous production of nitric oxide. We hypothesized that transient pulmonary vascular endothelial cell dysfunction could be shown in neonates and older children by documenting the loss of endothelium dependent vasodilation during the immediate postoperative period.

We recorded hemodynamic variables after a 2-minute infusion of the endothelium dependent vasodilator, acetylcholine, at a concentration of 10^{-6} M and after inhalation of the endothelium-independent smooth muscle relaxant, NO inhaled at 80 parts per million (ppm).¹⁸ The two agents were compared in patients with pulmonary hypertensive congenital heart disease before and after surgical repair on cardiopulmonary bypass. Plasma levels of cyclic GMP were measured before and after acetylcholine and NO administration. Pulmonary vasodilation to acetylcholine was present preoperatively but attenuated postoperatively, while response to inhaled nitric oxide was present both preoperatively and postoperatively. Baseline mean pulmonary artery pressure decreased $27\% \pm 4\%$ preoperatively but only $9\% \pm 2\%$ postoperatively with acetylcholine. However, after the attenuated response to acetylcholine was shown, postoperative inhalation of NO immediately lowered mean pulmonary artery pressure by $26\% \pm 3\%$ (Fig 2). Similarly, baseline pulmonary vascular resistance decreased $46\% \pm 5\%$ in preoperative patients, but declined only $11\% \pm 4\%$ in postoperative patients with acetylcholine. Inhalation of NO after acetylcholine infusion lowered pulmonary vascular resistance postoperatively by $33\% \pm 4\%$. This suggested that the functional integrity of the smooth muscle was intact in the presence of endothelial dysfunction resulting from cardiopulmonary bypass. Elevated pulmonary vascular resistance from atelectasis, microemboli, platelet plugging of vessels or other fixed obstructive

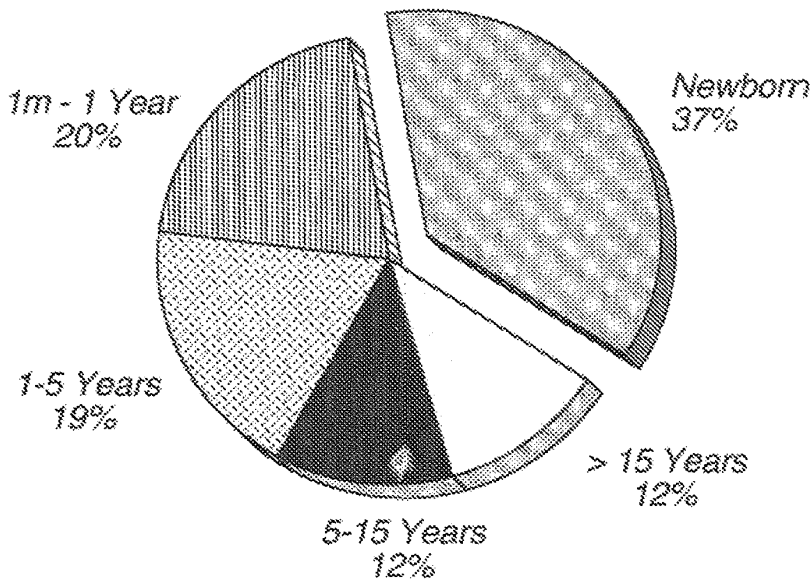
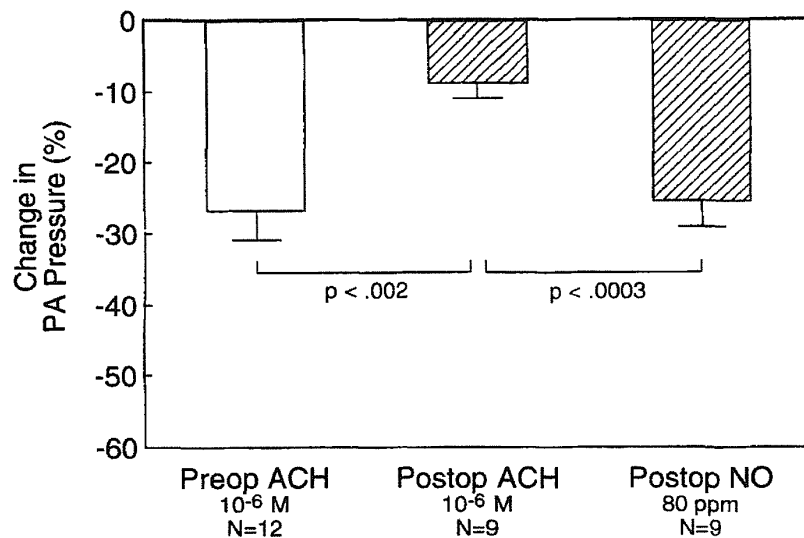


Figure 1. Age analysis of 405 consecutive patients who received inhaled NO at Children's Hospital, Boston.

processes could not be invoked as the cause of the blunted response to acetylcholine because resistance decreased so dramatically with NO. Plasma levels of cGMP in postoperative patients were unchanged after acetylcholine, but increased more than threefold during pulmonary vasodilation with NO. This finding was consistent with the purported role of cGMP as the second messenger effecting smooth muscle relaxation.

This study suggested that cardiopulmonary bypass is responsible for pulmonary endothelial dysfunction. This focused attention on the endothelium as an important organ to address in the management of pulmonary hypertension. It also highlighted the potential importance of maintaining at least some antegrade flow from right ventricle into pulmonary arteries during extracorporeal membrane oxygenation (ECMO).

Figure 2. The percentage change in mean pulmonary artery pressure (PA) with acetylcholine (ACH) in preoperative and postoperative patients. The vasodilator response is attenuated with ACH but retained with NO in the postoperative period. (Reprinted with permission from Wessel DL, et al: Use of inhaled nitric oxide and acetylcholine in the evaluation of pulmonary hypertension and endothelial function after cardiopulmonary bypass. *Circulation* 88:2128-2138, 1993.¹⁸ Copyright 1993 American Heart Association.)



The heart should be permitted to eject some flow into the pulmonary arteries rather than allowing ECMO to provide total cardiopulmonary bypass for several hours or days. These early findings further suggested an important diagnostic and therapeutic role that inhaled nitric oxide might play as a result of its selective pulmonary vasodilation with minimal systemic side effects in children with congenital heart disease.

Acute Respiratory Failure After Cardiopulmonary Bypass

Pulmonary parenchymal disease may coexist with heart disease in the newborn. It complicates evaluation and treatment of the child. In some instances, structural abnormalities in the heart produce pulmonary venous hypertension, flood the alveoli with pulmonary edema fluid, and induce severe intrapulmonary and extrapulmonary right to left shunting of blood.

Examples of this phenomenon include the child born with transposition of the great arteries and intact ventricular and atrial septa. In this example, inadequate mixing of blood occurs simultaneously with extreme elevation in left atrial pressure. Pulmonary venous oxygen desaturation may critically lower the systemic oxygen levels further in this cyanotic heart disease. Immediate performance of a balloon atrial septostomy is essential, but may not instantly correct the pulmonary parenchymal abnormalities and alveolar hypoxia.¹⁹ Treatment with inhaled NO may address ventilation-perfusion abnormalities in this circumstance as well as lower the still reactive pulmonary artery pressure. Reports have suggested that use of NO may obviate the need for ECMO in some such circumstances by accelerating improvements in gas exchange as well as hemodynamic recovery.^{20,21}

Transient acute respiratory failure may occur in other instances after cardiopulmonary bypass, notably after lung transplantation in children. Here the ischemic injury to the endothelium is exaggerated after hours of cold ischemic preservation of the donor lung. The lung parenchyma is injured such that transient graft dysfunction characterized by lung consolidation, decreased lung compliance, hypoxia, and pulmonary hypertension may plague the patient postoperatively. Again in this clinical scenario, the injured lung vasculature is unresponsive to the endothelium-dependent vasodilators but highly respon-

sive to inhaled nitric oxide.²² Pulmonary artery pressure decreased precipitously with treatment, but more importantly, PaO₂ increased dramatically (Fig 3).

In the presence of increased pulmonary vascular tone, patients with large intrapulmonary shunts respond to inhaled vasodilators with a reduction in intrapulmonary shunt fraction and improved systemic oxygenation. This contrasts with traditional intravenous vasodilators, which are prone to override hypoxic pulmonary vasoconstriction and worsen ventilation/perfusion abnormalities. Evidence now exists that NO can be administered to the donor lung to enhance preservation during storage and transport to the recipient.^{23,24} Although neonatal lung transplantation is a rare procedure, other forms of respiratory failure in newborns after cardiopulmonary bypass are more commonly encountered. Overwhelming pneumonia is a devastating complication that may be exacerbated by cardiopulmonary bypass. Mild infectious pneumonitis or bronchiolitis in the young preoperative infant can turn to life-threatening respiratory failure during postoperative recovery. As an inhaled vasodilator, NO therapy addresses both aspects of the disease: pulmonary hypertension and hypoxia. Inhaled NO, by virtue of its antioxidant effects, inhibition of unwanted platelet aggregation and suppression of deleterious inflammatory responses during reperfusion injury, may even have a role in routine prophylactic use for all patients at risk of postbypass respiratory complications.

NO or ECMO After Cardiopulmonary Bypass

ECMO support for severe cardiopulmonary failure after cardiac surgery in newborns and children has been advocated in many centers.^{25,26} Because postoperative pulmonary hypertension after reparative cardiac operations is believed to be life-threatening, yet reversible, NO treatment in this condition may diminish the need for ECMO. Certainly, Journois et al have shown the value of NO in the treatment of acute pulmonary hypertensive crises.²⁷ Goldman et al described 6 of 10 patients who met institutional ECMO criteria, but were managed with NO instead and survived to hospital discharge.²¹ This compares favorably with published survival rates in postcardiotomy patients supported by ECMO.²⁵

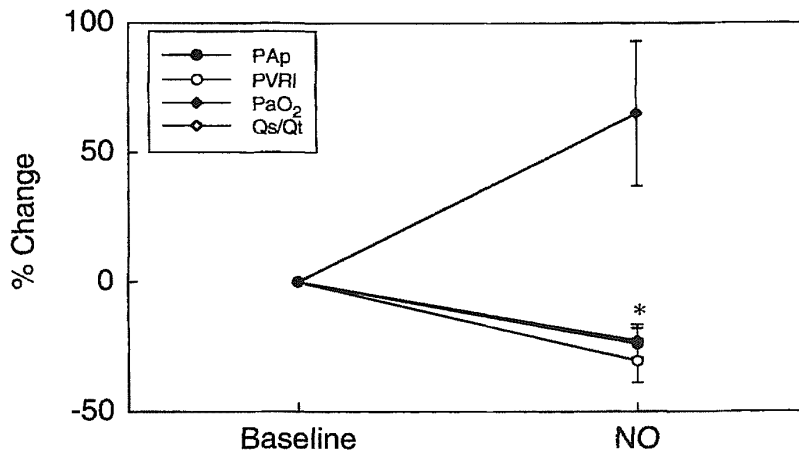


Figure 3. The effect of 80 ppm NO in six patients with transient graft dysfunction after lung transplantation. Pulmonary artery pressure (PAP), pulmonary vascular resistance (PVRI), and intrapulmonary shunt fraction (Qs/Qt) decreased significantly and PaO₂ increased. (Adapted and reprinted with permission from Adatia I, Wessel DL: Therapeutic use of inhaled nitric oxide. *Curr Op Pediatr* 6:583-590, 1994.)

Although there are no randomized trials examining the benefit of NO among cardiac patients, this information suggests that a trial of inhaled NO should be considered in these patients before cannulation for ECMO.

Total Anomalous Pulmonary Venous Connection

Infants with total anomalous pulmonary venous connection (TAPVC) frequently have obstruction of the pulmonary venous pathway as it connects anomalously to the systemic venous circulation. When pulmonary venous return is obstructed preoperatively, pulmonary hypertension is severe and demands urgent surgical relief. Increased neonatal pulmonary vasoreactivity, endothelial injury induced by cardiopulmonary bypass,¹⁸ and intrauterine anatomic changes in the pulmonary vascular bed in this disease²⁸ contribute to postoperative pulmonary hypertension. We hypothesized that infants with anatomically obstructed TAPVC would have a high occurrence rate of postoperative pulmonary hypertension, and that their pulmonary vascular bed could be selectively dilated with inhaled NO. Our aim was to define the incidence of postoperative pulmonary hypertension in infants with TAPVC and to describe the hemodynamic effects of initiation and withdrawal of inhaled NO in those postoperative patients with pulmonary hypertension. Twenty infants presented with isolated TAPVC over a 3-year period and were monitored for pulmonary hypertension. Nine patients had postoperative pulmonary hyperten-

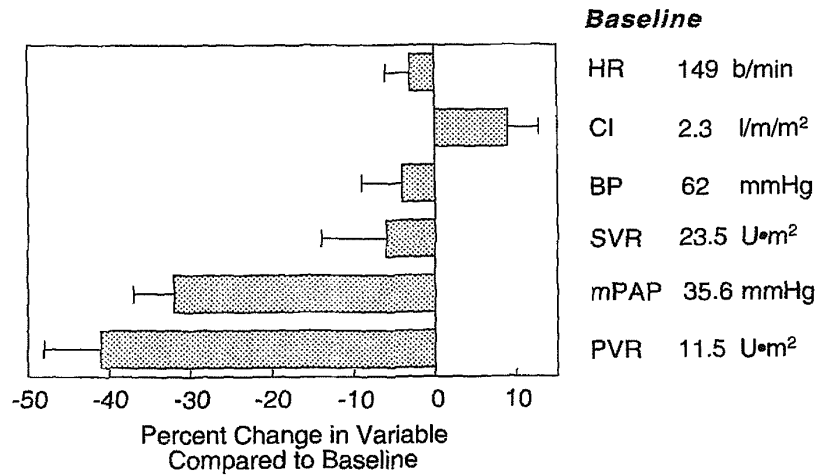
sion treated with a 15-minute trial of inhaled NO at 80 ppm. Five patients received prolonged treatment with NO at 20 ppm or less (median 28 hours, range 12 to 71 hours).

We showed a mean percentage decrease of 42% in pulmonary vascular resistance and 32% in mean pulmonary artery pressure.²⁹ There was no significant change in heart rate, systemic blood pressure, or vascular resistance. Although not statistically significant, cardiac index increased by 10% (Fig 4).

Congenital Mitral Stenosis

We examined the effect of inhaled NO at 80 ppm for 15 minutes in 15 children with pulmonary hypertension and congenital mitral stenosis to assess the extent of reversible pulmonary vasoconstriction.³⁰ Mean pulmonary artery pressure decreased from 42 ± 2 to 30 ± 2 ($P < .05$) during NO inhalation. Pulmonary vascular resistance declined from 5.8 ± 0.7 to 2.9 ± 0.4 U · m² ($P < .05$) (Fig 5). Cardiac index, left and right atrial pressure, mean systemic blood pressure, heart rate, systemic vascular resistance, PaO₂, and calculated intrapulmonary shunt fraction were not changed. Selective pulmonary vasodilation occurred in all patients, proving the presence of a significant reactive component of pulmonary hypertension in this disease. Prolonged therapy with inhaled NO facilitated the management and recovery of 4 patients. It is particularly useful adjunctive therapy during awakening and extubation when pulmonary hypertension worsens and predisposes patients to pulmonary

Figure 4. Percentage change in hemodynamic variables from baseline during 15 minutes of NO at 80 ppm in 9 patients with TAPVC. There is marked specificity for the pulmonary circulation.



edema. The vasoreactivity is greater than previously reported in adults with acquired mitral stenosis.^{31,32} This may be due to the particular sensitivity of pulmonary veins to inhaled NO when pulmonary venous hypertension has been present since birth.

We have found patients with TAPVC, congenital mitral stenosis, and other pulmonary venous hypertensive disorders to be the most responsive to NO. These infants are born with significantly increased amounts of smooth muscle in their pulmonary veins.^{33,34} Histological evidence of muscularized pulmonary veins as well as pulmonary arteries³⁵ suggest the presence of vascular

tone and capacity for change in resistance at both the arterial and venous sites. The increased responsiveness observed in younger patients with pulmonary venous hypertension to NO may result from pulmonary vasorelaxation at a combination of pre and postcapillary vessels.^{30,36}

Anatomic Obstruction Versus Pulmonary Vasoconstriction

As we have discussed, even if a neonatal cardiac operation is successfully performed, endothelium-dependent pulmonary vascular relaxation is impaired after cardiopulmonary bypass and the postoperative course may be complicated by

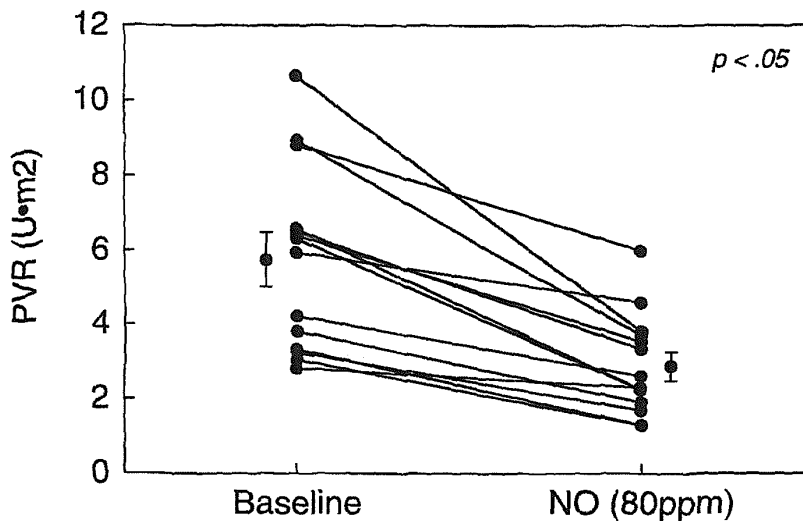


Figure 5. The effect of 80 ppm NO on pulmonary vascular resistance (PVR) in patients with congenital mitral stenosis. PVR decreased from baseline in all patients. (Reprinted with permission of the publisher from Atz AM, et al: Inhaled nitric oxide in children with pulmonary hypertension and congenital mitral stenosis. *Am J Cardiol* 77:316-319, 1996.³⁰ Copyright 1996 by Excerpta Medica Inc.)

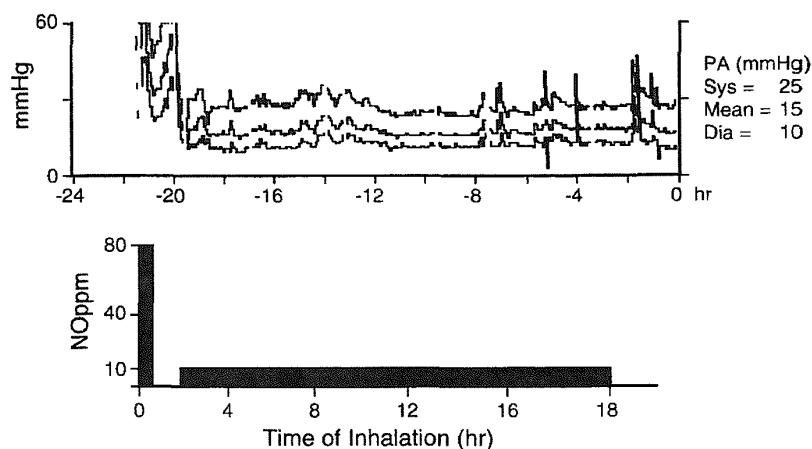


Figure 6. Bedside tracing of pulmonary artery pressure (PA) (systolic, mean, diastolic) with NO dose and duration of therapy on bottom. PA pressure decreased during 80 ppm trial. Vasodilation was sustained with 10 ppm NO for 18 hours of therapy.

transient pulmonary hypertension. As shown previously, pulmonary vasoconstriction in the postoperative newborn is exquisitely responsive to inhaled NO. However, reactive pulmonary vasoconstriction may not be the only cause of elevated pulmonary artery and right ventricular pressures. Differentiation between pulmonary vasoconstriction and anatomic obstruction to pulmonary blood flow may be difficult, especially in neonates. Branch pulmonary artery stenosis, hypoplastic distal pulmonary arteries, or iatrogenic causes of obstruction to pulmonary blood flow may be reflected in elevated pressure in the main pulmonary artery. A definitive diagnosis may require invasive and potentially dangerous investigation of the circulation.

We therefore proposed to use inhaled NO diagnostically in neonates with pulmonary hypertension after cardiac surgery to discern those with reversible vasoconstriction. Nine of 15 patients responded to a 15-minute trial with a reduction in mean pulmonary artery pressure from 35 ± 4 to 26 ± 4 mm Hg and pulmonary vascular resistance from 17 ± 6 to 10 ± 4 $U \cdot m^2$. There were insignificant changes in systemic hemodynamics. Two patients received prolonged therapy with inhaled NO after the initial trial. In both cases the use of continuous low dose (3 to 10 ppm) NO allowed management of the pulmonary artery pressure, without episodic increases, and optimization of the right ventricular afterload. It was also possible to wean ventilatory support and decrease sedation unpunctuated by increases in pulmonary artery pressure (Fig 6).

Six patients did not respond to inhaled NO

with either a decrease in proximal pulmonary artery pressure or an increase in systemic oxygen saturation. In each of these patients subsequent investigation, prompted by the failed response to inhaled NO, showed anatomic obstruction to pulmonary blood flow. Thus, failure of the postoperative newborn with pulmonary hypertension to respond to NO successfully discriminated anatomic obstruction to pulmonary blood flow from pulmonary vasoconstriction. Judicious use of a trial of inhaled NO may be of value to rule out pulmonary vasoconstriction and redirect investigation toward reassessment of the surgical result. Failure of the patient to show response to NO should be regarded as strong evidence of anatomic and possibly surgically remediable obstruction.

Other Lesions

Successful use of inhaled NO in a variety of congenital heart defects after cardiac surgery has been reported by several groups.^{20,27,37-41} Selective pulmonary vasodilation has been documented after surgical repair of ventricular septal defects, atrioventricular septal defects, transposition of the great arteries, total anomalous pulmonary venous connection, and other structural heart defects. Some studies suggest that there is a correlation between the response to NO and the extent of preoperative pulmonary hypertension.^{38,39} Synergistic use of NO with aerosolized or intravenous prostacyclin,^{42,43} atrial natriuretic peptide,⁴⁴ dipyridamole,^{45,46} or specific type V phosphodiesterase inhibitors holds considerable promise for more effective control of pulmonary

hypertension in infants with congenital heart disease.

Single Ventricle

Pulmonary blood flow in the newborn with a single ventricle and no anatomic obstruction of flow to the lungs may become excessive as pulmonary vascular resistance decreases after birth. A pulmonary artery band may be applied to limit pulmonary over circulation while the child grows and the lungs mature. More complex single ventricle anatomy with pulmonary or aortic valve atresia requires that reliable pulmonary blood flow be established surgically with a systemic to pulmonary artery shunt that is sufficiently restrictive to prevent congestive heart failure but adequate to permit oxygenation. Later during infancy, when pulmonary resistance has safely declined, a cavopulmonary anastomosis (ie, a bidirectional Glenn or later, a modified Fontan procedure) can be attempted as a more hemodynamically efficient method of providing pulmonary blood flow. If there is excessive cyanosis in the newborn after placement of a systemic to pulmonary artery shunt (eg, Blalock-Taussig), it is tempting to attribute the hypoxemia to pulmonary vasoconstriction. Indeed we have observed dramatic improvements in oxygenation in some of these newborns when NO is delivered. However, it is far more common for the reduction in pulmonary blood flow to result from a kinked or otherwise obstructed shunt that requires surgical revision⁴⁷ (Fig 7).

As a prelude to potential use of the cavopulmonary anastomosis in the newborn, we studied infants (2 to 8 months old) with refractory cyanosis after a bidirectional Glenn anastomosis.⁴⁸ Although median baseline oxygen saturation was only 65%, administration of inhaled NO provided minimal improvement in oxygenation. One child with respiratory syncytial virus bronchiolitis showed significant improvement in oxygenation, but NO did not substantially change systemic oxygenation or the transpulmonary pressure gradient in any other patient. Saturations and PaO₂ did not change despite the fact that there was a fivefold increase in plasma cyclic GMP production, suggesting that inadequate NO delivery or failure of guanylate cyclase activation could not explain the lack of therapeutic effect. We have extended these observations to nearly 30 patients. This suggests that the pulmo-

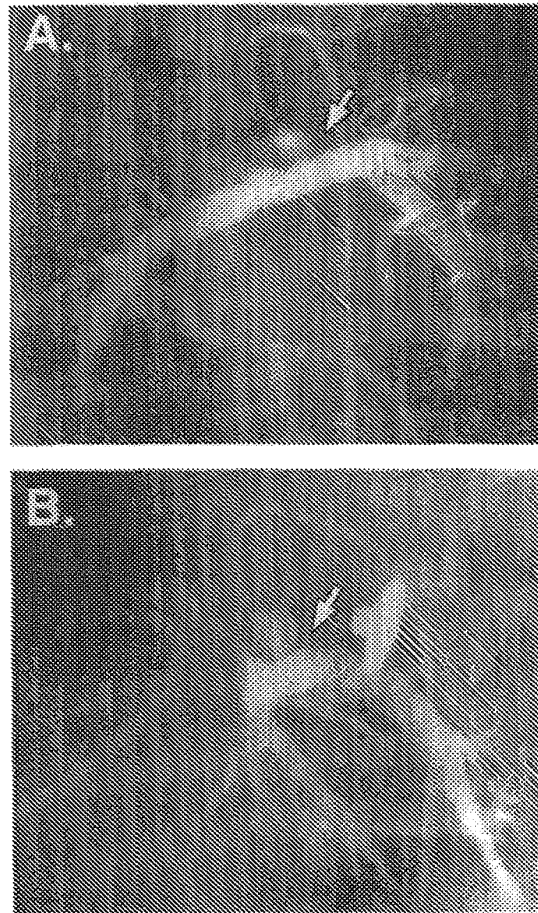


Figure 7. Anterior-posterior (A) and lateral (B) angiograms taken in a neonate with severe cyanosis and shunt-dependent pulmonary blood flow who failed to respond to inhaled NO. The arrow points to a discrete shunt narrowing that required surgical revision.

nary vascular bed in the newborn after a bidirectional Glenn will not be limited by pulmonary vasoconstriction, but rather by other regulatory mechanisms. Rather than refractory pulmonary vascular tone, it is likely that the limiting factor is pulmonary vascular cross-sectional area insufficient in the newborn to permit adequate passive blood flow through the lungs. Alternative treatment strategies may combine agents to accelerate postnatal growth of vessels for several days before a planned operation and then use NO postoperatively to avoid reactive pulmonary vasoconstriction.

Although not directly applicable to the newborn, the modified Fontan procedure is the ultimate reconstructive surgery for patients with a single ventricle. The Fontan physiology succeeds only with very low pulmonary vascular resistance, because flow through the lungs is conducted passively without a pumping chamber. NO has been used to considerable advantage by Macrae et al in the postoperative management of these patients.⁴⁹

Chronic NO Use

Although outpatient use of inhaled NO has been reported in a small number of adults, its use in younger patients with heart disease or as a therapeutic bridge to lung or heart lung transplantation is largely unstudied. NO inhibits smooth muscle growth and matrix protein synthesis in the extracellular matrix. It also reduces hypoxic remodeling in the rat lung,⁵⁰⁻⁵³ suggesting that it might have a salutary effect on scarring or pathological remodeling in the human lung. We hypothesized that the antioxidant and antiproliferative effects of NO combined with its antihypertensive action might provide a theoretical basis for prolonged treatment of idiopathic pulmonary hypertension. This might be particularly applicable to infants, who by virtue of their young age, have substantial capacity for smooth muscle regression, alveolar growth, and angiogenesis. We treated three infants younger than 3 months old who had severe unexplained pulmonary hypertension (biopsy-proven and presumed to be fatal) with a 25-day treatment regimen including inhaled NO. At the end of the treatment period, they had significantly lower (nearly normal) pulmonary artery pressures without recurrence of pulmonary hypertension during 3 to 22 months of follow-up. Although no conclusion can be drawn from such limited experience, it has prompted us to reevaluate our notion about presumed irreversibility of "primary" pulmonary hypertension early in life.

Adverse Effects

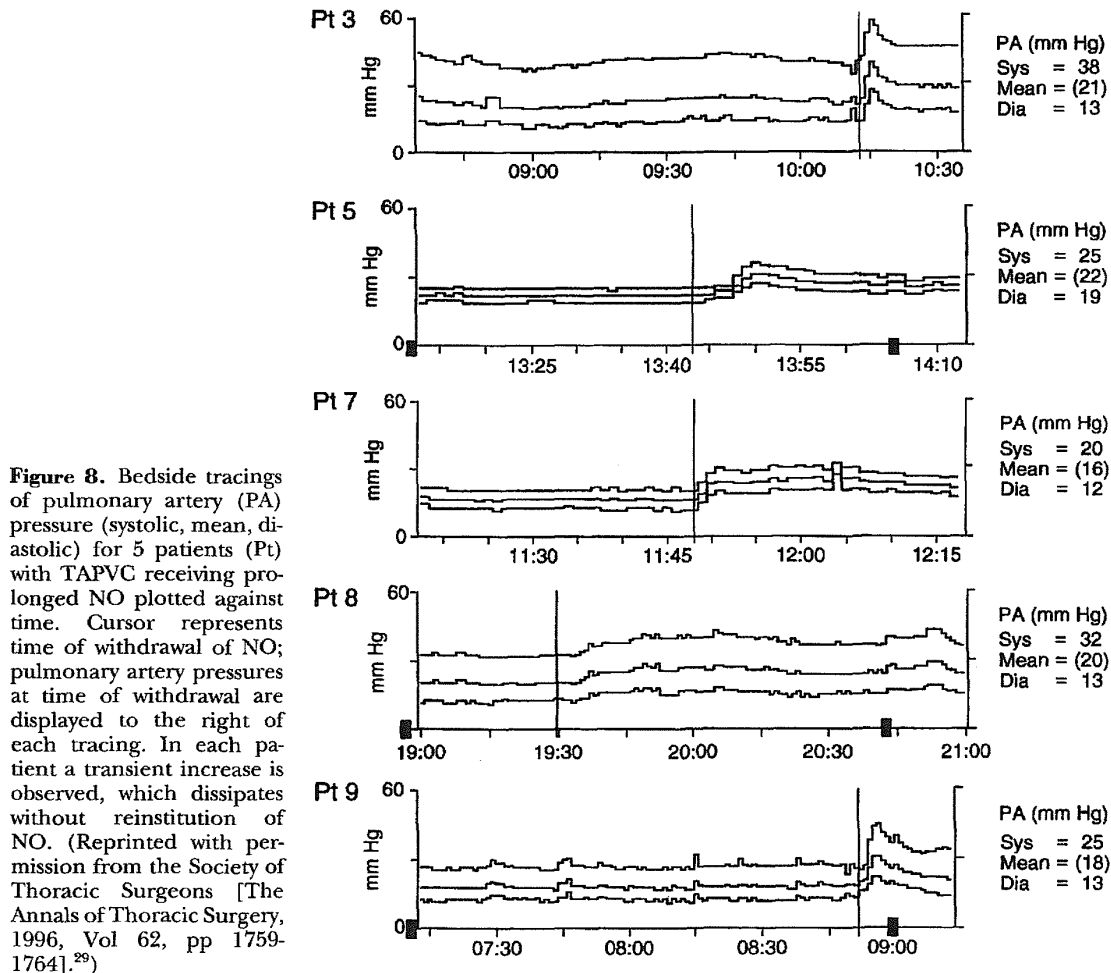
Rebound Pulmonary Hypertension

We observed in all patients with TAPVC after prolonged treatment with NO that a transient elevation in pulmonary artery pressure routinely

occurred when NO was successfully discontinued (Fig 8). Previous reports have described the abrupt return of pulmonary hypertension to systemic levels when NO was temporarily discontinued. When this phenomenon occurs very early in the postoperative course, and is accompanied by systemic hypotension and hypoxia, one is inclined to ascribe the changes to persistence of the underlying pulmonary hypertensive disorder. We described a somewhat different phenomenon. After several hours (12 to 72) of postoperative treatment and recovery NO could be discontinued, but a transient increase in pulmonary artery pressure was always observed. During the first minutes after successful NO withdrawal, pulmonary artery pressure increased moderately (peak effect 7 ± 3 minutes after withdrawal) and then declined to very low levels without impact on systemic hemodynamics. These changes were complete within 1 hour of withdrawal and were not attributable to any change in ventilation or pharmacological support.²⁹

Rebound pulmonary hypertension is not unique to inhaled vasodilators, but its causes are unclear. Negative feedback inhibition by exogenous NO has been postulated to account for this observation and shown to exist for inducible⁵⁴ and endothelial⁵⁵ NO synthase in vitro. NO donor agents inhibit endothelial NO biosynthesis in bovine arterial ring preparations by an apparent negative feedback on endothelial NO synthase. The arterial rings recovered responsiveness to endothelium-dependent relaxing agents within 30 to 40 minutes of withdrawing the NO donor agent, similar in timing to our witnessed rebound.⁵⁶ Decreased endogenous production of exhaled NO from smokers could also support a negative feedback theory.⁵⁷

Alternatively inhaled NO may play an unknown role in the modulation of endogenous pulmonary vasoconstrictors. It is reported that after abrupt withdrawal of nitroprusside (an NO donor), a transient rebound phenomenon exists.⁵⁸ Accordingly, one could hypothesize that pulmonary vasodilation by NO provoked secondary production or activation of vasoconstrictors. With the short half-life of NO, abrupt discontinuation allowed a brief period of unopposed vasoconstriction until stimulation of endogenous vasodilators or change in the stimulus for vasoconstriction achieved a new balance of vasomotor tone. A third alternative is that exposure



to exogenous NO altered membrane receptor conformation in vascular smooth muscle which reconfigured within 30 to 60 minutes after NO was withdrawn.

Rebound hypertension confounds assessment of whether postoperative pulmonary hypertension has resolved. NO therapy may be prolonged unnecessarily if clinicians are unaware that a moderate increase in pulmonary artery pressure on withdrawal may be transient and well tolerated if the underlying pathological process has improved. During weaning of NO, if mild elevations in pulmonary artery pressure are observed, it seems prudent to continue careful observation if the effect is transient and systemic hemodynamic stability is not impaired. Dose response testing for inhaled NO should be undertaken

during the initial exposure to NO, because information obtained during weaning may reflect rebound effects and not the true dose-response relationship.

Appreciation of rebound pulmonary hypertension and its transient characteristic may facilitate weaning from NO and has important implications for patients with persistent pulmonary hypertensive disorders when interruption of NO is necessary. If the underlying pulmonary hypertensive process has not resolved, then the tendency for an abrupt increase in pulmonary artery pressure may be hazardous if NO therapy must be withdrawn or interrupted. For example, one should continue to provide a source of NO when suctioning or changing NO tanks because abrupt discontinuation can result in cardiovascular col-

lapse.⁵⁹⁻⁶¹ If withdrawal of NO is necessary before resolution of the pathological process, hemodynamic instability may be expected. If a labile patient with pulmonary hypertension is stabilized with NO before transfer to a specialized center for further management, NO should be available during patient transport.

Severe Left Ventricular Dysfunction

Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension. In adults with ischemic cardiomyopathy, sudden pulmonary vasodilation may occasionally unload the right ventricle sufficiently to increase pulmonary blood flow and harmfully augment preload in a compromised left ventricle. The attendant increase in left atrial pressure may produce pulmonary edema.⁶² This is not likely to arise from any negative inotropic effect of NO⁶³ and may be ameliorated with vasodilators or diuretics. A different but related phenomenon may be operative in the newborn with severe left ventricular dysfunction and pulmonary hypertension. In these patients, the systemic circulation may depend in part on the ability of the right ventricle to sustain cardiac output through a right-to-left shunt across the patent ductus arteriosus. Selective pulmonary vasodilation may redirect the right ventricular output to the lungs and away from the systemic circulation. Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale and exclusively right to left shunting at the ductus arteriosus, NO should be used with extreme caution, if at all. We and others have reported adverse outcomes in this circumstance.^{64,65}

NO Dosage and Toxicity

There has been concern over potential NO induced cellular injury during exogenous exposure to the drug, as well as the generation of nitrogen dioxide and methemoglobinemia during the delivery of NO (see article by Dr Darley-Usmar). If the dose of NO is maintained below 40 ppm, there have been few acute problems reported as the result of methemoglobinemia or excessive nitrogen dioxide concentrations. At a dose of 80 ppm, we have reported in a very few infants a transient elevation of methemoglo-

bin.⁶⁶ Optimal dosing of NO to maximize pulmonary vascular relaxation without incurring toxic side effects, systemic hypotension, or an increase venous admixture is unclear. Miller showed in 10 infants and children that low and potentially less toxic doses of NO were effective after cardiac surgery, with nearly identical response at 2 ppm compared with 10 and 20 ppm.³⁹ Day showed little additional value with 60 ppm over 12 ppm in patients with congenital heart disease.⁶⁷ However, Roberts et al have shown a dose-response relationship up to 80 ppm in a similar population.⁶⁸

Maximal pulmonary vasodilator response to inhaled NO may occur at higher doses than that which produce optimal ventilation perfusion matching in patients with elevated pulmonary artery pressure and severe pulmonary parenchymal disease. By redistributing pulmonary blood flow away from underventilated alveoli toward normally ventilated areas of lung, inhaled NO in very low concentrations (<1 ppm) may improve intrapulmonary shunt fraction and raise PaO₂. It has been suggested that this effect may be optimized at doses of inhaled NO that are low (1 to 10 ppm), even though maximal pulmonary vasodilation occurred in the same patients at higher NO doses (10 to 100 ppm) among 12 adult patients with ARDS.⁶⁹ Improved oxygenation was lost at the higher NO doses in these patients in whom pulmonary vasodilation was maximized. Presumably, this occurred from a "spillover" effect of NO into poorly ventilated lung with loss of preferential delivery to and vasodilation of better ventilated areas. Thus, the desirable dose may depend in part on the severity of the pulmonary artery hypertension versus the severity of intrapulmonary shunting from lung disease. It seems likely that the recommended starting dose of NO for newborns with congenital heart disease will lie between 5 and 40 ppm.

Delivery Considerations

The potential toxicity of NO underscores the importance of developing reliable delivery and monitoring systems. Newborns are typically ventilated with devices designed to operate with continuous fresh gas flows from which all tidal breaths are derived. Stable NO concentrations can be achieved by titrating NO directly from the source tank into the inspiratory side of the continuous gas flow of the ventilator.⁷⁰ The resi-

dent times of NO and oxygen are minimized in continuous flow delivery systems because the gases are continuously purged through the ventilator. This system is limited to use in small patients who never require peak inspiratory flow rates greater than 10 to 12 L/min. It uses substantial amounts of NO gas and can be complicated by scavenging systems that interfere with the exhalation valve of the ventilator. NO source tanks are balanced with nitrogen and are available in a variety of concentrations from 100 to 10,000 parts per million (ppm). As NO is titrated into a delivery circuit, nitrogen will dilute the set FiO_2 . Using a ventilator gas flow rate of 9 L/min and a NO source tank of 800 ppm, 1 L/min flow of NO gas will be diluted to 80 ppm in inspiratory gas flow with a maximal FiO_2 of .90. Because doses as low as 1 ppm may achieve therapeutic benefit, low-flow meters are needed to obtain a wide range of NO doses. Nitric oxide can be titrated into other continuous flow devices such as high frequency ventilators and continuous positive airway pressure systems.⁷¹

An ideal delivery system uses medical grade quality gas manufactured by a process approved by the Food and Drug Administration. It minimizes the duration of gas in the delivery circuit, can deliver a wide range of precise NO doses with uniform mixing despite variable flow rates, has on-line analysis of NO, NO_2 and oxygen, incorporates stringent controls for exhaled gases, and has alarms to protect against excessive dosing or inadvertent discontinuation. Because rebound pulmonary hypertension or respiratory collapse after prolonged inhalation of NO in some patients represents an additional hazard of abrupt interruption of NO delivery, an appropriate alarm and back-up supply of NO must be in place. The system should be adaptable to different clinical situations, oxygen and NO concentrations should be independently controlled, and when used in conjunction with mechanical ventilation should not interfere with ventilator functions. Commercial products are just now available that use mass flow-controller technology capable of rapid and precise regulation and mixing of NO, oxygen, and air gas flows.⁷² When integrated into a microprocessor-governed, flow-sensing circuit, these devices promise to markedly improve the variability and precision of "homemade" systems, enabling the set NO concentration to remain constant during the dy-

namic flow of a single breath regardless of flow or ventilatory mode. They may be contained within standard ventilator housing with two separate control panels (oxygen and NO) directing output for the three relevant modules (air, oxygen, NO). Alternatively more flexible systems, similarly controlled, are now available to function in series with the most common mechanical ventilators.

Summary

Inhaled NO has emerged as an important diagnostic and therapeutic agent in the treatment of pulmonary hypertension among newborns with congenital heart disease. It is a selective pulmonary vasodilator with minimal adverse hemodynamic effects when administered and monitored in a judicious fashion. It seems to be more effective in the newborn than the older patient and has a number of advantages compared with intravenous vasodilators. Its hemodynamic benefit has been shown in patients with pulmonary hypertension associated with total anomalous pulmonary venous connection, congenital mitral stenosis, postoperative patients with preexisting left to right shunts, and other lesions. It can be used in the newborn to help discriminate anatomic obstruction to pulmonary blood flow from pulmonary vasoconstriction, and it may be used effectively in the treatment or prevention of pulmonary hypertensive crises after cardiopulmonary bypass. As an inhaled vasodilator, it has special advantage in the treatment of acute respiratory failure that may arise in conjunction with pulmonary hypertension after bypass. There are also potential benefits of chronic, outpatient administration of NO to facilitate growth, and beneficial remodeling of the abnormal pulmonary vasculature in unusual forms of idiopathic pulmonary hypertension identified in early infancy. However, none of the purported benefits of inhaled NO in children with congenital heart disease have been studied in a randomized, placebo-controlled manner with convincing demonstration of improved outcomes. This must be kept in mind when evaluating the risks and potential benefits of this new therapy.

References

1. Wegman ME: Annual Summary of Vital Statistics-1991. *Pediatrics* 90:835-845, 1992

2. Pollack MM, Yeh TS, Ruttimann UE, et al: Evaluation of pediatric intensive care. *Crit Care Med* 12:376-383, 1984
3. Moodie DS, Garson A, Freed MD, et al: 25th Bethesda Conference, Future Personnel Needs for Cardiovascular Health Care, Taskforce 6, Pediatric Cardiology. *J Am Coll Cardiol* 24:322-328, 1994
4. Hopkins RA, Bull C, Haworth SG, et al: Pulmonary hypertensive crises following surgery for congenital heart defects in young children. *Euro J Cardio-Thorac Surg* 5:628-634, 1991
5. Hoffman JIE, Rudolph AM, Heymann MA: Pulmonary vascular disease with congenital heart lesions: pathologic features and causes. *Circulation* 64:873-877, 1981
6. Rabinovitch M, Haworth SG, Castaneda AR, et al: Lung biopsy in congenital heart disease: A morphometric approach to pulmonary vascular disease. *Circulation* 58:1107-1122, 1978
7. Castaneda A, Mayer J, Jonas R, et al: The neonate with critical congenital heart disease: Repair—a surgical challenge. *J Thorac Cardiovasc Surg* 98:869-875, 1989
8. Wernovsky G, Chang AC, Wessel DL: Intensive care, in Emmanouilides GC, Riemenschneider TA, Allen HD, Gutgesell HP (eds): *Heart Disease in Infants, Children, and Adolescents-Including the Fetus and Young Adult*. Baltimore, MD, Williams and Wilkins, 1995, pp 398-439
9. Wernovsky G, Wypij D, Jonas RA, et al: Postoperative course and hemodynamic profile after the arterial switch operation in neonates and infants: A comparison of low-flow cardiopulmonary bypass versus circulatory arrest. *Circulation* 92:2226-2235, 1995
10. Hall SM, Haworth SG: Onset and evolution of pulmonary vascular disease in young children: Abnormal postnatal remodeling studied in lung biopsies. *J Pathol* 166:183-193, 1992
11. Yeager SB, Freed MD, Keane JF, et al: Primary surgical closure of ventricular septal defect in the first year of life: Results in 128 infants. *J Am Coll Cardiol* 3:1269-1276, 1984
12. Hanley FL, Heinemann MK, Jonas RA, et al: Repair of truncus arteriosus in the neonate. *J Thorac Cardiovasc Surg* 105:1047-1056, 1993
13. Wheller J, George BL, Mulder DG, Jarmakani JM: Diagnosis and management of postoperative pulmonary hypertensive crisis. *Circulation* 70:1640-1644, 1979
14. Del Nido PJ, Williams WG, Villamater J, et al: Changes in pericardial surface pressure during pulmonary hypertensive crises after cardiac surgery. *Circulation* 76:III-93-III-96, 1987
15. The Neonatal Nitric Oxide Study Group: Inhaled nitric oxide in full-term and nearly full-term infants with hypoxic respiratory failure. *N Engl J Med* 336:597-604, 1997
16. Roberts JD, Fineman JR, Morin FC, et al: Inhaled nitric oxide and persistent pulmonary hypertension of the newborn. *N Engl J Med* 336:605-610, 1997
17. Stark AR, Davidson D: Inhaled nitric oxide for persistent pulmonary hypertension of the newborn: Implications and strategy for future "high-tech" neonatal clinical trials. *Pediatrics* 96:1147-1151, 1995
18. Wessel DL, Adatia I, Giglia TM, et al: Use of inhaled nitric oxide and acetylcholine in the evaluation of pulmonary hypertension and endothelial function after cardiopulmonary bypass. *Circulation* 88(part I):2128-2138, 1993
19. Chang AC, Wernovsky G, Kulik TJ, et al: Management of the neonate with transposition of the great arteries and persistent pulmonary hypertension. *Am J Cardiol* 68:1253-1255, 1991
20. Luciani C, Chang A, Stames V: Surgical repair of transposition of the great arteries in neonates with persistent pulmonary hypertension. *Ann Thorac Surg* 61:800-805, 1996
21. Goldman AP, Delius RE, Deanfield JE, et al: Nitric oxide might reduce the need for extracorporeal support in children with critical postoperative pulmonary hypertension. *Ann Thorac Surg* 62:750-755, 1996
22. Adatia I, Lillehei C, Arnold JH, et al: Inhaled nitric oxide in the treatment of postoperative graft dysfunction after lung transplantation. *Ann Thorac Surg* 57:1311-1318, 1994
23. Date H, Triantafyllou A, Trulock E, et al: Inhaled nitric oxide reduces human lung allograft dysfunction. *J Thorac Cardiovasc Surg* 111:913-919, 1996
24. Bacha E, Herve P, Murakami S, et al: Lasting beneficial effects of short-term inhaled nitric oxide on graft function after lung transplantation. *J Thorac Cardiovasc Surg* 112:590-598, 1996
25. Kulik TJ, Moler FW, Palmisano JM, et al: Outcome-associated factors in pediatric patients treated with extracorporeal membrane oxygenator after cardiac surgery. *Circulation* 94:1163-1168, 1996
26. Ziomek S, Harrell JE, Fasules JW, et al: Extracorporeal membrane oxygenation for cardiac failure after congenital heart operation. *Ann Thorac Surg* 54:861-867, 1992
27. Journois D, Pouard P, Mauriat P, et al: Inhaled nitric oxide as a therapy for pulmonary hypertension after operations for congenital heart defects. *J Thorac Cardiovasc Surg* 107:1129-1135, 1994
28. Haworth SG: Total anomalous pulmonary venous return. Prenatal damage to pulmonary vascular bed and extrapulmonary veins. *Br Heart J* 48:513-524, 1982
29. Atz AM, Adatia I, Wessel DL: Rebound pulmonary hypertension after inhalation of nitric oxide. *Ann Thorac Surg* 62:1759-1764, 1996
30. Atz AM, Adatia I, Jonas RA, Wessel DL: Inhaled nitric oxide in children with pulmonary hypertension and congenital mitral stenosis. *Am J Cardiol* 77:316-319, 1996
31. Snow DJ, Gray SJ, Ghosh S, et al: Inhaled nitric oxide in patients with normal and increased pulmonary vascular resistance after cardiac surgery. *Br J Anaesth* 72:185-189, 1994
32. Rich GF, Murphy GD, Roos CM, Johns RA: Inhaled nitric oxide. Selective pulmonary vasodilation in cardiac surgical patients. *Anesthesia* 78:1028-1035, 1993
33. Newfeld EA, Wilson A, Paul MH, Reich JS: Pulmonary vascular disease in total anomalous pulmonary venous drainage. *Circulation* 61:103-109, 1980
34. Haworth SG, Reid L: Structural study of pulmonary circulation and of heart in total anomalous pulmonary venous return in early infancy. *Br Heart J* 39:80-92, 1977
35. Ferencz C, Dammann JF: Significance of the pulmonary vascular bed in congenital heart disease. *Circulation* 16:1046-1056, 1957
36. Adatia I, Perry S, Landzberg M, et al: Inhaled nitric oxide and hemodynamic evaluation of patients with pulmonary hypertension before transplantation. *J Am Coll Cardiol* 25:1656-1664, 1995

37. Curran R, Mavroudis C, Backer C, et al: Inhaled nitric oxide for children with congenital heart disease and pulmonary hypertension. *Ann Thorac Surg* 60:1765-1771, 1995
38. Beghetti M, Habre W, Friedli B, Berner M: Continuous low dose inhaled nitric oxide for treatment of severe pulmonary hypertension after cardiac surgery in paediatric patients. *Br Heart J* 73:65-68, 1995
39. Miller OI, Celermajer DS, Deanfield JE, Macrae DJ: Very low dose inhaled nitric oxide: A selective pulmonary vasodilator after operations for congenital heart disease. *J Thorac Cardiovasc Surg* 108:487-494, 1994
40. Yahagi N, Kumon K, Tanigami H: Inhaled nitric oxide for the postoperative management of Fontan-type operations. *Ann Thorac Surg* 57:1371-1372, 1994
41. Tibballs J: Clinical applications of gaseous nitric oxide. *Anaesth Intens Care* 21:866-871, 1993
42. Parker TA, Ivy DD, Kinsella JP, et al: Combined therapy with inhaled nitric oxide and intravenous prostacyclin in an infant with alveolar-capillary dysplasia. *Am J Respir Crit Care Med* 155:743-746, 1997
43. Schranz D, Huth R, Wippermann CF, et al: Nitric oxide and prostacyclin lower suprasystemic pulmonary hypertension after cardiopulmonary bypass. *Eur J Pediatr* 152:793-796, 1993
44. Ivy DD, Kinsella JP, Wolfe RR, Abman SH: Atrial natriuretic peptide and nitric oxide in children with pulmonary hypertension after surgical repair of congenital heart disease. *Am J Cardiol* 77:102-105, 1996
45. Kinsella JP, Torielli F, Ziegler JW, et al: Dipyrimadole augmentation of response to nitric oxide. *Lancet* 346:647-648, 1995
46. Fullerton DA, Jagers J, Piedalue F, et al: Effective control of refractory pulmonary hypertension after cardiac operations. *J Thorac Cardiovasc Surg* 113:363-368, 1997
47. Atz AM, Adatia I, Wessel DL: Inhaled nitric oxide in shunted single ventricle patients. *Circulation* 92:I-53-I-54, 1995
48. Adatia I, Thompson J, Wessel DL: Inhaled nitric oxide and hypoxemia after bidirectional Glenn operation. *Circulation* 88:A1798, 1993
49. Goldman AP, Delius RE, Deanfield JE, et al: Pharmacologic control of pulmonary blood flow with inhaled nitric oxide after the fenestrated Fontan operation. *Circulation* 94:II-44-II-48, 1996(suppl 2)
50. Garg U, Hassid A: Nitric oxide-generating vasodilators and 8-bromo-cyclic guanosine monophosphate inhibit mitogenesis and proliferation of cultured rat vascular smooth muscle cells. *J Clin Invest* 83:1774-1777, 1989
51. Kouyoumdjian C, Adnot S, Levame M, et al: Continuous inhalation of nitric oxide protects against development of pulmonary hypertension in chronically hypoxic rats. *J Clin Invest* 94:578-584, 1994
52. Roberts J, Roberts C, Jones R, et al: Continuous nitric oxide inhalation reduces pulmonary arterial structural changes, right ventricular hypertrophy, and growth retardation in the hypoxic newborn rat. *Circ Res* 76:215-222, 1995
53. Kolpakov V, Gordon D, Kulik T: Nitric oxide-generating compounds inhibit total protein and collagen synthesis in cultured vascular smooth muscle cells. *Circ Res* 76:305-309, 1995
54. Assreuy J, Cunha FQ, Liew FY, Moncada S: Feedback inhibition of nitric oxide synthase activity by nitric oxide. *Eur J Pharmacol* 108:833-837, 1993
55. Ravichandran LV, Johns RA, Rengasamy A: Direct and reversible inhibition of endothelial nitric oxide synthase by nitric oxide. *Am J Physiol* 268:H2216-H2223, 1995
56. Buga GM, Griscavage JM, Rogers NE, Ignarro LJ: Negative feedback regulation of endothelial cell function by nitric oxide. *Circ Res* 73:808-812, 1993
57. Gerlach H, Rossaint R, Pappert D, et al: Autoinhalation of nitric oxide after endogenous synthesis in nasopharynx. *Lancet* 343:518-519, 1994
58. Packer M, Meller J, Medina N, et al: Rebound hemodynamic events after the abrupt withdrawal of nitroprusside in patients with severe chronic heart failure. *N Engl J Med* 301:1193-1197, 1979
59. Grover R, Murdoch I, Smithies M, et al: Nitric oxide during hand ventilation in patient with acute respiratory failure. *Lancet* 340:1038-1039, 1992 (letter)
60. Miller O, Tang S, Keech A, Celermajer D: Rebound pulmonary hypertension on withdrawal from inhaled nitric oxide. *Lancet* 346:51-52, 1995
61. Lavoie A, Hall JB, Olson DM, Wylam ME: Life-threatening effects of discontinuing inhaled nitric oxide in severe respiratory failure. *Am J Respir Crit Care Med* 153:1985-1987, 1996
62. Bocchi EA, Bacal F, Auler JOC, et al: Inhaled nitric oxide leading to pulmonary edema in stable severe heart failure. *Am J Cardiol* 74:70-74, 1994
63. Hare JM, Shernan SK, Body SC, et al: Influence of inhaled nitric oxide on systemic flow and ventricular filling pressure in patients receiving mechanical circulatory assistance. *Circulation* 95:2250-2253, 1997
64. Henrichsen T, Goldman AP, Macrae DJ: Inhaled nitric oxide can cause severe systemic hypotension. *J Pediatr* 129:183, 1996
65. Wessel DL, Adatia I, Van Marter LJ, et al: Improved oxygenation in a randomized trial of inhaled nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics* 1997(in press)
66. Wessel DL, Adatia I, Thompson JE, Hickey PR: Delivery and monitoring of inhaled nitric oxide in patients with pulmonary hypertension. *Crit Care Med* 22:930-938, 1994
67. Day R, Lynch J, Shaddy R, Orsmond G: Pulmonary vasodilatory effects of 12 and 60 parts per million inhaled nitric oxide in children with ventricular septal defect. *Am J Cardiol* 75:196-198, 1995
68. Roberts JD, Lang P, Bigatello LM, et al: Inhaled nitric oxide in congenital heart disease. *Circulation* 87:447-453, 1993
69. Gerlach H, Rossaint D, Pappert D, Falke KJ: Time-course and dose-response of nitric oxide inhalation for systemic oxygenation and pulmonary hypertension in patients with adult respiratory distress syndrome. *Euro J Clin Invest* 23:499-502, 1993
70. Betit P, Adatia I, Benjamin P, et al: Inhaled nitric oxide: Evaluation of a continuous titration delivery technique developed for infant mechanical ventilation and manual ventilation. *Respir Care* 40:706-715, 1995
71. Kinsella JP, Abman SH: Methaemoglobin during nitric oxide therapy with high-frequency ventilation. *Lancet* 342:615, 1993
72. Lindberg L, Rydgren G, Larsson A, et al: A delivery system for inhalation of nitric oxide evaluated with chemiluminescence, electrochemical fuel cells, and capnography. *Crit Care Med* 25:190-196, 1997

Pulmonary Hypertension

Combined Effects of Nitric Oxide and Oxygen During Acute Pulmonary Vasodilator Testing

Andrew M. Atz, MD, Ian Adatia, FRCP(C), James E. Lock, MD, FACC, David L. Wessel, MD
Boston, Massachusetts

- OBJECTIVES** We compared the ability of inhaled nitric oxide (NO), oxygen (O₂) and nitric oxide in oxygen (NO+O₂) to identify reactive pulmonary vasculature in pulmonary hypertensive patients during acute vasodilator testing at cardiac catheterization.
- BACKGROUND** In patients with pulmonary hypertension, decisions regarding suitability for corrective surgery, transplantation and assessment of long-term prognosis are based on results obtained during acute pulmonary vasodilator testing.
- METHODS** In group 1, 46 patients had hemodynamic measurements in room air (RA), 100% O₂, return to RA and NO (80 parts per million [ppm] in RA). In group 2, 25 additional patients were studied in RA, 100% O₂ and 80 ppm NO in oxygen (NO+O₂).
- RESULTS** In group 1, O₂ decreased pulmonary vascular resistance (PVR) (mean ± SEM) from 17.2 ± 2.1 U·m² to 11.1 ± 1.5 U·m² (p < 0.05). Nitric oxide caused a comparable decrease from 17.8 ± 2.2 U·m² to 11.7 ± 1.7 U·m² (p < 0.05). In group 2, PVR decreased from 20.1 ± 2.6 U·m² to 14.3 ± 1.9 U·m² in O₂ (p < 0.05) and further to 10.5 ± 1.7 U·m² in NO+O₂ (p < 0.05). A response of 20% or more reduction in PVR was seen in 22/25 patients with NO+O₂ compared with 16/25 in O₂ alone (p = 0.01).
- CONCLUSIONS** Inhaled NO and O₂ produced a similar degree of selective pulmonary vasodilation. Our data suggest that combination testing with NO+O₂ provides additional pulmonary vasodilation in patients with a reactive pulmonary vascular bed in a selective, safe and expeditious fashion during cardiac catheterization. The combination of NO+O₂ identifies patients with significant pulmonary vasoreactivity who might not be recognized if O₂ or NO were used separately. (J Am Coll Cardiol 1999;33:813-9) © 1999 by the American College of Cardiology

Elevated pulmonary vascular resistance (PVR) complicates the evaluation, clinical course and outcome of patients with congenital heart disease or end-stage pulmonary disease. It is a crucial factor in determining the timing or type of intervention, and has been invoked as the primary determinant of mortality in many lesions (1,2). Opinion varies on what resistance must be achieved with vasodilator testing to insure safe operability for children with congenital heart disease. An increased or fixed elevation in PVR may deny patients the chance of corrective surgery, leaving them susceptible to the development of progressive obliterative pulmonary vascular disease and reduced life expectancy (3,4). Demonstration of pulmonary vasoreactivity in patients with end-stage pulmonary disease may differentiate

patients who would benefit from long-term medical therapy (5,6) from those with high, fixed resistance who should be more urgently considered for lung transplantation (3). Safe and expeditious demonstration of maximal pulmonary vasodilation in patients with a reactive pulmonary bed is therefore an important objective.

Many vasodilators have been utilized for diagnostic testing during cardiac catheterization. Systemic vasodilators with their attendant risks of hypotension and increased intrapulmonary shunt may be hazardous (7), especially in patients with ventricular outflow tract obstruction. Breathing oxygen (O₂) remains a standard means of pulmonary vasodilator testing in pediatric cardiac catheterization laboratories (8,9). However, failure to respond to acute treatment with O₂ has been reported in some patients who did indeed have reactive pulmonary vasculature (3,10).

Inhaled nitric oxide (NO) is a selective pulmonary vasodilator with minimal systemic effects and does not increase intrapulmonary shunting. It can be administered easily with O₂ or room air (RA) during cardiac catheterization by either ventilator or mask. The purpose of this study was to compare the ability of NO and O₂ to identify patients with a reactive pulmonary vascular bed during cardiac catheter-

From the Department of Cardiology, Children's Hospital, and the Department of Pediatrics, Harvard Medical School, Boston, Massachusetts. Dr. Atz is supported by an award from the National Institutes of Child Health and Human Development and a grant from the United States Food and Drug Administration. Dr. Wessel is supported by grants from the United States Food and Drug Administration and the Research Endowment of Children's Hospital. Presented in part at the 45th Annual Scientific Sessions of the American College of Cardiology, Orlando, Florida, March 1996.

Manuscript received April 10, 1998; revised manuscript received September 18, 1998, accepted October 30, 1998.

Abbreviations and Acronyms	
FiO ₂	= fraction of inspired oxygen
NO	= nitric oxide
NO ₂	= nitrogen dioxide
O ₂	= oxygen
PaCO ₂	= partial pressure of carbon dioxide, arterial
PCO ₂	= partial pressure of carbon dioxide
ppm	= parts per million
PVR	= pulmonary vascular resistance
RA	= room air

ization. We further compared the hemodynamic effects of breathing nitric oxide in oxygen (NO+O₂) to breathing O₂ alone during acute vasodilator testing.

METHODS

We enrolled patients between January 1992 and December 1996 who had mean pulmonary artery pressure ≥30 mm Hg, PVR >3 U·m², and were determined during catheterization to require vasodilator testing. We included for analysis 71 patients who had complete hemodynamic measurements to allow calculation of vascular resistances.

Study groups. The first 46 patients (group 1) were studied under the following four study conditions: A) in RA; B) after breathing 100% O₂ for 15 min; C) after another 15 min in RA, and D) after 15 min breathing NO at 80 parts per million (ppm) in 23% O₂ (NO+RA). As NO is titrated into a delivery circuit, the delivered fraction of inspired O₂ (FiO₂) is decreased. Therefore a small amount of supplemental O₂ (23%) was added to NO to avoid administration of a hypoxic gas mixture. The patients in group 1 had a median age of 6.5 years, range 4 months to 59 years.

Twenty-five additional patients (group 2) were studied in the following three conditions: A) in RA; B) after breathing 100% O₂ for 15 min, and C) after 15 min of inhaling 80 ppm NO in 91% O₂. This was the maximal FiO₂ attainable after dilution with 80 ppm of NO. Patients in group 2 had a median age of 3.5 years, range 5 months to 69 years.

The patients in each group represented a broad spectrum of diagnoses characteristic of a high volume pediatric cardiac catheterization laboratory. Most had unrepaired or previously palliated congenital heart disease, although some had end-stage pulmonary disease (Tables 1 and 2). Four of 46 patients in group 1 and three of 25 patients in group 2 were mechanically ventilated. The remainder in each group were breathing spontaneously. Sedation was given according to a routine, which included intravenous morphine and midazolam. Partial pressure of carbon dioxide (PCO₂) was normal throughout the study in both groups.

Hemodynamic assessment. Hemodynamic measurements included left atrial, right atrial, pulmonary and systemic arterial pressures during each of the conditions described above. Cardiac output was measured by thermodilution in patients without an intracardiac shunt. In those with shunts, O₂ consumption was measured (Waters Inc., model MM20, Rochester, Minnesota), and systemic and pulmonary blood flows were calculated using the Fick equation with inclusion of dissolved O₂. Errors related to sampling site variances were minimized by ensuring that, for each patient, venous samples were collected at the same site during each of the study conditions.

Delivery and monitoring of NO. Detailed descriptions of the technical aspects of our delivery of NO in both ventilated and spontaneously breathing patients have been published previously (11,12). We used NO gas (Scott Specialty Gases, Plumsteadville, Pennsylvania or BOC Gases, Murray Hill, New Jersey) of medical grade quality, which

Table 1. Diagnoses of Patients in Group 1 (n = 46)

Unrepaired Heart Disease (n = 26)		Repaired Heart Disease (n = 14)		Lung Pathology (n = 6)	
	n		n		n
VSD	5(1)	Complex single ventricle postpalliation	4(1)	Pulmonary emboli	3(2)
CAVC	5	TGA post Senning	3(1)	Restrictive lung disease (lupus)	1
Shone's syndrome	5	TGA/VSD post PAB	2	Primary pulmonary hypertension	1
PDA	2	TGA post Mustard	1	Cystic fibrosis	1
Cardiomyopathy	2	TGA post ASO	1(1)		
VSD with PDA	1	CAVC repair	1		
Truncus arteriosus	1	TOF/PA full repair	1		
ASD primum	1	ASD secundum	1		
ASD secundum with PDA	1				
Supracardiac TAPVC	1				
ASD secundum	1				
TGA/VSD	1				

In parentheses is the number of patients who did not respond to either oxygen or nitric oxide.

ASD = atrial septal defect; ASO = arterial switch operation; CAVC = complete atrioventricular canal; PAB = pulmonary artery band; PDA = patent ductus arteriosus; Shone's syndrome = multiple left-sided obstructive lesions; TAPVC = total anomalous pulmonary venous connection; TGA = transposition of the great arteries; TOF/PA = tetralogy of Fallot with pulmonary atresia; VSD = ventricular septal defect.

Table 2. Diagnoses of Patients in Group 2 (n = 25)

Unrepaired Heart Disease (n = 19)		Repaired Heart Disease (n = 3)		Lung Pathology (n = 3)	
	n		n		n
VSD	5	PDA	1	COPD	1(1)
CAVC	1	TAPVC with PV stenosis	1(1)	Primary pulmonary hypertension	1
Shone's syndrome	3	TOF/PA	1	Pulmonary emboli	1
PDA	1				
ASD secundum	4(1)				
VSD with mitral stenosis	2				
VSD with coarctation	1				
ASD primum	1				
Cardiomyopathy	1				

In parentheses is the number of patients who did not respond to either oxygen or nitric oxide in oxygen.
 COPD = chronic obstructive pulmonary disease; PV = pulmonary vein; other abbreviations as in Table 1.

conformed to Food and Drug Administration standards. In the spontaneously breathing individuals NO was delivered using the titration technique from source tanks with an 800-ppm concentration. Flow rates greater than the patients' minute volumes were delivered through a one-way inspiratory valve to a face mask. The expired gases were scavenged using a reservoir bag and regulated wall suction. In the seven patients who were mechanically ventilated, ventilator settings were kept constant throughout the study. Nitric oxide, nitrogen dioxide (NO₂) and FiO₂ were continuously monitored from a sampling port at the airway (Thermoenvironmental Instruments Chemiluminescence model 42H, Franklin, Massachusetts or NOxBOX Electrochemical Inhaled NO Therapy Monitor, Bedford Scientific USA, Medford, New Jersey). Peak measured NO₂ concentrations were recorded in all patients during delivery of the drug. Because there were no reports of methemoglobinemia during 15-min diagnostic trials of NO at 80 ppm (11), we eventually ceased to routinely measure methemoglobin levels during brief inhalations. Therefore, methemoglobin levels were obtained by coximetry (CIBA-Corning model 2500, Medfield, Massachusetts) after 15 min in the first 22 of 46 patients in group 1 and not thereafter. Written informed consent was obtained from the patients or their parents under a protocol approved by the Clinical Investigation Committee of Children's Hospital and submitted to the Food and Drug Administration.

Statistical analysis and calculations. Results are presented as mean values ± SEM. Vascular resistances were calculated using standard equations and were expressed in Wood units corrected for body surface area (U·m²). Groups 1 and 2 were analyzed separately with patients in each group acting as their own controls. Repeated measures analysis of variance was used to look for differences in the measurements over the four study conditions in group 1 and the three conditions in group 2. If differences were found, then the Bonferroni multiple comparisons procedure was used to determine where differences existed. A p value <0.05 was considered significant.

RESULTS

Group 1: comparison of RA, O₂, RA and NO+RA.

Pulmonary vascular resistance differed across the four conditions, (p < 0.0001) (Table 3). Oxygen decreased PVR from 17.2 ± 2.1 U·m² to 11.1 ± 1.5 U·m² (p < 0.05). Administration of inhaled NO at 80 ppm in RA caused a comparable decrease from 17.8 ± 2.2 U·m² to 11.7 ± 1.7 U·m² (p < 0.05) (Fig. 1). Comparison of the mean percentage decreases from RA to O₂ (36.9 ± 3.3%) and RA to NO+RA (35.1 ± 3.5%) revealed no difference by paired t test. Changes in pulmonary artery pressures may not reflect pulmonary vasodilation, because there were patients with intracardiac shunts. Nevertheless, the mean pulmonary artery pressure was significantly lower in both O₂ and NO+RA compared with RA despite increases in pulmonary blood flow in 21 of 23 patients with intracardiac shunts during treatment.

Mean systemic arterial pressure, systemic vascular resistance, right atrial pressure, left atrial pressure, heart rate, pH and PCO₂ did not change with administration of O₂ or NO. Arterial PCO₂ (PaO₂) increased from 66 ± 3 mm Hg in RA to 78 ± 23 mm Hg with 100% O₂; however, there was no significant difference in PaO₂ between RA and NO+RA (68 ± 4 vs. 73 ± 4 mm Hg).

Using a reduction in PVR of 20% or more as a marker for responsiveness, we compared individual patient results to O₂ and NO+RA (Fig. 2). Oxygen caused a positive response in 36/46 patients. Of the 10 nonresponders, four responded with a 20% or more decrease to NO. Nitric oxide in RA caused a positive response in 32/46. Of the 14 nonresponders to NO+RA, eight responded to O₂. Six patients did not respond to either vasodilator (Table 1).

The peak NO₂ level was recorded in all 46 patients and was 1.3 ± 0.2 ppm. Methemoglobin measured at the conclusion of the 15-min period of NO inhalation in 22/46 patients was 0.8 ± 0.1%.

Group 2: comparison of RA, O₂ and NO+O₂.

Pulmonary vascular resistance differed across the three conditions (p < 0.0001) (Table 4). Pulmonary vascular resistance

Table 3. Hemodynamic Data for Group 1

Variable (mean ± SEM)	A: RA	B: Oxygen	C: RA	D: NO+RA	ANOVA p Value
PVR (U·m ²)	17.2 ± 2.1	11.1 ± 1.5	17.8 ± 2.2	11.7 ± 1.7	< 0.0001*†
mPAp (mm Hg)	62.7 ± 3.3	54.9 ± 3.1	60.9 ± 3.4	51.2 ± 3.0	< 0.0001*†
LAp (mm Hg)	13.7 ± 0.8	14.6 ± 1.0	14.0 ± 0.9	14.9 ± 1.1	0.05
CI (liters/min/m ²)	3.6 ± 0.3	3.2 ± 0.2	3.5 ± 0.2	3.3 ± 0.2	0.19
RAp (mm Hg)	9.0 ± 0.5	9.1 ± 0.5	8.8 ± 0.5	8.4 ± 0.5	0.08
MAP (mm Hg)	79.2 ± 2.3	81.0 ± 2.3	79.5 ± 2.6	79.4 ± 2.6	0.55
SVR (U·m ²)	24.2 ± 1.8	25.7 ± 1.6	24.2 ± 1.8	24.8 ± 1.7	0.33
pH	7.36 ± 0.01	7.36 ± 0.01	7.35 ± 0.01	7.35 ± 0.01	0.43
Pco ₂	41.6 ± 1.1	41.2 ± 1.0	41.8 ± 1.1	43.0 ± 1.2	0.07
Po ₂	65.6 ± 2.7	277.6 ± 23.2	68.1 ± 3.6	73.5 ± 3.5	< 0.0001*
Heart rate	108 ± 4	107 ± 4	104 ± 5	105 ± 5	0.24

*Variable in oxygen (B) is different than in room air (A) ($p < 0.05$). †Variable in nitric oxide (D) is different than in room air (C) ($p < 0.05$).

ANOVA = analysis of variance; CI = cardiac index; LAp = left atrial pressure; MAP = mean arterial blood pressure; mPAp = mean pulmonary artery pressure; Pco₂ = partial pressure of carbon dioxide; Po₂ = partial pressure of oxygen; PVR = pulmonary vascular resistance; RA = room air; RAp = right atrial pressure; SVR = systemic vascular resistance.

decreased from 20.1 ± 2.6 U·m² in RA to 14.3 ± 1.9 U·m² in O₂ and further to 10.5 ± 1.7 U·m² in NO+O₂ (Fig. 3). Pulmonary vascular resistance was significantly lower in O₂ compared to RA ($p < 0.05$). The PVR with combination therapy was statistically lower than that measured in air or in O₂ ($p < 0.05$ for both). Oxygen caused a reduction in PVR from baseline of 20% or more in 16 of 25 patients. Of the remaining nine patients, six responded with a 20% or more decrease when inhaling NO+O₂. Three patients did not have a positive response to either O₂ or the combination of O₂ and NO (see Table 2). Using the McNemar's test, if responsiveness differed between the two treatments, patients were more likely to respond to NO+O₂ than to O₂ alone ($p = 0.01$). Ten of the 25 patients underwent complete surgical repair of their cardiac defects within 1 month of their catheterization. Those 10 patients had a baseline PVR in RA of 12.9 ± 1.9 U·m² that decreased to 7.1 ± 1.9 U·m² in O₂ and to 4.1 ± 1.9 U·m² in NO+O₂. Each patient undergoing surgical repair had a baseline PVR in RA >6 U·m². Five of 10 had PVR >6 U·m² in O₂, but only one had PVR >6 U·m² in NO+O₂. All 10 patients survived

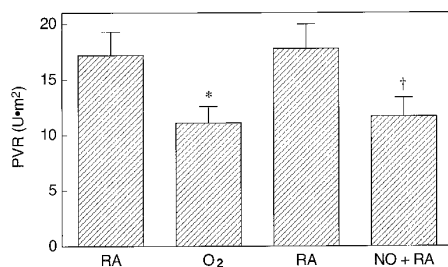


Figure 1. Pulmonary vascular resistance (PVR) (mean ± SE) differed across the four study conditions in group 1 ($p < 0.0001$); PVR was lower in oxygen (O₂) compared with room air (RA) (*) and was lower in nitric oxide in RA (NO+RA) compared with RA (†) ($p < 0.05$ for both).

and were discharged home on median postoperative day 5.5, range 4 to 29.

Mean pulmonary artery pressure decreased from 63.4 ± 3.7 mm Hg in RA to 57.7 ± 3.5 mm Hg in O₂ to 50.6 ± 3.5 mm Hg in NO+O₂. This occurred despite an increase in pulmonary blood flow in 13 of 15 patients with shunts. The pulmonary artery pressure with NO+O₂ was significantly lower than that measured in air or in O₂ ($p < 0.05$ for both). There was no difference between left atrial pressure in RA and in O₂. Left atrial pressure was significantly higher in NO+O₂ (15.5 ± 1.3 mm Hg) than in RA (13.1 ± 1.1 mm Hg) or O₂ (12.7 ± 1.0 mm Hg).

Mean systemic blood pressure increased over the three study conditions, from 76.8 ± 2.9 mm Hg in RA to 80.6 ± 2.5 mm Hg in O₂ to 83.4 ± 2.6 mm Hg in NO+O₂. Blood pressure was significantly higher in NO+O₂ than in RA, but not statistically different from blood pressure in O₂. Cardiac index, systemic vascular resistance, right atrial pressure, heart rate, pH and Pco₂ did not change. Arterial

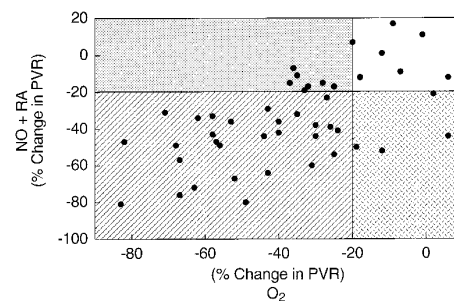


Figure 2. Individual patients' percentage change in PVR with O₂ is plotted against percentage change in PVR with NO+RA. Using a 20% decrease in PVR as a marker for responsiveness, some patients responded to one drug only. Neither O₂ nor NO+RA identified all patients with pulmonary vasoreactivity. Abbreviations as in Figure 1.

Table 4. Hemodynamic Data for Group 2

Variable (mean ± SEM)	A: RA	B: Oxygen	C: NO+O ₂	ANOVA p Value
PVR (U·m ²)	20.1 ± 2.6	14.3 ± 1.9	10.5 ± 1.7	< 0.0001*†‡
mPAp (mm Hg)	63.4 ± 3.7	57.7 ± 3.5	50.6 ± 3.5	0.0002†‡
LAp (mm Hg)	13.1 ± 1.1	12.7 ± 1.0	15.5 ± 1.3	0.002†‡
CI (liter/min/m ²)	3.1 ± 0.3	3.2 ± 0.3	3.2 ± 0.3	0.93
RAp (mm Hg)	8.0 ± 0.7	8.3 ± 0.8	8.4 ± 0.7	0.78
MAP (mm Hg)	76.8 ± 2.9	80.6 ± 2.5	83.4 ± 2.6	0.004‡
SVR (U·m ²)	26.8 ± 2.7	28.1 ± 2.6	29.8 ± 3.0	0.34
pH	7.38 ± 0.01	7.36 ± 0.01	7.36 ± 0.01	0.08
Pco ₂	38.8 ± 1.2	39.7 ± 1.5	40.5 ± 1.7	0.27
Po ₂	67.3 ± 3.9	277.6 ± 30.4	302.8 ± 27.9	< 0.0001*†
Heart rate	108 ± 4	107 ± 4	105 ± 5	0.58

*Variable in oxygen (B) is different than in room air (A) (p < 0.05). †Variable in NO+O₂ (C) is different than in oxygen (B) (p < 0.05). ‡Variable in NO+O₂ (C) is different than in room air (A) (p < 0.05). Abbreviations as in Table 3.

partial pressure of O₂ was significantly higher both in O₂ and in NO+O₂ as compared with RA. Arterial partial pressure of O₂ was not different in NO+O₂ compared with O₂ (302.8 ± 27.9 vs. 277.6 ± 30.4 mm Hg). The peak NO₂ level during NO delivery was 2.3 ± 0.3 ppm.

DISCUSSION

We compared the inhaled vasodilators O₂ and NO in 71 patients during acute vasodilator testing at cardiac catheterization. In 46 patients, 100% O₂ and inhaled NO at 80 ppm in air produced comparable and selective decreases in mean pulmonary artery pressure and PVR. However, O₂ or NO used separately failed to identify all patients with a significant capacity for pulmonary vasodilation. The combination of NO (80 ppm) with 91% O₂ in an additional group of 25 patients produced significantly more pulmonary vasorelaxation compared with O₂ used alone. In 22/25 patients there was a positive pulmonary vasodilator response during combination therapy compared to only 16/25 when breathing O₂ alone. None of the 71 patients studied showed any evidence of toxicity from either drug during the brief period of this diagnostic trial. Our data suggest that combination

testing with NO in O₂ provides additional pulmonary vasodilation, can be safely and accurately delivered to patients during diagnostic cardiac catheterization and can rapidly identify patients with pulmonary vasoreactivity. The combination of agents appears to identify patients with significant pulmonary vasoreactivity who might not be recognized if O₂ or NO were used separately.

Importance of vasodilator testing. The precise stage when pulmonary vascular disease has progressed to a point where surgical repair of congenital heart lesions cannot be safely performed is unknown. Morphologic criteria (2) and pulmonary hemodynamics (13) are useful, but imprecise. Pulmonary vascular resistance calculated to be more than 6 to 8 U·m² has been shown to be associated with poor operative outcome regardless of lung histology (1,4,14). In contrast, patients who respond to vasodilators with a PVR less than 6 to 8 U·m² do well postoperatively (13). Demonstration of a reactive pulmonary bed in patients being evaluated for transplantation has enabled patients to be offered a single organ heart instead of heart-lung block with successful results (15). Patients with elevated resistance but reactive pulmonary vasculature may need more intensive postoperative care and presumably would be excellent candidates for NO therapy in the postoperative period should pulmonary hypertension emerge. Response to acute vasodilator testing in patients with primary pulmonary hypertension is an important marker for survival (3) and may identify patients who would benefit from chronic medical therapy (5,6).

Comparison with other studies. Prior research in children with pulmonary hypertension has shown that O₂ failed to unmask all reversible pulmonary vasoconstriction (3,10). Prostacyclin administration in patients with pulmonary hypertension breathing O₂ caused further pulmonary vasodilation. However, prostacyclin can cause systemic side effects including tachycardia and hypotension (16). Previous studies of vasoreactivity in children during cardiac catheterization found variable responsiveness to NO that seemed to

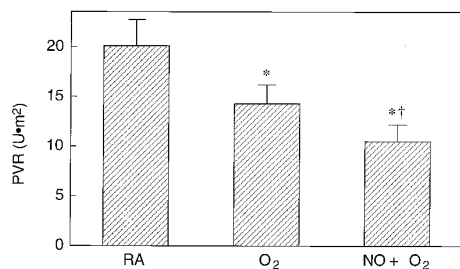


Figure 3. Pulmonary vascular resistance (mean ± SE) differed across the three study conditions in group 2 (p < 0.0001); PVR was lower in O₂ compared with RA (*) and was lower in NO+O₂ compared with RA (*) and O₂ (†) (p < 0.05 for all comparisons). Abbreviations as in Figure 1.

parallel the progression of established vascular disease (17). Studies examining the efficacy of NO in O₂, including recent work by Allman and colleagues, have suggested differences between the responses to NO, O₂ and/or the combination of agents (18-20). Each prior study, however, has had insufficient power to establish a significant difference in PVR.

Nitric oxide causes vasorelaxation through a cyclic guanosine monophosphate-mediated pathway. The mechanism of vasorelaxation caused by O₂ is not clearly known (21). The fact that some patients responded to one agent with significant vasodilation but not the other, and that the majority of patients experienced increased vasodilation with combination therapy compared with O₂ alone, suggests that the mechanisms may not be identical.

Potential toxicities. The major recognized toxicities associated with inhaling NO are cytotoxic effects in the lung due to exposure to excess NO₂ and methemoglobinemia due to the intravascular binding to hemoglobin. Nitrogen dioxide will develop in delivery systems at a rate that is proportional to NO and O₂ concentrations and contact times between the two gases. When NO was delivered with maximal amounts of O₂ in this study, NO₂ levels averaged 2.3 ± 0.3 ppm, below the accepted environmental exposure level of 5 ppm (22). Nitrogen dioxide should be continuously monitored, especially in patients mechanically ventilated with circuits that do not use continuous gas flows. If patients receive prolonged treatment with NO in high concentrations of O₂, we recommend reduction in the NO dose to diminish potential dose-related toxicity. There have been no reports of clinically significant methemoglobinemia during brief exposure to NO at doses as high as 80 ppm. Methemoglobin measured at the conclusion of the 15-min period of NO inhalation in 22/46 patients was $0.8 \pm 0.1\%$. This along with previously published results (11) supports the contention that routine measurement of methemoglobin may be unnecessary during brief diagnostic trials of NO.

It is notable that the combination of NO in O₂ resulted in an increase in left atrial pressure compared with RA or O₂ alone. Reports have suggested that O₂ (23) or NO (24) may have deleterious effects to patients with heart failure. In this study no patient demonstrated clinically important pulmonary edema, hemodynamically significant systemic vasoconstriction or decreased cardiac index during the brief administration of O₂ or NO in O₂. Nevertheless, we believe that NO, especially when used with O₂, should be carefully monitored in patients with elevated left atrial pressures due to the potential induction of pulmonary edema.

Study limitations. The patient population studied was quite heterogeneous. However, this accurately reflects the typical spectrum of patients presenting for vasodilator testing during cardiac catheterization. Subgroup analysis of patients with congenital heart disease showed no differences in response compared to the group as a whole. Patients with lung pathology analyzed separately showed similar results, but numbers were too small to form conclusions. Subgroup

analysis of patients with left to right shunts did not reveal any difference in response compared to those without shunts. The definition of responder and nonresponder is arbitrary, but a 20% change is often used in drug testing as a marker of responsiveness. There was no apparent predictive marker in patients who responded to one agent but not the other. It may be that repeated exposure to O₂ or NO would minimize differences between responders and nonresponders. Nonetheless, a single exposure to a drug is the common catheterization protocol. Limited information exists concerning optimal dosing of NO, with some investigators showing maximal vasodilation at doses as low as 2 ppm (19), and others demonstrating a dose-response relationship up to 80 ppm in a similar population (18). This study was designed as a brief diagnostic trial in a catheterization laboratory to determine the most effective and inclusive method of identifying patients with pulmonary vasoreactivity. Accordingly, 80 ppm was used during this brief testing with the appreciation that, if delivered for prolonged periods, it may be associated with dose-related increased toxicity. This study was not designed to demonstrate differences in long-term patient outcomes or clinical value of vasodilator testing. Maximal vasodilatory capacity may be of limited clinical value in some patients. Nevertheless, as a result of information acquired during combination therapy, some patients were offered surgery who did not respond to NO or O₂ alone; all patients survived.

Summary. Individually, NO and O₂ produced significant and comparable selective pulmonary vasodilation in a heterogeneous group of patients presenting to cardiac catheterization for pulmonary vasodilator testing. However, neither agent used separately identified all patients with the capacity to relax their pulmonary vascular bed. The combination of NO+O₂ caused significantly greater pulmonary vasodilation compared to O₂ and identified patients who had pulmonary vasoreactivity that was not appreciated during O₂ breathing alone. This study suggests that combination testing with NO+O₂ provides additional pulmonary vasodilation in patients with a reactive pulmonary vascular bed in a specific, safe and expeditious fashion during cardiac catheterization. Nitric oxide in O₂ distinguishes patients with significant pulmonary vasoreactivity who might not be identified using either agent separately.

Acknowledgments

We are grateful to John F. Keane, MD for his critical review of the manuscript and to Kimberlee Gauvreau, ScD for her expert assistance with statistical analysis.

Reprint requests and correspondence: Dr. David L. Wessel, Cardiac ICU Office, Farley 653, Children's Hospital, 300 Longwood Avenue, Boston, Massachusetts 02115. E-mail: wessel@a1.tch.harvard.edu.

REFERENCES

- Hoffman JI, Rudolph AM, Heymann MA. Pulmonary vascular disease with congenital heart lesions: pathologic features and causes. *Circulation* 1981;64:873-7.
- Rabinovitch M, Haworth SG, Castaneda AR, Nadas AS, Reid LM. Lung biopsy in congenital heart disease: a morphometric approach to pulmonary vascular disease. *Circulation* 1978;58:1107-22.
- Houde C, Bohn DJ, Freedom RM, Rabinovitch M. Profile of paediatric patients with pulmonary hypertension judged by responsiveness to vasodilators. *Br Heart J* 1993;70:461-8.
- Bush A, Busst CM, Haworth SG, et al. Correlations of lung morphology, pulmonary vascular resistance, and outcome in children with congenital heart disease. *Br Heart J* 1988;59:480-5.
- Raffy O, Azarian R, Brenot F, et al. Clinical significance of the pulmonary vasodilator response during short-term infusion of prostacyclin in primary pulmonary hypertension. *Circulation* 1996;93:484-8.
- Rich S, Kaufmann E, Levy PS. The effect of high doses of calcium-channel blockers on survival in primary pulmonary hypertension. *N Engl J Med* 1992;327:76-81.
- Packer M. Vasodilator therapy for primary pulmonary hypertension. *Ann Intern Med* 1985;103:258-70.
- Marshall HW, Swan HJC, Burchell HB, Wood EH. Effect of breathing oxygen on pulmonary artery pressure and pulmonary vascular resistance in patients with ventricular septal defect. *Circulation* 1961;23:241-52.
- Hals J, Hagemo PS, Thaulow E, Sorland SJ. Pulmonary vascular resistance in complete atrioventricular septal defect. A comparison between children with and without Down's syndrome. *Acta Paediatr* 1993;82:595-8.
- Bush A, Busst C, Knight WB, Shinebourne EA. Modification of pulmonary hypertension secondary to congenital heart disease by prostacyclin therapy. *Am Rev Respir Dis* 1987;136:767-9.
- Wessel DL, Adatia I, Thompson JE, Hickey PR. Delivery and monitoring of inhaled nitric oxide in patients with pulmonary hypertension. *Crit Care Med* 1994;22:930-8.
- Betit P, Adatia I, Benjamin P, Thompson JE, Wessel DL. Inhaled nitric oxide: evaluation of a continuous titration delivery technique developed for infant mechanical ventilation and manual ventilation. *Respir Care* 1995;40:706-15.
- Neutze JM, Ishikawa T, Clarkson PM, Calder AL, Barratt-Boyes BG, Kerr AR. Assessment and follow-up of patients with ventricular septal defect and elevated pulmonary vascular resistance. *Am J Cardiol* 1989;63:327-31.
- Blackstone EH, Kirklin JW, Bradley EL, DuShane JW, Appelbaum A. Optimal age and results in repair of large ventricular septal defects. *J Thorac Cardiovasc Surg* 1976;72:661-79.
- Adatia I, Perry S, Landzberg M, Moore P, Thompson JE, Wessel DL. Inhaled nitric oxide and hemodynamic evaluation of patients with pulmonary hypertension before transplantation. *J Am Coll Cardiol* 1995;25:1656-64.
- Bush A, Busst C, Booth K, Knight WB, Shinebourne EA. Does prostacyclin enhance the selective pulmonary vasodilator effect of oxygen in children with congenital heart disease? *Circulation* 1986;74:135-44.
- Berner M, Beghetti M, Spahr-Schopfer I, Oberhansli I, Friedli B. Inhaled nitric oxide to test the vasodilator capacity of the pulmonary vascular bed in children with long-standing pulmonary hypertension and congenital heart disease. *Am J Cardiol* 1996;77:532-5.
- Roberts JD, Lang P, Bigatello LM, Vlahakes GJ, Zapol WM. Inhaled nitric oxide in congenital heart disease. *Circulation* 1993;87:447-53.
- Miller OI, Celermajer DS, Deanfield JE, Macrae DJ. Very low dose inhaled nitric oxide: a selective pulmonary vasodilator after operations for congenital heart disease. *J Thorac Cardiovasc Surg* 1994;108:487-94.
- Allman KG, Young JD, Carapiet D, Stevens JE, Ostman-Smith I, Archer LN. Effects of oxygen and nitric oxide in oxygen on pulmonary arterial pressures of children with congenital cardiac defects. *Pediatr Cardiol* 1996;17:246-50.
- Cornfield DN, Reeve HL, Tolarova S, Weir EK, Archer S. Oxygen causes fetal pulmonary vasodilation through activation of a calcium-dependent potassium channel. *Proc Natl Acad Sci USA* 1996;93:8089-94.
- NIOSH recommendations for occupational safety and health standards. *MMWR* 1988;37:21.
- Haque WA, Boehmer J, Clemson BS, Leuenberger UA, Silber DH, Sinoway LI. Hemodynamic effects of supplemental oxygen administration in congestive heart failure. *J Am Coll Cardiol* 1996;27:353-7.
- Semigran MJ, Cockrill BA, Kacmarek R, et al. Hemodynamic effects of inhaled nitric oxide in heart failure. *J Am Coll Cardiol* 1994;24:982-8.

本複製物は、特許庁が著作権法第42条第2項第1号の規定により複製したものです。取扱いにあたっては、著作権侵害とならないよう十分にご注意ください。

2780

Cardiovascular Effects of Inhaled Nitric Oxide in Patients With Left Ventricular Dysfunction

Evan Loh, MD; Jonathon S. Stamler, MD; Joshua M. Hare, MD;
Joseph Loscalzo, MD, PhD; Wilson S. Colucci, MD

Background Pulmonary vascular resistance (PVR) is frequently elevated in patients with advanced heart failure. Nitric oxide (NO), which contributes to the activity of endothelium-derived relaxing factor, causes relaxation of pulmonary arteries and veins *in vitro*. Inhalation of NO gas causes pulmonary vasodilation in patients with primary and secondary forms of pulmonary hypertension.

Methods and Results To test the hypothesis that inhalation of NO gas lowers PVR in patients with heart failure, we studied the hemodynamic effects of a 10-minute inhalation of NO (80 ppm) in 19 patients with New York Heart Association class III (n=5) and class IV (n=14) heart failure due to left ventricular (LV) dysfunction. Although inhalation of NO had no effect on pulmonary artery pressures, the PVR decreased by 31±7% (P<.001) due to a 23±7% increase (P<.001) in

pulmonary artery wedge pressure and despite a 4±2% (P<.05) decrease in cardiac index. The magnitude of the decrease in PVR with inhaled NO was inversely related (r=-.713; P<.001) to the baseline PVR. Inhaled NO had no effect on heart rate, systemic arterial pressure, systemic vascular resistance, or LV peak +dP/dt or -dP/dt.

Conclusions In patients with heart failure due to LV dysfunction, inhalation of NO causes a decrease in the PVR associated with an increase in LV filling pressure. These findings predict that inhaled NO, if used alone at this dose (80 ppm), may have adverse effects in patients with LV failure. (Circulation. 1994;90:2780-2785.)

Key words • nitric oxide • lung • heart failure • endothelium-derived factors

The endothelium plays an essential role in the dynamic regulation of vascular tone by synthesizing and releasing a variety of substances, one of which, endothelium-derived relaxing factor (EDRF), has the physicochemical properties of nitric oxide (NO) or a closely related substance.^{1,2} Endogenous NO produced by endothelial cells diffuses into neighboring vascular smooth muscle cells, where it binds to the heme component of guanylyl cyclase, thereby activating the enzyme, resulting in increased cyclic GMP production and relaxation.^{3,4} Arterial and venous endothelial cells in the pulmonary vasculature produce NO constitutively and in response to a variety of stimuli.⁵⁻⁸ NO appears to be involved both in the regulation of basal pulmonary vascular resistance (PVR)^{9,10} and in counterregulating the effects of vasoconstrictor substances.¹¹⁻¹⁵

PVR is frequently increased in patients with advanced heart failure. The underlying mechanism for increased PVR in heart failure is not known, but it almost certainly involves activation of vasoconstrictor pathways by the sympathetic nervous system, the renin-angiotensin system, and/or endothelin.^{16,17} Although there is evidence that endothelium-dependent vasodilation is impaired in the systemic vasculature of both animal models¹⁸ and patients with heart failure,¹⁹⁻²² it is

not known whether this mechanism contributes to increased PVR.

Inhalation of NO gas causes pulmonary vasodilation in patients with primary pulmonary hypertension²³ and pulmonary hypertension secondary to congenital heart disease²⁴ and to adult respiratory distress syndrome.²⁵ These observations suggest that inhaled NO might ameliorate pulmonary vasoconstriction, and they led to our hypothesis that inhalation of NO would lower PVR in patients with heart failure. To test this hypothesis, we studied the hemodynamic effects of a 10-minute inhalation of NO (80 ppm) in 19 patients with moderate to severe heart failure secondary to LV dysfunction from idiopathic or ischemic dilated cardiomyopathy.

Methods

Study Population

Nineteen patients with New York Heart Association functional class III (n=5) or IV (n=14) heart failure were studied. All patients were receiving digitalis, diuretics, and angiotensin-converting enzyme inhibitors. There were 15 men and 4 women, with a mean age of 52±3 years. The cause of heart failure was ischemic cardiomyopathy in 10 patients and idiopathic dilated cardiomyopathy in 9. The peak VO₂ averaged 9.9±1.6 mL·kg⁻¹·min⁻¹. The study protocol was approved by the Committee for the Protection of Human Subjects from Research Risks at the Brigham and Women's Hospital, and written informed consent was obtained in all cases.

Hemodynamic Measurements

Vasodilators, converting enzyme inhibitors, digitalis, and diuretics were withheld on the morning of the catheterization. A 7F Swan-Ganz catheter (Arrow International, Inc) was placed in the pulmonary artery. Femoral artery pressure was monitored via an 8F side-arm sheath (Cordis Laboratories). In 10 patients, a 7F micromanometer-tipped pigtail catheter

Received June 20, 1994; revision accepted August 7, 1994.
From the Cardiovascular (E.L., J.M.H., J.L., W.S.C.) and Respiratory (J.S.S.) Divisions, Departments of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Mass.

Correspondence to Wilson S. Colucci, MD, Cardiovascular Division, Brigham and Women's Hospital, 75 Francis St, Boston, MA 02115.

© 1994 American Heart Association, Inc.

本複製物は、特許庁が著作権法第42条第2項第1号の規定により複製したものです。
取扱いにあたっては、著作権侵害とならないよう十分にご注意ください。

TABLE 1. Hemodynamic Effects of Inhaled NO in Patients With Congestive Heart Failure (n=19)

	Room Air	NO	P
HR, bpm	90±3	93±3	NS
MAP, mm Hg	79±3	81±3	NS
SVR, dynes · s · cm ⁻⁵	1102±104	1041±97	NS
PA, mm Hg	35±4	37±4	NS
PAWP, mm Hg	25±3	31±4	<.001
LVEDP, mm Hg; n=10	28±4	34±5	.02
PVR, dynes · s · cm ⁻⁵	228±30	119±13	<.001
PA-PAWP, mm Hg	11±1	6±0.5	<.001
SVI, mL/m ²	26±2	24±2	.03
CI, L · min ⁻¹ · m ⁻²	2.3±0.2	2.1±0.2	.03

HR indicates heart rate; bpm, beats per minute; MAP, mean arterial pressure; SVR, systemic vascular resistance; PA, mean pulmonary artery pressure; PAWP, pulmonary artery wedge pressure; LVEDP, left ventricular end-diastolic pressure; PVR, pulmonary vascular resistance; SVI, stroke volume index; and CI, cardiac index.

(Miller Industries) was placed in the left ventricle (LV), allowing for simultaneous dP/dt and right heart pressure measurements. The ECG, femoral artery pressure, pulmonary artery pressure, and LV pressure were recorded on a strip chart recorder (Electronics for Medicine, PPG Biomedical Systems Division). Cardiac output was determined by the Fick method, based on the measured oxygen uptake (model MRM 2B, Waters Instruments, Inc) and oxygen content in the pulmonary and femoral arteries.²⁵ Oxygen content was calculated from the blood hemoglobin and oxygen saturation by standard methods.²⁶ Blood oxygen saturation was determined in duplicate samples on a Co-Oximeter model 270 Co-oximeter. LV peak +dP/dt (+dP/dt) and peak -dP/dt (-dP/dt) were computed on-line by an Electronics for Medicine amplifier (model 221A). Values for heart rate, arterial pressure, pulmonary arterial pressure, pulmonary artery wedge pressure, LV systolic pressure, LV end-diastolic pressure

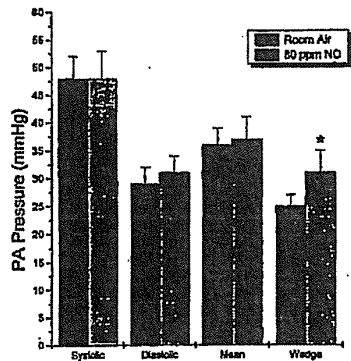


FIG 1. Bar graph showing effect of inhalation of NO gas (80 ppm, 10 minutes) on pulmonary artery (PA) pressures in 19 patients with heart failure secondary to left ventricular dysfunction. Measurements were made after the patients inhaled room air (shaded bars) or NO (solid bars) from a face mask for 10 minutes. *P<.001 vs room air.

Loh et al Cardiovascular Effects of NO 2781

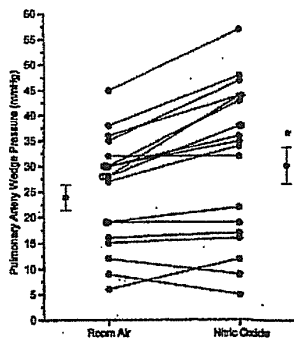


FIG 2. Graph showing pulmonary artery wedge pressure before and after a 10-minute inhalation of room air or NO. *P<.001 vs room air.

(LVEDP), and LV +dP/dt and -dP/dt were calculated by averaging at least 50 consecutive beats under each experimental condition.

Inhalation of Nitric Oxide

NO gas (800 ppm) and N₂ (Airco) were mixed by use of a standard low-flow blender (Low Flow MicroBlender, Bird Products Corp) before introduction into the inspiratory limb of a closed breathing circuit attached to a face mask. The inhaled concentrations of NO and oxygen were regulated separately. The inhaled O₂ concentration was measured directly with an on-line oximeter (Ohmeda Oximeter). The inhaled concentrations of NO, nitrogen dioxide (NO₂), and the higher oxides of nitrogen (NO_x) were measured continuously by a chemiluminescence technique (Chemiluminescent NO_x-NO₂ Analyzer, Thermo Environmental Instruments, Inc). The exhaled gases were scavenged by a vacuum system.

To establish baseline conditions, patients inhaled room air (FIO₂, 21%; N₂, 79%) via the closed face mask system for 10 minutes before the baseline hemodynamic measurements. Patients then inhaled NO at 80 ppm (FIO₂, 21%; N₂, 79%) via

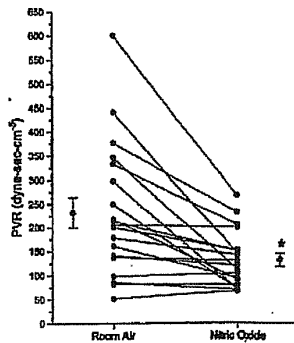


FIG 3. Graph showing effect of NO inhalation on pulmonary vascular resistance (PVR). *P<.001 vs room air.

本複製物は、特許庁が著作権法第42条第2項第1号の規定により複製したものです。
取扱いにあたっては、著作権侵害とならないよう十分にご注意ください。

2782 Circulation Vol 90, No 6 December 1994

face mask for 10 minutes, and hemodynamic measurements were repeated.

Statistical Methods

All data are presented as the mean±SEM. Differences between two observations for one variable within the same group were determined by two-tailed paired *t* test. Differences between groups were determined by two-tailed unpaired *t* test. Differences were considered significant if the null hypothesis could be rejected at the .05 probability level.

Results

Hemodynamic Effect of Inhaled NO

Baseline measurements during inhalation of room air revealed moderate LV failure with elevation of the LVEDP and mean pulmonary artery wedge pressure, and reduced stroke volume and cardiac indexes (Table 1). There was moderate reactive pulmonary hypertension, with an average PVR of 226±30 dyne·sec·cm⁻⁵.

Inhalation of NO caused no change in heart rate, mean systemic arterial pressure, systemic vascular resistance, or pulmonary artery pressure (systolic, diastolic, or mean) but caused a 23±7% increase in the mean pulmonary artery wedge pressure (Table 1, Figs 1 and 2) associated with 4±2% and 7±2% decreases in cardiac index and stroke volume index, respectively (Table 1). The mean transpulmonary pressure gradient decreased by 35±7% (Table 1), and the PVR decreased by 31±7% (Table 1 and Fig 3).

The decrease in PVR was due to the increase in pulmonary artery wedge pressure, as shown by the correlation (*r*=-.848, *P*=.0001) between the changes in PVR and pulmonary artery wedge pressure (Fig 4A) and lack of correlation with changes in pulmonary artery pressure (Fig 4B; *r*=.13) or cardiac index (Fig 4C; *r*=.04). The increase in mean pulmonary artery wedge pressure was due to an increase in LV filling pressure, as shown by the correlation (*r*=.939, *P*<.0001) between the changes in LV end-diastolic pressure and pulmonary artery wedge pressure with inhaled NO (Fig 5).

TABLE 2. Hemodynamic Characteristics of Patients With a Change in Pulmonary Artery Wedge Pressure Above or Below the Median With Inhalation of NO

	% PAWP <0.26 (n=9)	% PAWP >0.26 (n=10)	P
HR, bpm	87±4	84±3	NS
MAP, mm Hg	75±3	84±3	.02
SVR, dyne·s·cm ⁻⁵	987±153	1218±148	NS
PA, mm Hg	29±5	42±5	.02
PAWP, mm Hg	21±4	28±4	.02
SVI, mL/m ²	30±2	21±2	.004
CI, L·min ⁻¹ ·m ⁻²	2.6±0.2	1.9±0.2	.01
PVR, dyne·s·cm ⁻⁵	138±23	295±40	.002
LVEDD, cm	6.2±0.4	7.1±0.3	.04
VO ₂	9.6±0.1	11.7±0.8	NS

LVEDD indicates left ventricular end-diastolic dimension; VO₂, peak oxygen consumption. Other abbreviations as in Table 1. n=19 for all parameters except EDD (n=16) and VO₂ (n=17).

Hemodynamic Determinants of an Increase in Pulmonary Artery Wedge Pressure With Inhaled NO

The most prominent hemodynamic effect of NO inhalation was the increase in pulmonary artery wedge pressure (median increase, 26%). In the 10 patients with an increase in pulmonary artery wedge pressure of ≥26% (mean increase, 33±7%), the baseline pulmonary artery pressure, pulmonary vascular resistance, and LV end-diastolic dimension (by M-mode echocardiography; n=16) were higher and the cardiac index and stroke volume index were lower than in the 9 patients with an increase of <26% (Table 2). Thus, more severe LV dysfunction (as evidenced by higher left heart filling pressures, lower stroke volume, and larger LV cavity size) was present in the patients who had the largest increases in pulmonary artery wedge pressure with inhaled NO.

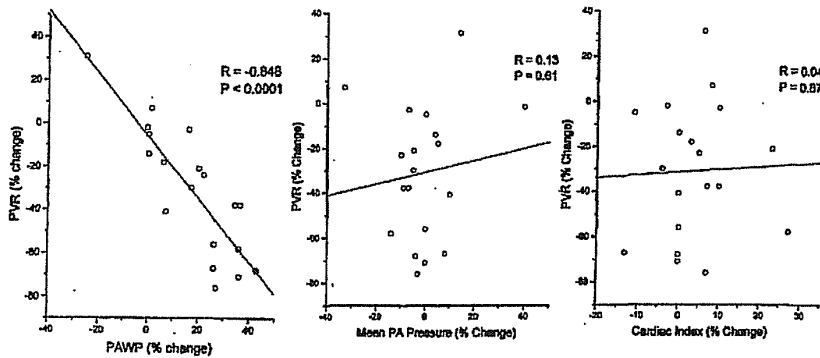


FIG 4. Scatterplots of regression analyses depicting the relation between the change in pulmonary vascular resistance (PVR) with NO (vs room air) and the change in pulmonary artery wedge pressure (PAWP) (left), mean PA pressure (middle), or cardiac index (right) in 19 patients.

本複製物は、特許庁が著作権法第42条第2項第1号の規定により複製したものです。
取扱いにあたっては、著作権侵害とならないよう十分にご注意ください。

The baseline PVR was more than twofold higher in the group that had the largest increases in pulmonary artery wedge pressure with inhaled NO (Table 2), suggesting that resting PVR might be a determinant or predictor of the response to inhaled NO. Consistent with this view, there was a strong correlation ($r = -0.713$, $P < .001$) between the baseline PVR and the decrease in PVR with inhaled NO (Fig 6).

As an alternative approach to this issue, we identified a subgroup of 5 patients who had "compensated" LV failure, as defined by a pulmonary artery wedge pressure ≤ 18 mm Hg (mean, 12 ± 2 mm Hg) and a cardiac index ≥ 2.5 L \cdot min $^{-1}$ \cdot m $^{-2}$ (mean, 2.8 ± 0.3 L \cdot min $^{-1}$ \cdot m $^{-2}$). In these patients, inhalation of NO has no effect on pulmonary artery wedge pressure ($+7 \pm 3\%$) or PVR ($+5 \pm 13\%$). In the remaining 14 patients with "decompensated" LV failure (mean pulmonary artery wedge pressure, 30 ± 2 mm Hg; mean cardiac index, 1.9 ± 0.1 L \cdot min $^{-1}$ \cdot m $^{-2}$), inhalation of NO increased the pulmonary artery wedge pressure by $27 \pm 3\%$ ($P < .001$) and decreased the PVR by $43 \pm 7\%$ ($P < .001$).

Effects of Inhaled NO on LV Function

Since it has been suggested that NO can depress the contractile function of isolated cardiac myocytes,²⁷ we considered the possibility that inhaled NO exerted a negative inotropic effect on the LV. A negative inotropic effect of inhaled NO was suggested by a decrease in stroke volume index despite an increase in pulmonary artery wedge pressure (Fig 7A). However, in the 10 patients in whom it was measured, inhaled NO had no effect on LV peak $+dP/dt$, despite increasing LVEDP by 8 ± 1 mm Hg (Fig 7B). LV peak $-dP/dt$, which reflects isovolumic relaxation in the absence of changes in loading conditions or heart rate,^{28,29} was also not affected by inhaled NO (baseline, 807 ± 140 mm Hg/s; NO, 800 ± 139 mm Hg/s; $P = NS$; $n = 10$).

Discussion

The major finding of this study is that in patients with reactive pulmonary arterial hypertension secondary to LV failure, inhalation of NO causes reciprocal changes in the PVR (decrease) and LV filling pressure (increase). In patients with primary pulmonary hypertension, inhalation of NO causes a decrease in pulmonary artery pressure.²³ In contrast, in patients with LV failure, we found that inhalation of NO is associated not with a decrease in pulmonary artery pressure, but rather, with an increase in LV filling pressure that accounts for the decrease in PVR. Preliminary reports from two other groups^{30,31} also indicate a similar effect of inhaled NO on LV filling pressure in patients with LV failure.

The observed decrease in transpulmonary artery pressure gradient, particularly in the setting of no change or a small decrease in cardiac output, indicates that inhaled NO caused pulmonary vasodilation. NO diffuses readily through tissues, and therefore inhalation of NO may increase the concentration of NO in the vicinity of vascular smooth muscle cells in pulmonary resistance vessels, thereby exerting a direct vasodilator effect.

We believe that the NO-induced increase in LV filling pressure is due to a small increase in LV volume that

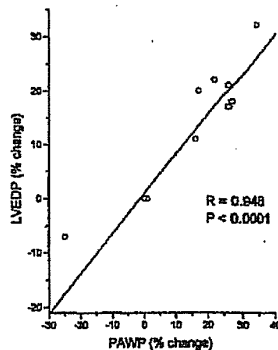


Fig 5. Scatterplot showing relation between the percent changes in pulmonary artery wedge pressure (PAWP) and left ventricular end-diastolic pressure (LVEDP) with inhaled NO in 10 patients.

occurred secondary to an increase in pulmonary venous return to the LV. For a given pulmonary artery pressure, a decrease in PVR will result in an increase in the net driving force for LV filling. Although an increase in LV volume would result in increases in ejection fraction and stroke volume in a normal LV, in our patients LV function was severely depressed and may have been on the flat portion of the Starling relation. In addition, an NO-induced increase in LV volume may have increased the magnitude of functional mitral regurgitation that is present in the majority of such hearts.^{32,33} Thus, an NO-induced redistribution of blood from the right ventricle to the LV may occur with no increase, or even a small decrease, in stroke volume. Since the failing LV often operates on the steep portion of the diastolic pressure/volume relation, a substantial increase in LV filling pressure might reflect only a small NO-induced increase in LV volume.

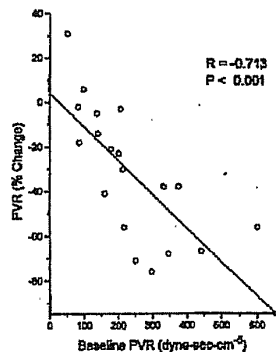


Fig 6. Scatterplot showing relation between the baseline pulmonary vascular resistance (PVR) and the percent changes in PVR after inhalation of NO in 18 patients.

本複製物は、特許庁が著作権法第42条第2項第1号の規定により複製したものです。
取扱いにあたっては、著作権侵害とならないよう十分にご注意ください。

2784 Circulation Vol 90, No 6 December 1994

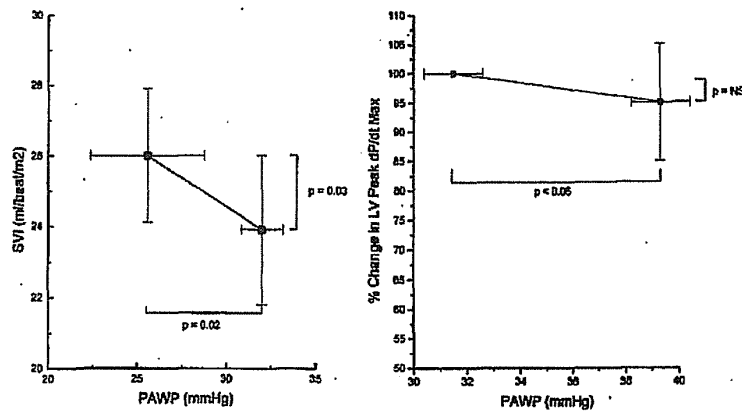


Fig 7. Graphs showing (left) effect of inhaled NO on the relation between stroke volume index (SVI) and mean pulmonary artery wedge pressure (PAWP) and (right) effect of inhaled NO on the relation between left ventricular (LV) peak +dP/dt and PAWP.

The NO-induced changes in LV filling pressure and PVR correlated with both the baseline PVR (see Fig 6) and the severity of hemodynamic compromise (see Table 2). It was previously observed that inhaled NO has no hemodynamic effects in control subjects who have a normal PVR.³⁴ Since the degree of reactive pulmonary hypertension is generally related to the severity of hemodynamic compromise in patients with LV failure, it might be anticipated that patients with more severe heart failure will have a more marked hemodynamic response to inhaled NO. To examine this prediction further, we compared the effects of inhaled NO in a subset of 5 patients with relatively compensated hemodynamics ("compensated group," defined by a pulmonary artery wedge pressure ≤ 18 mm Hg and a cardiac index ≥ 2.5 L \cdot m⁻²) and those of the remaining 14 patients ("decompensated group," defined by a pulmonary artery wedge pressure ≥ 18 mm Hg and/or a cardiac index < 2.5 L \cdot m⁻²). Although the LV ejection fractions were comparable in the two groups, the baseline PVR was higher in the decompensated group (Table 2). As predicted by our hypothesis, the NO-induced fall in PVR (43% versus 7%) and increase in LV filling pressure (27% versus 0%) were larger in the decompensated group. Taken together, these observations suggest that the greater effect of inhaled NO in patients with decompensated LV failure is due to the greater degree of reactive pulmonary hypertension present in such patients.

A second potential explanation for the decrease in transpulmonary gradient is that inhaled NO exerts a direct negative inotropic effect on the LV, resulting in a primary increase in LV filling pressure. In this scenario, passive pulmonary vasodilation might occur because of recruitment of precapillary vessels, an effect that has been demonstrated in animals.³⁵ However, we feel that a direct negative inotropic effect of inhaled NO is less likely, for several reasons. First, NO is rapidly inactivated by hemoglobin¹ and might not be expected to reach the coronary circulation under these conditions.

Second, we observed no decrease in LV +dP/dt, a highly sensitive measure of changes in contractile state. Third, it has been shown that in humans, the intracoronary infusion of nitroprusside, to donate NO to the myocardium, has no effect on +dP/dt and, contrary to our findings with inhaled NO, caused a decrease in LV filling pressure apparently due to an increase in ventricular distensibility.³⁶

An interesting corollary of these observations is that selective pulmonary vasodilation, in the absence of systemic vasodilation, may not be desirable in patients with severe LV failure. Clearly, inhaled NO, administered alone at the dose used in this study (80 ppm), may have adverse effects in such patients. Nevertheless, the ability of inhaled NO to reduce PVR selectively (ie, without causing systemic vasodilation), resulted in a unique physiological situation and thus provided the basis for these novel observations. Finally, on the basis of these observations, it is intriguing to speculate that an elevation in PVR may play an important adaptive role in patients with LV failure by limiting LV filling and thereby "protecting" the LV from excessive dilation, albeit at the expense of increased right ventricular work.

Acknowledgments

This study was supported in part by grants MOI-RR0088, HL-42539, HL-43344, and HL-48763 from the National Institutes of Health (NIH). Dr Loh is the recipient of Physician-Scientist Award KL-HL-02514 from the National Heart, Lung, and Blood Institute. Dr Colucci was a Sandoz Established Investigator of the American Heart Association. Dr Loscalzo is the recipient of a Research Career Development Award (HL-02273) from the NIH. We would like to thank Dr Eugene Braunwald for his insightful comments, Erin Graydon for technical assistance with NO gas administration, Dr Jeffrey Drazen for his generous support, the staff of the Cardiac Catheterization Laboratory for their help and patience, and Paula McColgan for expert typing.

References

1. Palmer RMJ, Ashton DS, Moncada S. Vascular endothelial cells synthesize nitric oxide from L-arginine. *Nature*. 1988;333:664-666.

本複製物は、特許庁が著作権法第42条第2項第1号の規定により複製したものです。
取扱いにあたっては、著作権侵害とならないよう十分にご注意ください。

2. Ignarro LJ, Buga GM, Wood KS, Byrns RE, Chaudhuri G. Endothelium-derived relaxing factor produced and released from artery and vein is nitric oxide. *Proc Natl Acad Sci U S A*. 1987;84:9265-9269.
3. Ignarro LJ. Nitric oxide: a novel signal transduction mechanism for transcellular communication. *Hypertension*. 1990;16:477-483.
4. Ignarro LJ. Biological actions and properties of endothelium-derived nitric oxide formed and released from artery and vein. *Circ Res*. 1989;65:1-21.
5. Ignarro LJ, Byrns RE, Wood KS. Endothelium-dependent modulation of cGMP levels and intracellular smooth muscle tone in isolated bovine intrapulmonary artery and vein. *Circ Res*. 1987;61:82-92.
6. Ignarro LJ, Byrns RE, Buga GM, Wood KS. Endothelium-derived relaxing factor from pulmonary artery and vein possesses pharmacologic and chemical properties identical to those of nitric oxide radical. *Circ Res*. 1987;61:866-879.
7. Cremona G, Dinh Xuan AT, Higgenbottom TW. Endothelium-derived relaxing factor and the pulmonary circulation. *Lung*. 1991;169:185-202.
8. Dinh-Xuan AT. Endothelial modulation of pulmonary vascular tone. *Eur Respir J*. 1992;5:757-762.
9. Cremona G, Higgenbottom T, Dinh Xuan AT, Wells F, Larga S, Stewart S, Wallwork J. Influence of endothelium derived relaxing factor (EDRF) on basal vascular resistance in isolated perfused human lungs. *Thorax*. 1991;46:283. Abstract.
10. Fineman JR, Crowley MR, Heymann MA, Solfer SJ. In vivo attenuation of endothelium-dependent pulmonary vasodilation by methylcellulose blue. *J Appl Physiol*. 1991;71:735-741.
11. Nishiwaki K, Nyhan DP, Rock P, Desai PM, Peterson WP, Fribble CG, Murray PA. N^G -Nitro-L-arginine and pulmonary vascular pressure-flow relationship in conscious dogs. *Am J Physiol*. 1992;262:H1331-H1337.
12. Fanburg BL. Relationship of the pulmonary vascular endothelium to altered pulmonary vascular resistance: state of the art. *Chest*. 1988;92:1015S-1055S.
13. Chand N, Altura BM. Acetylcholine and bradykinin relax intrapulmonary arteries by acting on endothelial cells: role in lung vascular disease. *Science*. 1981;213:1376-1379.
14. Fineman JR, Chang R, Solfer SJ. EDRF inhibition augments pulmonary hypertension in intact newborn lambs. *Am J Physiol*. 1992;262:H1365-H1371.
15. Fineman JR, Heymann MA, Solfer SJ. N^G -nitro-L-arginine attenuates endothelium-dependent pulmonary vasodilation in lambs. *Am J Physiol*. 1991;260:H1299-H1306.
16. Cody RJ, Haux GJ, Binkley PF, Capers Q, Kelley R. Plasma endothelin correlates with the extent of pulmonary hypertension in patients with chronic congestive heart failure. *Circulation*. 1992;85:584-589.
17. Francis GS, Goldsmith SR, Levine TB, Olivari MT, Cohn JN. The neurohumoral axis in congestive heart failure. *Ann Intern Med*. 1984;101:370-377.
18. Kaiser L, Spickard RC, Olivier NB. Heart failure depresses endothelium-dependent responses in canine femoral artery. *Am J Physiol*. 1989;256:H962-H967.
19. Dresler H, Hayoz D, Münzel T, Homig B, Just H, Brunner HR, Zelis R. Endothelial function in chronic congestive heart failure. *Am J Cardiol*. 1992;69:1596-1601.
20. Kubo SH, Rector RS, Bank AJ, Williams RE, Heifetz SM. Endothelium-dependent vasodilation is attenuated in patients with heart failure. *Circulation*. 1991;84:1589-1596.
21. Katz SD, Biasucci L, Sabba C, Strum JA, Jondeau G, Galvo M, Solomon S, Nikolic S, Fisman R, LeJemtel TH. Impaired endothelium-mediated vasodilation in the peripheral vasculature of patients with congestive heart failure. *J Am Coll Cardiol*. 1992;19:918-925.
22. Treasure CB, Vira JA, Cox DA, Fish RD, Gordon JB, Mudge GH, Colucci WS, St John Sutton MG, Selwyn AP, Alexander RW, Ganz P. Endothelium-dependent dilation of the coronary microvasculature is impaired in dilated cardiomyopathy. *Circulation*. 1990;81:772-779.
23. Pepke-Zaba J, Higgenbottom TW, Dinh Xuan AT, Stone D, Wallwork J. Inhaled nitric oxide as a cause of selective pulmonary vasodilation in pulmonary hypertension. *Lancet*. 1991;338:1173-1174.
24. Roberts JD Jr, Lang P, Bigatello LM, Viohakka GI, Zapol WM. Inhaled nitric oxide in congenital heart disease. *Circulation*. 1993;87:447-453.
25. Rossaint R, Felke KJ, López F, Slama K, Finam U, Zapol WM. Inhaled nitric oxide for the adult respiratory distress syndrome. *N Engl J Med*. 1993;328:399-405.
26. Grossman W, In: Grossman W, Bain DS, eds. *Cardiac Catheterization, Angiocardiology and Intervention*. 4th ed. Philadelphia, Pa: Lea & Febiger; 1991:105-122.
27. Brady AR, Warren JB, Poole-Wilson PA, Williams TJ, Harding SE. Nitric oxide attenuates cardiac myocyte contraction. *Am J Physiol*. 1993;H176-H182.
28. McLaurin LP, Rolett EL, Grossman W. Impaired left ventricular relaxation during pacing-induced ischemia. *Am J Cardiol*. 1973;32:751-757.
29. Hirota Y. A clinical study of left ventricular relaxation. *Circulation*. 1980;62:756-763.
30. Lundin S, Kleier-Jensen N, Waagstein F, Wennmalm A. Hemodynamic effects and metabolic fate of inhaled nitric oxide in patients with severe congestive heart failure. *Circulation*. 1992;86(suppl 1):I-770. Abstract.
31. Semigran MJ, Cockrill BA, Kazmarek R, Thompson ET, Zapol WA, Dec GW, Fifer MA. Nitric oxide is an effective pulmonary vasodilator in cardiac transplant candidates with pulmonary hypertension. *J Am Coll Cardiol*. 1993;21:428A. Abstract.
32. Keren G, Katz S, Strum J, Sonnenblick EE, LeJemtel TH. Non-invasive quantification of mitral regurgitation in dilated cardiomyopathy: correlation of two Doppler echocardiographic methods. *Am Heart J*. 1988;116:753-764.
33. Keren G, Katz S, Strum J, Sonnenblick EE, LeJemtel TH. Dynamic response to load alterations and inotropic therapy in severe heart failure. *Circulation*. 1989;80:3066-3073.
34. Freestell CK, Blomquist H, Hedenstierna G, Lundberg J, Zapol WM. Inhaled nitric oxide reverses human hypoxic pulmonary vasoconstriction without causing systemic vasodilation. *Anesthesiology*. 1993;78:427-435.
35. Hakim TS, Michel RP, Chang HK. Partitioning of pulmonary vascular resistance in dogs by arterial and venous occlusion. *Am J Physiol*. 1982;52:710-715.
36. Paulus WJ, Ventroneo FJ, Shah AM. Acute effects of nitric oxide on left ventricular relaxation and diastolic distensibility in humans: assessment by bicoronary sodium nitroprusside infusion. *Circulation*. 1994;89:2070-2078.

Inhaled nitric oxide in premature neonates with severe hypoxaemic respiratory failure: a randomised controlled trial

John P Kinsella, William F Walsh, Carl L Bose, Dale R Gerstmann, J J Labella, Smeeta Sardesai, Michele C Walsh-Sukys, Martin J McCaffrey, David N Cornfield, Vinod K Bhutani, Gary Cutter, Monika Baier, Steven H Abman

Summary

Background Inhaled nitric oxide improves oxygenation and lessens the need for extracorporeal-membrane oxygenation in full-term neonates with hypoxaemic respiratory failure and persistent pulmonary hypertension, but potential adverse effects are intracranial haemorrhage and chronic lung disease. We investigated whether low-dose inhaled nitric oxide would improve survival in premature neonates with unresponsive severe hypoxaemic respiratory failure, and would not increase the frequency or severity of intracranial haemorrhage or chronic lung disease.

Methods We did a double-blind, randomised controlled trial in 12 perinatal centres that provide tertiary care. 80 premature neonates (gestational age ≤ 34 weeks) with severe hypoxaemic respiratory failure were randomly assigned inhaled nitric oxide ($n=48$) or no nitric oxide ($n=32$, controls). Our primary outcome was survival to discharge. Analysis was by intention to treat. We studied also the rate and severity of intracranial haemorrhage, pulmonary haemorrhage, duration of ventilation, and chronic lung disease at 36 weeks' postconceptional age.

Findings The two groups did not differ for baseline characteristics or severity of disease. Inhaled nitric oxide improved oxygenation after 60 min ($p=0.03$). Survival at discharge was 52% in the inhaled-nitric-oxide group and 47% in controls ($p=0.65$). Causes of death were mainly related to extreme prematurity and were similar in the two groups. The two groups did not differ for adverse events or outcomes (intracranial haemorrhage grade 2–4, 28% inhaled nitric oxide and 33% control; pulmonary haemorrhage 13% and 9%; chronic lung disease 60% and 80%).

Interpretation Low-dose inhaled nitric oxide improved oxygenation but did not improve survival in severely hypoxaemic premature neonates. Low-dose nitric oxide in the most critically ill premature neonates does not increase the risk of intracranial haemorrhage, and may decrease risk of chronic lung injury.

Lancet 1999; **354**: 1061–65

See *Commentary* page xxx

University of Colorado School of Medicine, Children's Hospital, Denver, CO, USA (J P Kinsella MD, G R Cutter PhD, M Baier MS, Prof S H Abman MD); Vanderbilt University, Nashville, TN (W F Walsh MD); University of North Carolina, Chapel Hill, NC (C L Bose MD); Utah Valley Regional Medical Center, Provo, UT (D R Gerstmann MD); Magee Women's and Children's Hospital, Pittsburgh, PA (J J Labella MD); University of Southern California, Los Angeles, CA (S Sardesai MD); Case Western Reserve University, Cleveland, OH (M C Walsh-Sukys MD); Regional Naval Medical Center, San Diego, CA (M J McCaffrey MD); University of Minnesota, Minneapolis, MN (D N Cornfield MD); and Pennsylvania Hospital, Philadelphia, PA (Prof V K Bhutani MD)

Correspondence to: Dr John P Kinsella, Division of Neonatology, Box B-070, Children's Hospital, 1056 E 19th Avenue, Denver, CO 80218-1088, USA

Introduction

Early reports of inhaled nitric oxide in full-term neonates with persistent pulmonary hypertension showed sustained improvement in oxygenation.^{1,2} Subsequently, randomised controlled trials of inhaled nitric oxide confirmed that this selective pulmonary vasodilator improves oxygenation and lessens the need for extracorporeal-membrane oxygenation in such neonates.^{3–5} Inhaled nitric oxide did not, however, improve morbidity or survival.⁴ In full-term neonates, survival is unlikely to be altered by innovative therapies for persistent pulmonary hypertension because extracorporeal-membrane oxygenation is widely available and can be started quickly when more conservative therapies fail. The role of inhaled nitric oxide in premature neonates with hypoxaemic respiratory failure is, however, more controversial in terms of efficacy and safety.⁶ In addition, extracorporeal-membrane oxygenation is not generally offered to premature neonates because of the risks of intracranial haemorrhage associated with heparinisation, internal-jugular and common-carotid-vessel ligation, and mechanical cardiopulmonary bypass.⁷

Laboratory studies have shown that low-dose inhaled nitric oxide (5–20 parts per million [ppm]) leads to pulmonary vasodilation and improves gas exchange in premature lambs with respiratory-distress syndrome,^{8–10} and previous clinical studies have suggested that inhaled nitric oxide acutely improves oxygenation in premature neonates.^{11–14} Effects on morbidity and survival in premature neonates have not, however, been tested in a controlled trial. Premature neonates are uniquely susceptible to oxidant lung injury, which could increase the risk of chronic lung disease, but the effects of inhaled nitric oxide on chronic lung disease have not been studied. Laboratory and clinical studies suggest that high doses of inhaled nitric oxide can increase bleeding time,^{15–17} and two case reports have suggested a high rate of intracranial haemorrhage in premature neonates treated with inhaled nitric oxide.^{18,19} These case reports did not include control groups to find out the actual risk of intracranial haemorrhage, and there is no evidence from controlled trials that inhaled nitric oxide increases the risk of clinical bleeding complications in full-term neonates.

We tested the hypothesis in a double-blind, randomised, controlled trial that the use of low-dose inhaled nitric oxide (5 ppm) would improve survival in premature neonates with severe hypoxaemic respiratory failure unresponsive to conventional therapies, and would not increase the incidence or severity of bleeding complications. Because of the uncertainty about the safety of exposure to inhaled nitric oxide in premature neonates, we limited the study population to selected premature neonates with severe hypoxaemic respiratory failure despite maximum therapeutic intervention and a high predicted mortality rate.

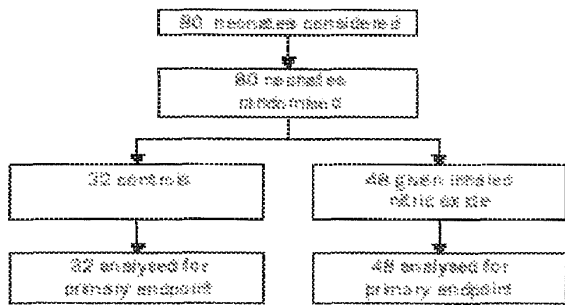


Figure 1: Trial profile

Methods

Patients

12 tertiary perinatal centres with clinical experience in inhaled-nitric-oxide therapy participated in the trial. The study was approved by the Institutional Review Board at each centre, and by the US Food and Drug Administration under an investigator-initiated investigational new drug exemption. Criteria for enrolment were: delivery at gestational age 34 weeks or less; age 7 days or younger; severe hypoxaemia (arterial/alveolar oxygen ratio <0.10 on two sequential arterial-blood-gas measurements) despite mechanical ventilation and surfactant treatment (Survanta, Abbott Laboratories, Columbus, OH, USA, 4 mL/kg) when indicated (based on a predicted mortality rate of 50%).²⁰ Exclusion criteria were fatal congenital anomalies or congenital heart disease (except atrial and ventricular septal defects). We enrolled neonates after informed consent was obtained from parents.

Study design

Treatment assignment was designated by the central coordinating centre according to sequentially numbered randomisation cards, provided in sealed opaque envelopes with the order varied among hospitals. Randomisation was stratified by centre and gestational age (≤ 28 weeks or >28 weeks), balanced in blocks of ten in each stratum, based on an expected total enrolment of 210 patients. Cranial ultrasound examinations were done before enrolment to find out the baseline incidence and severity of intracranial haemorrhage (Papile standards).²¹

After randomisation, the ventilator circuit was configured to allow delivery of nitric oxide at 5 ppm, as described previously.³ In patients assigned nitric oxide ($n=48$) the delivery system was activated. No supplemental gas was delivered to patients in the control group ($n=32$). Caregivers were unaware of whether nitric oxide was delivered. Delivery systems were monitored routinely (sham monitoring in the control group). Delivered nitric oxide and nitrogen dioxide concentrations were monitored by chemiluminescence or electrochemical sensors.³ After 7 days' administration, a period of no administration of study gas was tried. We limited the frequency of these periods to keep the risk of unmasking treatment assignment to a minimum. A threshold of 15% or more increase in oxygenation index (fraction of inspired oxygen $[FiO_2] \times$ mean airway pressure $\times 100$ /arterial partial pressure of oxygen $[PaO_2]$) was used to warrant restarting study gas. If study gas was restarted, periods without gas were kept to every 2 days for a maximum treatment duration of 14 days. We used oxygenation index for periods off gas because the calculation is straightforward for immediate bedside assessments, but after we had done analyses, we believed that PaO_2/FiO_2 would be a more clinically useful comparison and present results in this way.

Patients were mechanically ventilated with standard neonatal, time-cycled, pressure-limited ventilators or with high-frequency devices (SensorMedics 3100A High Frequency Oscillator, SensorMedics Inc, Yorba Linda, CA, USA, or Infant Star HFV, Infracor Inc, San Diego, CA). The consensus among centres

Characteristic	Inhaled nitric oxide (n=48)	Control (n=32)
Mean (SD) weight (g)	1040 (461)	988 (387)
Mean (SD) gestational age (weeks)	27.1 (2.5)	26.8 (2.5)
Sex (female/male)	20/28	12/20
Median (range) 1 min Appgar score	4 (1-8)	4 (1-9)
Median (range) 5 min Appgar score	7 (2-9)	6 (1-9)
No intracranial haemorrhage	35 (73%)	19 (59%)
Intracranial haemorrhage (grade 2-4)	7 (15%)	6 (19%)
Mean (SD) age at enrolment (h)	30 (38)	27 (37)
Mean (SD) PaO_2/FiO_2 (kPa)	5.6 (2.4)	5.6 (2.1)
Mean (SD) pH	7.33 (0.12)	7.32 (0.10)
Mean (SD) $PaCO_2$ (kPa)	5.7 (1.9)	6.0 (2.1)

$PaCO_2$ =arterial partial pressure of carbon dioxide.

Table 1: Baseline characteristics

was that a high-volume strategy would be used during high-frequency oscillatory ventilation. The only ventilator prohibited was the Life Pulse High Frequency Ventilator (Bunnell Inc, Salt Lake City, UT, USA), because of limited information of the accurate measurement of delivered concentrations of inhaled nitric oxide. We did not allow changes in ventilator device or ventilator settings for the first 60 min of the trial to enable recording of acute responses to treatment.

Statistical analysis

We based sample-size estimates on a predicted 50% mortality in the control group.²¹ We estimated that 80% power to detect a 30% decrease in mortality with inhaled nitric oxide required 105 neonates in each treatment group. Safety analyses of mortality and rates of intracranial haemorrhage were done by an independent data, safety, and monitoring committee after enrolment of 20, 40, and 60 neonates, to find out whether the rate of adverse events warranted ending the trial. No such need was seen.

A planned interim analysis after enrolment of 80 neonates, based on a randomisation-date cut off (study duration 2.5 years) showed that no significant difference was detectable for the main outcome measure (survival to discharge) and that at the current enrolment rate, projections suggested detection of differences was unlikely in a reasonable time frame (based upon stochastic curtailment procedures). Interim analyses were done by the coordinating centre and the investigators were unaware of results. We did planned secondary analyses (eg, chronic lung disease and intracranial haemorrhage) of differences between treatment groups after the end of study.

For the primary and secondary outcome measures, we did analyses by intention to treat. For acute changes in respiratory variables, the results for seven neonates (four on inhaled nitric oxide, three controls) were censored because of protocol violations in the first 60 min of the trial (changes in ventilator devices or settings). Data from these neonates were, however, included for other study endpoints.

We analysed binomial data with χ^2 or Fisher's exact tests where appropriate. We compared normally distributed continuous data with Student's *t* test. Continuous data that were

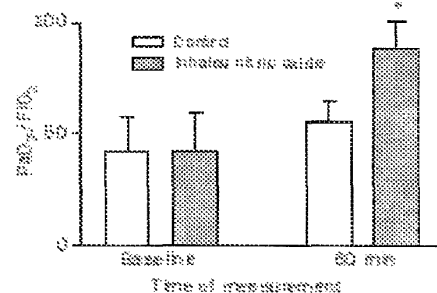


Figure 2: PaO_2/FiO_2 results at baseline and 60 min after treatment

* $p<0.05$ vs control.

not normally distributed were compared with the Mann-Whitney *U* test. We set the significance level at $p < 0.05$.

Results

Complete data were available for 80 neonates during the planned interim analysis (figure 1). The unequal distribution of neonates was because of the stratification scheme, which was based on our anticipated enrolment of 20 neonates in each centre (ten of 12 centres enrolled fewer than ten neonates). Centres did not differ significantly in randomisation ($p = 0.92$). No randomisation violations were reported to the coordinating centre.

There were no differences between groups in baseline characteristics (table 1). 79 (99%) neonates were treated with surfactant. Distribution of ethnic origin, antenatal corticosteroid treatment or treatment, with high-frequency oscillatory ventilation at enrolment were similar in the inhaled-nitric-oxide and control groups.

In the inhaled-nitric-oxide group, there was an acute improvement in PaO_2 after 60 min compared with the control group ($p = 0.03$, figure 2). Arterial pH (7.32 [0.18] inhaled nitric oxide *vs* 7.32 [0.16] control) or arterial partial pressure of carbon dioxide (5.7 [2.9] *vs* 5.5 [2.4] kPa) did not differ between groups after 60 min. Methaemoglobin concentrations were also similar in the two groups (1.1% [0.72], inhaled nitric oxide 0.96 [0.60] control). Arterial-blood-gas measurements did not differ between groups after 60 min. In the first period off study gas after 7 days of treatment, treatment had to be restarted in three neonates (treatment was discontinued successfully on day 9 for one neonate and day 11 for two). Days on ventilators in survivors were significantly fewer in the inhaled-nitric-oxide group than in the control group ($p = 0.046$).

Survival to discharge or chronic lung disease (table 2) and days spent in hospital (median 86.5 [range 31–395] inhaled nitric oxide *vs* 79.0 [14–106] control) were similar in the two groups. Groups did not differ for incidence of pulmonary haemorrhage (13 *vs* 9%) or symptomatic patent ductus arteriosus (21 *vs* 19%). Periventricular leucomalacia occurred in two (8%) of 25 neonates receiving inhaled nitric oxide and in two (13%) of 15 controls ($p = 0.62$). Four neonates had retinopathy of prematurity that required treatment (one in the inhaled-nitric-oxide group, three in the control group, $p = 0.10$).

The rate and severity of intracranial haemorrhage at study entry was similar in the two groups (table 3). For intracranial-haemorrhage outcomes, the highest grade recorded (right or left) at age 7 days or 36 weeks postconceptional age was chosen to reflect intracranial-haemorrhage severity. The rate of intracranial haemorrhage for each group did not differ in survivors (table 2).

We did cranial ultrasound scans at study entry and at age 7 days, because most intracranial haemorrhages occur in this time.²² Therefore, to find out whether intracranial haemorrhage occurred in neonates who died before age 7 days, we did a separate analysis that included results of cranial ultrasound scans done before 7 days as well as the results of necropsy. No intracranial-haemorrhage results were available for 11 of the 80 neonates who died suddenly before age 7 days and who did not undergo necropsy (five in the inhaled nitric oxide group, six in the control group). 13 neonates had cranial ultrasound scans

Outcome	Inhaled nitric oxide	Control	Relative risk (95%CI)	p
Survival	25/48 (52%)	15/32 (47%)	1.11 (0.70–1.8)	0.65
Chronic lung disease (oxygen at 36 weeks)	15/25 (60%)	12/15 (80%)	0.75 (0.5–1.13)	0.30
Death, chronic lung disease, or both	37/48 (77%)	29/32 (91%)	0.85 (0.7–1.03)	0.14
Discharged on oxygen	13/25 (54%)	12/15 (80%)	0.65 (0.41–1.02)	0.10
Median (range) ventilator days for survivors	26 (3–69)	37 (8–395)	..	0.046

Table 2: Relative risks of outcomes

after enrolment and before death before age 7 days, and additional intracranial-haemorrhage results were available from necropsies done in seven neonates. Therefore, results for intracranial haemorrhage were available for 43 (90%) of 48 neonates in the inhaled-nitric-oxide group and 26 (81%) of 32 controls (table 3). To find out whether inhaled nitric oxide increased the likelihood of new or worsened intracranial haemorrhage, we analysed the change in intracranial-haemorrhage grade from baseline between the two groups. A higher grade of intracranial haemorrhage after enrolment occurred in 19 (44%) of 43 neonates in the inhaled-nitric-oxide group and 11 (42%) of 26 controls ($p = 0.88$). The groups did not differ for the incidence of intracranial haemorrhage within the stratum 28 weeks or less estimated gestational age (ie, at highest risk for intracranial haemorrhage). The rate of intracranial haemorrhage (grades 1–4) was 56% (18 of 32) for the inhaled-nitric-oxide group and 59% (ten of 17) for the control group. The rate of the grade 4 intracranial haemorrhage was 19% for the inhaled-nitric-oxide group and 29% for the control group. 11 (46%) of the 24 neonates on inhaled nitric oxide and four (50%) of eight controls in this stratum who did not have intracranial haemorrhage at baseline subsequently developed intracranial haemorrhage.

Because the rate of intracranial haemorrhage in premature neonates is important to subsequent trials, we also did an analysis based on worst case scenario. We calculated the incidence of intracranial haemorrhage based on the premise that neonates in the inhaled-nitric-oxide group who died before age 7 days with unknown intracranial-haemorrhage status ($n = 5$) actually had grade 4 intracranial haemorrhage and all neonates in the control group who died before age 7 days with unknown intracranial-haemorrhage status ($n = 6$) actually had no intracranial haemorrhage. This analysis yielded a maximum potential rate for grade 4 intracranial haemorrhage of 29% for the inhaled-nitric-oxide group and 27% for the control group. With the prediction for the worst case scenario, a clinical trial designed to prove a significant increase in risk for grade 4 intracranial

	Inhaled nitric oxide (n=48)	Control (n=32)	p
Total unknown ICH status	5/48 (10%)	6/32 (19%)	0.29
Alive without ICH	15/25 (60%)	10/15 (67%)	0.67
Alive with ICH <grade 1	18/25 (72%)	10/15 (67%)	0.72
Alive with ICH grade 2–4	7/25 (28%)	5/15 (33%)	0.72
Died without ICH (<grade 1)	6/18 (33%)	3/11 (27%)	0.73
Died with ICH grade 2–4	12/18 (67%)	8/11 (73%)	0.73
Total known ICH incidence (survivors plus non-survivors)			
Grade 1–4	22/43 (51%)	13/26 (50%)	0.93
Grade 2–4	19/43 (44%)	13/26 (50%)	0.56
Grade 3–4	16/43 (37%)	10/26 (40%)	0.92
Grade 4	7/43 (16%)	7/26 (27%)	0.29

ICH=intracranial haemorrhage.

Table 3: Outcomes for intracranial haemorrhage

	Inhaled nitric oxide (n=23)	Control (n=17)	p
Support withdrawn for severe ICH	6 (26%)	4 (24%)	0.85
Extreme prematurity (<25 weeks) and MSOF	6 (26%)	4 (24%)	0.85
HE/ refractory respiratory failure	3 (13%)	3 (18%)	0.49
Bacterial sepsis	3 (13%)	2 (12%)	0.90
Renal failure	2 (9%)	2 (12%)	0.75
Pulmonary hypoplasia (non-CHD)	1 (4%)	2 (12%)	0.56
Congenital diaphragmatic hernia	2 (9%)	0	0.50

ICH=intracranial haemorrhage; MSOF=multisystem organ failure; HE=pulmonary interstitial emphysema; CHD=coronary heart disease.

Table 4: Cause of death and associated disorders

haemorrhage in neonates treated with inhaled nitric oxide (80% power, $\alpha=0.05$) would require a minimum of 15 000 neonates (with illness similar to those in this study). Causes of death and major associated disorders were similar in the two groups (table 4).

Discussion

Low-dose inhaled nitric oxide did not affect survival, but this study population had a high rate of mortality associated with complications of prematurity such as multisystem organ failure and intracranial haemorrhage. Because the potential adverse effects of inhaled nitric oxide on platelet adhesion and the attendant risks of intracranial haemorrhage are severe consequences of prematurity, we included only neonates with the most severe respiratory failure.

One of our most important findings was that low-dose inhaled nitric oxide (5 ppm) did not affect the rate of severity of intracranial haemorrhage, in contrast to observational reports.^{18,19} However, no increased incidence of intracranial haemorrhage was found in a small, unblinded trial that tested the effects of inhaled nitric oxide and dexamethasone.²³ In our trial, we found that intracranial haemorrhage occurred with similar frequency in the inhaled-nitric-oxide and control groups. By obtaining all available ultrasound and necropsy findings, it is unlikely that we missed any hidden morbidity of intracranial haemorrhage. This observation is important to future studies of inhaled nitric oxide in premature neonates. Less severely ill premature neonates may be safely treated with low-dose inhaled nitric oxide without the risk of a bleeding diathesis. We did, however, use a constant low dose of inhaled nitric oxide for a minimum of 7 days. We based the use of low-dose inhaled nitric oxide on the results of previous laboratory and clinical studies, which showed optimum beneficial vasoactive and anti-inflammatory effects and low potential adverse effects on platelet adhesion. There is little information about the safety and efficacy of higher doses of inhaled nitric oxide in premature neonates. We did not use laboratory-based assessments of bleeding tendency because, in premature neonates, such laboratory measurements are imprecise, variable, and would not replace the clinically relevant endpoints we reported.

Low-dose inhaled nitric oxide improved oxygenation and decreased the need for mechanical ventilation. Moreover, inhaled nitric oxide substantially lowered the frequency of chronic lung disease. We did not design this trial to test whether inhaled nitric oxide would have this effect on chronic lung disease. However, the possibility that inhaled nitric oxide may have preventive effects on lung injury is important, because, in addition to its effects on pulmonary haemodynamics and gas exchange during inhalation, this treatment may affect neutrophil adhesion

in the microcirculation.²⁴ In premature lambs at 78% of term, inhaled nitric oxide increased pulmonary blood flow and improved gas exchange without increasing pulmonary oedema^{14,15} and decreased lung neutrophil accumulation.¹⁶ The effects of low-dose inhaled nitric oxide on early neutrophil accumulation may have important clinical implications because neutrophils play an important part in the inflammatory cascade that contributes to lung injury and the evolution of the most important sequel of respiratory-distress syndrome, chronic lung disease.²⁵⁻²⁸ Sequestration of neutrophils in the lung is an early step in a complex inflammatory response mediated through the elaboration of oxyradicals, proteases, phospholipases, and lipid compounds.²⁹ Therapies that lower neutrophil accumulation in the lung in respiratory-distress syndrome could potentially modify the early inflammatory process that amplifies acute lung injury and contribute to the development of chronic lung disease.³⁰

We did not study long-term effects of inhaled nitric oxide in premature neonates. We are continuing follow-up studies on premature infants treated with inhaled nitric oxide and controls after 1 year, 2 years, and 6 years to assess neurodevelopmental outcomes.

Low-dose inhaled nitric oxide may be effective as a lung-specific anti-inflammatory therapy to lessen lung neutrophil accumulation and the attendant inflammatory injury that contributes to the evolution of chronic lung disease. Sufficient evidence may now be available to warrant a controlled trial of low-dose inhaled nitric oxide in premature neonates with less severe disease.

Contributors

John Kinsella and Steven Abman designed the study. Gary Cutter and Monika Baier did the statistical analysis. John Kinsella, William Walsh, Carl Bose, Dale Gerstmann, J Labelle, Smeeta Sardesai, Michele Walsh-Sukys, Martin McCaffrey, David Cornfield, Vinod Bhutani, Gary Cutter, Monika Baier, and Steven Abman all contributed to the writing of the paper.

Acknowledgments

This work was supported by the General Clinical Research Centres Program (MO1 RR00069), National Center for Research Resources, and INO Therapeutics Inc.

We thank Elaine St John, Ronald N Goldberg, J Schmidt, J Griebel, and L Fashaw for their support.

References

- Roberts JD, Polaner DM, Lang P, et al. Inhaled nitric oxide in persistent pulmonary hypertension of the newborn. *Lancet* 1992; **340**: 818-19.
- Kinsella JP, Neish SR, Shaffer E, Abman SH. Low-dose inhalational nitric oxide in persistent pulmonary hypertension of the newborn. *Lancet* 1992; **340**: 819-20.
- Kinsella JP, Truog WE, Walsh WF, et al. Randomized, multicentre trial of inhaled nitric oxide and high frequency oscillatory ventilation in severe persistent pulmonary hypertension of the newborn. *J Pediatr* 1997; **131**: 55-62.
- The Neonatal Inhaled Nitric Oxide Study Group. Inhaled nitric oxide in full-term and nearly full-term infants with hypoxic respiratory failure. *N Engl J Med* 1997; **336**: 597-604.
- Roberts JD, Fineman JR, Morin FC, et al. Inhaled nitric oxide and persistent pulmonary hypertension of the newborn. *N Engl J Med* 1997; **336**: 605-10.
- Kinsella JP, Abman SH. Inhaled nitric oxide in the premature neonate: animal models and clinical experience. *Semin Perinatol* 1997; **21**: 418-25.
- Hardart GE, Fackler JC. Predictors of intracranial hemorrhage during neonatal extracorporeal membrane oxygenation. *J Pediatr* 1999; **134**: 156-59.
- Kinsella JP, Ivy DD, Abman SH. Ontogeny of NO activity and response to inhaled NO in the developing ovine pulmonary circulation. *Am J Physiol* 1994; **267**: H1955-61.
- Kinsella JP, Ivy DD, Abman SH. Inhaled nitric oxide lowers pulmonary vascular resistance and improves gas exchange in severe experimental hyaline membrane disease. *Pediatr Res* 1994; **36**: 402-08.

- 10 Kinsella JP, Parker TA, Galan H, et al. Effects of inhaled nitric oxide on pulmonary edema and lung neutrophil accumulation in severe experimental hyaline membrane disease. *Pediatr Res* 1997; **41**: 457-63.
- 11 Abman SH, Kinsella JP, Schaffer MS, Wilkening RB. Inhaled nitric oxide in the management of a premature newborn with severe respiratory distress and pulmonary hypertension. *Pediatrics* 1993; **92**: 606-09.
- 12 Peliowski A, Finer NN, Etches PC, Tierney AJ, Ryan CA. Inhaled nitric oxide for premature infants after prolonged rupture of the membranes. *J Pediatr* 1995; **126**: 450-53.
- 13 Skimming JW, Bender KA, Hutchison AA, Drummond WH. Nitric oxide inhalation in infants with respiratory failure. *J Pediatr* 1997; **130**: 225-30.
- 14 Subhedar NV, Shaw NJ. Changes in oxygenation and pulmonary haemodynamics in preterm infants treated with inhaled nitric oxide. *Arch Dis Child* 1997; **77**: F191-97.
- 15 Hogman M, Frostell C, Arnberg H, Hedenstierna G. Bleeding time prolongation and NO inhalation. *Lancet* 1993; **341**: 1664-65.
- 16 Simon DI, Stamler JS, Jaraki O, et al. Antiplaquet properties of protein S-nitrosothiols derived from nitric oxide and endothelium-derived relaxing factor. *Arterioscler Thromb* 1993; **13**: 791-99.
- 17 George TN, Johnson KJ, Bates JN, Segar JL. The effect of inhaled nitric oxide therapy on bleeding time and platelet aggregation in neonates. *J Pediatr* 1998; **132**: 731-34.
- 18 Van Meurs KP, Rhine WD, Asselin IM, Durand DJ. Response of premature infants with severe respiratory to inhaled nitric oxide. *Pediatr Pulmonol* 1997; **24**: 319-23.
- 19 Cheung P, Peliowski A, Robertson CMT. The outcome of very low birth weight neonates (≤ 1500 g) rescued by inhaled nitric oxide: neurodevelopment in early childhood. *J Pediatr* 1998; **133**: 735-39.
- 20 The UAC Trial Study Group. the relationship of intraventricular hemorrhage or death with the level of umbilical artery catheter placement: a multicenter randomized clinical trial. *Pediatrics* 1992; **90**: 881-87.
- 21 Papile L, Burstein J, Burstein R, Kofler H. Incidence and evaluation of subependymal and intraventricular hemorrhage: a study of infants with birth weights less than 1500 g. *J Pediatr* 1978; **92**: 529-34.
- 22 Partridge JC, Babcock DS, Steichen JJ, et al. Optimal timing for diagnostic cranial ultrasound in low-birth-weight infants; detection of intracranial hemorrhage and ventricular dilation. *J Pediatr* 1983; **102**: 281.
- 23 Subhedar NV, Ryan SW, Shaw NJ. Open randomised controlled trial of inhaled nitric oxide and early dexamethasone in high risk preterm infants. *Arch Dis Child* 1997; **77**: F185-90.
- 24 Kanwar S, Kubes P. Nitric oxide is an antiadhesive molecule for leukocytes. *New Horiz* 1995; **3**: 93-104.
- 25 Merritt TA, Cochrane CG, Holcomb K, bohl B, Hallman M, Strayer D, Edwards DK. Elastase and α -1-proteinase inhibitor activity in tracheal aspirates during respiratory distress syndrome. *J Clin Invest* 1983; **72**: 656-66.
- 26 Ogden BE, Murphy S, Saunders GC, Johnson JD. Lung lavage of newborns with respiratory distress syndrome: prolonged neutrophil influx is associated with bronchopulmonary dysplasia. *Chest* 1983; **83**: 31-33.
- 27 Speer CP, Ruess D, Harms K, Herting E, Gefeller O. Neutrophil elastase and acute pulmonary damage in neonates with severe respiratory distress syndrome. *Pediatrics* 1993; **91**: 794-99.
- 28 Brus F, Van Oeveren W, Heikamp A, Okken A, Oetomo SB. Leakage of protein into lungs of preterm ventilated rabbits is correlated with activation of clotting, complement, and polymorphonuclear leukocytes in plasma. *Pediatr Res* 1996; **39**: 958-65.
- 29 Zimmerman JJ. Bronchoalveolar inflammatory pathophysiology of bronchopulmonary dysplasia. *Clin Perinatal* 1995; **22**: 429-56.
- 30 Sugiura M, McCulloch PR, Wren S, Dawson RH, Froese AB. Ventilator pattern influences neutrophil influx and activation in atelactasis-prone rabbit lung. *J Appl Physiol* 1994; **77**: 1355-65.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO)	
Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1613
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF JAMES S. BALDASSARRE, M.D.
UNDER 37 C.F.R. § 1.132

I, James S. Baldassarre, declare the following:

1. I currently hold the position of Vice President of Clinical Research at Ikaria, Inc. ("Ikaria"), the assignee of U.S. Patent Application No. 12/820,866. My *curriculum vitae* is attached as Exhibit 1.
2. I have over 20 years of experience as a physician, and over fifteen years of experience directing clinical research in the pharmaceutical industry.
3. Ikaria markets pharmaceutical grade nitric oxide (NO) gas under the brand name INOMAX[®] (nitric oxide) for inhalation. INOMAX[®] was approved by the U.S. Food and Drug Administration ("FDA") in December 1999, for the treatment of term and near-term (>34 weeks) neonates with hypoxic respiratory failure (HRF) associated with clinical or echocardiographic evidence of pulmonary hypertension, where it improves oxygenation and reduces the need for extracorporeal membrane oxygenation (ECMO).

4. In May 2004, INO Therapeutics LLC¹ initiated a clinical trial, entitled "Comparison of Supplemental Oxygen and Nitric Oxide for Inhalation Plus Oxygen in the Evaluation of the Reactivity of the Pulmonary Vasculature During Acute Pulmonary Vasodilator Testing", and designated the INOT22 trial, to compare the utility and side effects of oxygen (O₂), nitric oxide (iNO) and a combination of iNO and O₂ for determining pulmonary reactivity.

5. The INOT22 study was to be an open, prospective, randomized, multi-center, controlled diagnostic trial, with an expected total enrollment of a minimum of 150 patients, in approximately 18 study sites over approximately 2 years.

6. The expected patient population for enrollment into the INOT22 trial were subjects between the ages of four (4) weeks and eighteen (18) years undergoing diagnostic right heart catheterization scheduled to include acute pulmonary vasodilation testing to assess pulmonary vasoreactivity. The expected population were subjects with idiopathic pulmonary arterial hypertension, congenital heart disease (with or without intravascular shunt) with pulmonary hypertension and cardiomyopathies.

7. The INOT22 study was established and designed by the study sponsor, INO Therapeutics LLC (INO), and a Steering Committee comprising internationally recognized experts in the field of pediatric heart and lung disease, whose members would assist INO to develop the INOT22 protocol, monitor the progress of the trial, and provide recommendations to INO on changes in the procedures and conduct of the trial.

8. The Steering Committee consisted of:

- a. David L. Wessel, MD, presently Division Chief, Pediatric Critical Care Medicine at Children's National Medical Center, Washington, DC (co-author of Atz., et al., Seminars in Perinatology);²

¹ INO Therapeutics LLC is a wholly owned subsidiary of Ikaria, Inc., and holder of the NDA for INOMAX.

² Cited in pending Office Action.

- b. Robyn J. Barst, MD, presently Professor Emeritus of Pediatrics and Medicine, Columbia University College of Physicians and Surgeons, New York; and
- c. Duncan J. Macrae, MD, presently Director, Pediatric Intensive Care, Royal Brompton Hospital, London, U.K. (lead author of Macrae, et al., Intensive Care Medicine, 2004)³

9. The original INOT22 protocol designed by INO and the Steering Committee contained the following inclusion and exclusion criteria:

Inclusion Criteria

The patient must meet the following criteria:

1. *Have any one of the three disease categories:*

a. *Idiopathic Pulmonary Arterial Hypertension*

i. *PAPm >25mmHg at rest, PCWP ≤ 15mmHg, and PVRI >3 u·m² or diagnosed clinically with no previous catheterization.*

b. *CHD with pulmonary hypertension repaired and unrepaired,*

i. *PAPm >25mmHg at rest, and PVRI >3 u·m² or diagnosed clinically with no previous catheterization*

c. *Cardiomyopathy*

i. *PAPm >25mmHg at rest, and PVRI >3 u·m² or diagnosed clinically with no previous catheterization.*

2. *Scheduled to undergo right heart catheterization to assess pulmonary vasoreactivity by acute pulmonary vasodilation testing.*

3. *Males or females, ages 4 weeks to 18 years, inclusive.*

³ Cited in pending Office Action.

4. Signed IRB/IEC approved informed consent (and assent if applicable).

Exclusion Criteria

The patient will be excluded from enrollment if any of the following are true:

- 1. Focal pulmonary infiltrates on chest radiograph.*
- 2. Diagnosed with severe obstructive or restrictive pulmonary disease that is significantly contributing to the patient's pulmonary hypertension.*
- 3. Received treatment with nitric oxide for inhalation within 30 days prior to study initiation, are on other investigational medications, nitroglycerin, sodium nitroprusside, sildenafil, other PDE-5 inhibitors, or prostacyclin.*
- 4. Pregnant (urine HCG +).*

10. The INOT22 investigational plan and study protocol was further reviewed, and approved by the Institutional Review Board (IRB) and/or Independent Ethics Committee (IEC) at each of the participating study institutions, including review by the principal investigator within each study institution.

11. At no time did any member of the Steering Committee, nor any member of an IRB, IEC, or individual principal investigator, appreciate, recognize or otherwise suggest that the exclusion criteria be amended to exclude study subjects with pre-existing left ventricular dysfunction (LVD), due to an anticipated or predicted risk of adverse events or serious adverse events arising from the use of iNO in patients with pre-existing LVD, and/or elevated pulmonary capillary wedge pressure. Nor was it, in my expert opinion, common sense to any expert in this field of medicine to exclude neonates, near-term neonates or children diagnosed with pre-existing LVD to be excluded from having iNO administered for diagnostic or treatment purposes.

12. After initiation and enrollment of the first 24 subjects in INOT22, there were 5 serious adverse events (SAEs) – a rate much higher than expected by iNO and

the Steering Committee based on prior clinical experience. These were all cardiovascular events, and included pulmonary edema, cardiac arrest and hypotension (low blood pressure).

13. Thereafter, in February 2005, INO and the Steering Committee convened to review the unexpected SAEs described above, and upon review and discussion, expressed concern that the unexpected SAEs may be due to the administration of iNO in subjects having pre-existing LVD. Accordingly, based upon a review of the cases, the exclusion criteria of the INOT22 protocol was amended to thereafter exclude subjects with pre-existing LVD. For the purpose of the study, the exclusion criteria was amended to exclude subjects from enrollment if the subjects demonstrated an elevated pulmonary capillary wedge pressure (PCWP), defined within the study as subjects having a PCWP greater than 20 mmHg. All study sites were notified immediately. The amended exclusion criteria (see point 5.) was as follows:

Exclusion Criteria

The patient will be excluded from enrollment if any of the following are true:

1. *Focal pulmonary infiltrates on chest radiograph.*
2. *Diagnosed with severe obstructive or restrictive pulmonary disease that is significantly contributing to the patient's pulmonary hypertension.*
3. *Received treatment with nitric oxide for inhalation within 30 days prior to study initiation, are on other investigational medications, nitroglycerin, sodium nitroprusside, sildenafil, other PDE-5 inhibitors, or prostacyclin.*
4. *Pregnant (urine HCG +)*
5. *Baseline PCWP > 20 mmHg*

14. Upon conclusion of the INOT22 study and completion of the final study report, INO noted that subsequent to excluding patients with pre-existing LVD, the rate of serious adverse events (including serious adverse events associated with heart failure) was significantly reduced. There were 5 SAEs amongst the first 24 subjects

prior to the additional exclusion criteria, but only 2 SAEs amongst the last 80 subjects in the study after the additional exclusion. Furthermore, there were 2 SAEs amongst the 4 subjects with evidence of pre-existing left ventricular dysfunction, but only 5 SAEs amongst the 120 subjects without evidence of left ventricular dysfunction.

15. Based upon this unexpected finding, on February, 25, 2009, INO submitted a labeling supplement to the FDA seeking to amend the prescribing information for INOMAX to include a warning statement for physicians such that the use of iNO in patients with pre-existing LVD could cause serious adverse events, such as pulmonary edema.

16. On August 28, 2009, the FDA approved the INO labeling supplement and included (i) a statement in the Warnings and Precautions section of the INOMAX prescribing information that states "Heart Failure: In patients with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary capillary wedge pressure leading to pulmonary edema", and (ii) new section 5.4 of the INOMAX prescribing information that states "Patients who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced serious adverse events (e.g., pulmonary edema)."

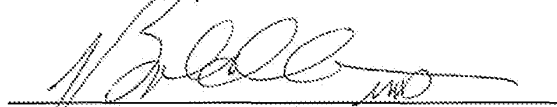
17. Based upon my review of the medical literature of record in this patent application and pending Office Action, none of the prior art suggests, appreciates or otherwise recognizes that exclusion of neonates, near-term neonates or children with LV dysfunction from administration of iNO for diagnostic or treatment purposes would reduce the risk of adverse events and/or serious adverse events, as such terminology is well understood in the medical arts.

Applicant : Baldassarre, James S.
Serial No. : 12/820,866
Filed : June 22, 2010
Page : 7 of 7

Attorney's Docket No.: I001-0002USC1

18. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of any patent issuing from this patent application.

Dated: Sept 29, 2010



James S. Baldassarre, M.D.

CURRICULUM VITAE

James S. Baldassarre, MD

HOME ADDRESS: 145 Pebble Woods Dr **PHONE:** 215-348-2835
Doylestown, Pa
18901

PERSONAL: Married (Susan Cohen-Baldassarre)
Children Alyssa (18), Julia (16) and Andrew (10)
Citizenship: USA

BUSINESS ADDRESS: **PHONE:** 908-238-6363
Ikaria/ INO Therapeutics
6 Route 1173
Clinton, NJ 08809

EDUCATION: S.U.N.Y. Downstate Medical Center
Brooklyn, NY
1986 - M.D.

S.U.N.Y., Binghamton, NY
1982 - Biology, B.S.

EMPLOYMENT:

2007- present	Ikaria (INO Therapeutics) VP, Clinical Research
2009-present	Project Team Leader: IK 5001
2008-2010	Project Team Leader: INOmax®
2003- 2007	INO Therapeutics Senior Director, Clinical Research
2003	Johnson & Johnson Pharmaceutical Research and Development LLC Compound Development Team Leader/Clinical Leader-REGRANEX®
2001-2003	Johnson & Johnson Pharmaceutical Research and Development LLC Senior Director, Operations Team Management
1999-2001	Janssen Research Foundation Director of Clinical Research Italy/Greece
1997 -1999	Janssen-Cilag Limited, UK Head of Clinical Research and Senior Medical Advisor
1993 - 1997	R.W. Johnson Pharmaceutical Research Institute Spring House, PA 1995-1997 Associate Director, Clinical Research 1993-1995 Assistant Director, Clinical Research
1992 - 1993	Presbyterian Medical Center Philadelphia, PA Attending Physician, Division of Infectious Diseases
1986 - 1993	Medical College of Pennsylvania Philadelphia, PA 1990-1993 Fellow, Division of Infectious Diseases 1989-1990 Medical Director (half time)

1986-1989 Internship/Residency Internal Medicine

1989 - 1990 **Philadelphia Department of Health**
Philadelphia, PA
Medical Director, Sexually Transmitted Diseases Clinic (half time)

ACADEMIC APPOINTMENT :

John Radcliffe Hospital, Oxford, UK

1999-2000 Honorary SHO, Dept of Clinical Pharmacology

Medical College of Pennsylvania, Philadelphia, USA

1994 - Clinical Assistant Professor, Department of Medicine

1991 - 1993 Instructor in Medicine

CERTIFICATION:

Diplomat, A.B.I.M.
Internal Medicine, 1989
Infectious Diseases, 1992
Limited GMC registration, 1999

EMPLOYMENT-RELATED ACTIVITIES/COMMITTEES:

RWJ-PRI Continuous Process Improvement Committee	1995-1996
Johnson & Johnson Signature of Quality submission	1997 and 1999
JJ PRD New Product Development Committee Implementation Team	2002-2003
Ikaria Opportunity Review Team	2007-present

PUBLICATIONS:

1. Levison M E and Baldassarre J S: Intra-Abdominal Infections. *Current Practice of Medicine* 1993.
2. Baldassarre J S and Abrutyn E: Antibiotic-Resistant Streptococcus pneumoniae. *Infectious Disease Practice* 1993; 17 (9).
3. Baldassarre J S and Abrutyn E: Genital Ulcer Disease. *Infectious Disease Practice* 1992; 16 (9); 1-7.
4. Levison M E and Baldassarre J S: Community Acquired Pneumonia: Time to Reassess Treatment Strategies. *Modern Med* 1992; 60:12 86-91.
5. Levison M E and Baldassarre J S: Community Acquired Pneumonia: Keys to Making the Diagnosis. *Modern Med* 1992; 60: 11 42-58.
6. Baldassarre J S, Ingerman M J, Nansteel J, and Santoro J: Development of Listeria Meningitis during Vancomycin Therapy: A Case Report. *J Infect Dis* 1991; 164: 221-222.
7. Baldassarre J S, Update on the Management of Sexually Transmitted Diseases. *Phila Med* 1991; 87-5 230-233.
8. Baldassarre J S and Kaye D: Special Problems in Urinary Tract Infection in the Elderly. *Med Clin North Am* 1991; 75:2 375-390.
9. Baldassarre J S, Johnson CC and Levison M E: Peritonitis: Update on Pathophysiology, Clinical Manifestations and Management. *Clinical Infectious Diseases* 1997; 24(6); 1035-47.

10. Baldassarre JS and Levison ME: Intra-abdominal Infections *Current Practice of Medicine* 1999, vol 2 (4)591-605
11. Baldassarre JS and Pledger GW Clinical Trial Design for New Antiepileptic Drugs: Determination of Dose and Titration Schedules *Rev Contemp Pharmacother* 1999; 10
12. E. Potapov, D. Meyer, M. Swaminathan, M. Ramsay, A. El Banayosy, C. Diehl et al. Use of Inhaled Nitric Oxide After Left Ventricular Assist Device Placement: Results of a Prospective, Randomized, Double-Blind, Multicenter, Placebo-Controlled Trial *J Heart Lung Transplant* 2010 accepted
13. Mercier JC, Hummler H, Durrmeyer X, Sanchez-Luna M, Carnielli V, Field D, Greenough A, Van Overmeire B, Jonsson B, Hallman M, Baldassarre J; EUNO Study Group. Inhaled nitric oxide for prevention of bronchopulmonary dysplasia in premature babies (EUNO): a randomised controlled trial. *Lancet*. 2010 Jul 31;376(9738):346-54.
14. Barst RJ, Agnoletti G, Fraise A, Baldassarre J, Wessel DL; NO Diagnostic Study Group. Vasodilator testing with nitric oxide and/or oxygen in pediatric pulmonary hypertension *Pediatr Cardiol*. 2010 Jul;31(5):598-606.

Book Chapters

Baldassarre J S and Kaye D: Principles and Overview of Antibiotic Use in Infective Endocarditis. In: Kaye D (ed) *Infective Endocarditis* 2nd ed. New York: Raven Press, 1992; 169-190.

Abstracts

1. Baldassarre J S and Stull T L: Cytosol-Mediated Ulcerogenesis in *Haemophilus ducreyi*. 1993 Annual Meeting of the Infectious Diseases Society of America, Abst #19, Oct. 16 and 17, 1993.
2. Sutherland J and Baldassarre JS : Mediastinal Adenopathy in a Patient with AIDS. American College of Physicians Regional Scientific Meetings, October 2, 1992.
3. Baldassarre J S and Stull T L: Characterization of Aminopeptidase (AP) Activity in *Haemophilus ducreyi*. American College of Physicians Regional Scientific Meetings, October 3, 1992.
4. Fontinella E, Dorfman M, Baldassarre J, Kaye D and Murasko D: Immune Response to Influenza Immunization in an Elderly Community Dwelling Africa American Population. *FASEB J* 1991 5: A1373 Abst 5814.
5. Doose DR, Walker SA, Baldassarre J. The effect of food on the oral bioavailability of topiramate from an investigational paediatric sprinkle formulation. *Epilepsia* 1997; 38(suppl 3):147.
6. Glauser TA, Olberding L, Clark P, Reife R, Baldassarre J, Conover D. Topiramate monotherapy substitution in children with partial epilepsy. *Epilepsia* 1996; 37(suppl 4):98.
7. JC Mercier, H. Hummler, X Durrmeyer, M. Sanchez-Luna, V Carnielli, D Field, A. Greenough, B. Van Overmeire, B Jonsson, M Hallman, J Baldassarre, for the EUNO Study Group. The effects of inhaled nitric oxide on the development of bronchopulmonary dysplasia (BPD) in preterm infants: the 'EUNO' multicentre randomised clinical trial. *European Academy of Pediatrics*; Nice, France October 2008
8. RJ Barst, G Agnoletti, A Fraise, J Baldassarre, DL Wessel. Nitric Oxide in Combination with Oxygen Versus Either Oxygen Alone or Nitric Oxide Alone for Acute Vasodilator Testing in Children with Pulmonary Hypertension: A Multicenter, Randomized Study. *Pediatric Academic Societies Scientific Meeting*, Baltimore Md; May 2009 [3861.195]
9. EV Potapov; D Meyer; M Swaminathan; M Ramsay; A El Banayosy; C Diehl; B Veynovich; ID Gregoric; J Baldassarre; M J Zucker; R Hetzer Use of Inhaled Nitric Oxide After Left Ventricular

Assist Device Placement: Results of a Prospective, Randomized, Double-Blind, Multicenter,
Placebo-Controlled Trial. American Heart Association Scientific Sessions Orlando, FL; Nov 2009
[3663]

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V Arnold
	Attorney Docket Number	I001-0002USC1

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	12820866
Filing Date	2010-06-22
First Named Inventor	James S. Baldassarre
Art Unit	1613
Examiner Name	Ernst V Arnold
Attorney Docket Number	I001-0002USC1

1	Cuthbertson et al., "UK guidelines for thee use of inhaled nitric oxide therapy in adults ICUs*", Intensive Care Med (1997), 23, Springer-Verlag, 1997, pp#1212-pp#1218	<input type="checkbox"/>
2	Ivy, et al., "Dipyridamole attenuates rebound pulmonary hypertension after inhaled nitric oxide withdrawal in postoperative congenital heart disease", J Thorac Cardiovasc Surg 1998; 115:875-882.	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	Date Considered
--------------------	-----------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	12820866		
Filing Date	2010-06-22		
First Named Inventor	James S. Baldassarre		
Art Unit	1613		
Examiner Name	Ernst V Arnold		
Attorney Docket Number	I001-0002USC1		

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).


OR

That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

- See attached certification statement.
- Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.
- None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature		Date (YYYY-MM-DD)	2010-10-01
Name/Print	Christopher P. Rogers	Registration Number	36,334

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Patent Application Fee Transmittal

Application Number:	12820866
Filing Date:	22-Jun-2010
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Filer:	Daniel Leo Hayes/Anna Goforth
Attorney Docket Number:	I001-0002USC1

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
Total in USD (\$)				180

Electronic Acknowledgement Receipt

EFS ID:	8544668
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Daniel Leo Hayes/Anna Goforth
Filer Authorized By:	Daniel Leo Hayes
Attorney Docket Number:	I001-0002USC1
Receipt Date:	01-OCT-2010
Filing Date:	22-JUN-2010
Time Stamp:	14:43:19
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$180
RAM confirmation Number	638
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
-----------------	----------------------	-----------	----------------------------------	------------------	------------------

1		O10343.PDF	291639	yes	28
			92f1e4bdb149172154de3c1f5718492af60f40a3		
Multipart Description/PDF files in .zip description					
		Document Description	Start	End	
		Accelerated Exam - Transmittal amendment/reply	1	1	
		Claims	2	5	
		Applicant Arguments/Remarks Made in an Amendment	6	27	
		Miscellaneous Incoming Letter	28	28	
Warnings:					
Information:					
2	Oath or Declaration filed	O10404.PDF	17158212	no	181
			7747cca95f83131e6e3d7e34ef6c8c1d31824a2e		
Warnings:					
Information:					
3	Oath or Declaration filed	O10410.PDF	1701683	no	11
			68bb24613c7eb381be457d7e989e8be49ec355ef		
Warnings:					
Information:					
4	Information Disclosure Statement (IDS) Filed (SB/08)	O10367.PDF	187769	no	3
			8ed452887bc4235e37710cf3799852caac194af7		
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
5	NPL Documents	lvy.pdf	176390	no	10
			0dd50795fee9d23bc1e794af9c662a0bf36bc529		
Warnings:					
Information:					
6	NPL Documents	Cuthbertson.pdf	1532031	no	7
			d23d88b2286c697f7135825f349e208b8d6c5701		
Warnings:					
Information:					
7	Fee Worksheet (PTO-875)	fee-info.pdf	30308	no	2
			3627367a7c54c6a2805173e940e9dae471a88f31		

Warnings:	
Information:	
Total Files Size (in bytes):	21078032
<p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p>	

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 12/820,866		Filing Date 06/22/2010		<input type="checkbox"/> To be Mailed							
APPLICATION AS FILED – PART I															
(Column 1)			(Column 2)			SMALL ENTITY <input checked="" type="checkbox"/>		OR		OTHER THAN SMALL ENTITY					
FOR		NUMBER FILED	NUMBER EXTRA		RATE (\$)	FEE (\$)	OR		RATE (\$)	FEE (\$)					
<input type="checkbox"/> BASIC FEE <small>(37 CFR 1.16(a), (b), or (c))</small>		N/A	N/A		N/A				N/A						
<input type="checkbox"/> SEARCH FEE <small>(37 CFR 1.16(k), (l), or (m))</small>		N/A	N/A		N/A		N/A								
<input type="checkbox"/> EXAMINATION FEE <small>(37 CFR 1.16(o), (p), or (q))</small>		N/A	N/A		N/A		N/A								
TOTAL CLAIMS <small>(37 CFR 1.16(i))</small>		minus 20 =	*		X \$ =		X \$ =								
INDEPENDENT CLAIMS <small>(37 CFR 1.16(h))</small>		minus 3 =	*		X \$ =		X \$ =								
<input type="checkbox"/> APPLICATION SIZE FEE <small>(37 CFR 1.16(s))</small>		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).													
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT <small>(37 CFR 1.16(j))</small>															
* If the difference in column 1 is less than zero, enter "0" in column 2.															
APPLICATION AS AMENDED – PART II															
(Column 1)			(Column 2)			(Column 3)			SMALL ENTITY		OR		OTHER THAN SMALL ENTITY		
AMENDMENT	10/01/2010	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)					
	Total <small>(37 CFR 1.16(o))</small>	* 19	Minus	** 20	= 0	X \$26 =	0	OR	X \$ =						
	Independent <small>(37 CFR 1.16(h))</small>	* 3	Minus	***3	= 0	X \$110 =	0	OR	X \$ =						
	<input type="checkbox"/> Application Size Fee <small>(37 CFR 1.16(s))</small>														
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <small>(37 CFR 1.16(j))</small>														
TOTAL ADD'L FEE										0		OR		TOTAL ADD'L FEE	
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)					
	Total <small>(37 CFR 1.16(o))</small>	*	Minus	**	=	X \$ =		OR	X \$ =						
	Independent <small>(37 CFR 1.16(h))</small>	*	Minus	***	=	X \$ =		OR	X \$ =						
	<input type="checkbox"/> Application Size Fee <small>(37 CFR 1.16(s))</small>														
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <small>(37 CFR 1.16(j))</small>														
TOTAL ADD'L FEE												OR		TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.															
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".															
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".															
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.															
Legal Instrument Examiner: /EVELYN G. NIMMONS/															

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/820,866	06/22/2010	James S. Baldassarre	I001-0002USC1	2913
49584	7590	11/02/2010	EXAMINER	
LEE & HAYES, PLLC 601 W. RIVERSIDE AVENUE SUITE 1400 SPOKANE, WA 99201			ARNOLD, ERNST V	
			ART UNIT	PAPER NUMBER
			1613	
			MAIL DATE	DELIVERY MODE
			11/02/2010	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 12/820,866	Applicant(s) BALDASSARRE ET AL.	
	Examiner ERNST V. ARNOLD	Art Unit 1613	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) Responsive to communication(s) filed on 01 October 2010.
- 2a) This action is **FINAL**. 2b) This action is non-final.
- 3) Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) Claim(s) 1-19 is/are pending in the application.
4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) Claim(s) _____ is/are allowed.
- 6) Claim(s) 1-19 is/are rejected.
- 7) Claim(s) _____ is/are objected to.
- 8) Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) The specification is objected to by the Examiner.
- 10) The drawing(s) filed on _____ is/are: a) accepted or b) objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) All b) Some * c) None of:
1. Certified copies of the priority documents have been received.
2. Certified copies of the priority documents have been received in Application No. _____.
3. Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
- * See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|--|---|
| 1) <input type="checkbox"/> Notice of References Cited (PTO-892) | 4) <input type="checkbox"/> Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____ |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948) | 5) <input type="checkbox"/> Notice of Informal Patent Application |
| 3) <input checked="" type="checkbox"/> Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date <u>10/1/10</u> . | 6) <input type="checkbox"/> Other: _____ |

DETAILED ACTION

Claims 1-19 are pending and under examination.

Information Disclosure Statement

The information disclosure statement (IDS) submitted on 10/1/10 was filed after the mailing date of the Office Action on 9/23/10. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

Withdrawn rejections:

Applicant's amendments and arguments filed 10/1/10 are acknowledged and have been fully considered. Any rejection and/or objection not specifically addressed below is herein withdrawn. Claims 1-19 were rejected under 35 U.S.C. 112, second paragraph. Applicant has shown that the art recognizes 'adverse events' and 'serious adverse events' as two separate 'events'. The terminology is now clear on the record and the rejection is withdrawn. Claims 11-19 were rejected under 35 U.S.C. 112, first paragraph. Applicant's have amended the claims to overcome this rejection. Accordingly, the rejection is withdrawn. Claims 3, 6, 11 and 15 were rejected under 35 U.S.C. 102(b) as being anticipated by The NIH (Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, May 2000, 13 pages). Applicant has amended the claims and changed the claim dependency and the rejection over these claims is withdrawn. Claims 1, 3, 5, 6, 11, 13 and 15 were rejected under 35 U.S.C. 102(b) as being anticipated by Kinsella et al.

Art Unit: 1613

(The Lancet 1999, 354, 1061-1065). Applicant has argued and amended the claims and changed the claim dependency and the rejection over these claims is withdrawn. Claims 3, 5, 6, 11, 13 and 15 were rejected under 35 U.S.C. 102(b) as being anticipated by Atz et al. (Seminars in Perinatology 1997, 21(5), pp 441-455). Applicant has amended the claims and changed the claim dependency and the rejection over these claims is withdrawn.

The following rejections and/or objections are either reiterated or newly applied. They constitute the complete set of rejections and/or objections presently being applied to the instant application.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

Claims 1 remains rejected under 35 U.S.C. 102(b) as being anticipated by The NIH (Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, May 2000, 13 pages).

The NIH (Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, May 2000, 13 pages) discloses that administration of NO has been approved for use in the treatment of term or near term neonates and that that inhaled NO therapy is relative contraindicated for patients with severe left ventricular failure and to beware of increased left ventricular filling associated with rapid changes in pulmonary pressures

Art Unit: 1613

(pages 2-3 of 13). A contraindication means literally contra- (against) an indication, against something that is indicated as advisable or necessary and a relative contraindication is a condition which makes a particular treatment or procedure inadvisable but does not rule it out. Therefore, in reading the guidelines set forth by the NIH one of ordinary skill in the art would practice the instant method by identifying a patient eligible for iNO treatment and then diagnosing/evaluating/screening/determining for a pre-existing left ventricular dysfunction in the patient and if present exclude the neonate from treatment to avoid/reduce the risk of the adverse events/hazards/complications but administer the treatment if the patient is not contraindicated. Claim 1 is therefore anticipated.

Response to arguments:

Applicant asserts that the Magnuson Clinical Center does not have a neonatal intensive care unit. This is irrelevant. The NIH (Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy) teaches that neonates are the target population for iNO treatment. “NO has been approved for use in the treatment of term or near term (> 34 weeks) neonates...” (page 2 of 13; 3.1 Administration of NO in the MICU).

Applicant asserts that the NIH reference does not teach elevated PCWP or PCWP > 20 mmHg. This is irrelevant. Claim 1 does not recite this limitation either.

Applicant notes, as did the Examiner, that iNO is a relative contraindication for severe left ventricular failure. Applicant erroneously concludes that this does not apply to children because the hospital does not have a neonatal ICU. The Examiner cannot agree because the NIH manual states that neonates are the approved patient population as discussed above.

Applicant asserts the reference is nonenabling and does not exclude children from receiving iNO where such children have LVD, elevated PCWP or PCWP > 20 mmHg and it fails to mention reducing the risk of adverse events or serious adverse events. Respectfully, the Examiner cannot agree. The PCWP is not a limitation of claim 1. The manual clearly sets forth iNO as a relative contraindication with the consequence of adverse events from its use. That is what **HAZARDS/COMPLICATIONS** means (see page 3 of 13). Applicant argues that one would not add NaCl to water unless the reference teaches the act of adding NaCl to water. Somehow this applies to the NIH reference allegedly not stating *ipsis verbis* excluding children with pre-existing LVD. As explained by the Examiner, a relative contraindication makes the treatment inadvisable but does not rule it out. If something is inadvisable then the practitioner can exclude the treatment. This is inherent in the term. As stated above, the ordinary practitioner in reading the guidelines set forth by the NIH one of ordinary skill in the art would practice the instant method by identifying a patient eligible for iNO treatment and then diagnosing/evaluating/screening/determining for a pre-existing left ventricular dysfunction in the patient and if present exclude the neonate from treatment to avoid/reduce the risk of the adverse events/hazards/complications but administer the treatment if the patient is not contraindicated. This is inherent in the disclosure of the NIH.

Applicant's arguments are not persuasive and the rejection is maintained.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

Claims 1 remains rejected under 35 U.S.C. 102(b) as being anticipated by Atz et al. (Seminars in Perinatology 1997, 21(5), pp 441-455).

Atz et al. disclose methods using inhaled nitric oxide in the neonate with cardiac disease (title and Abstract pages 441-453). Atz et al. disclose that: “Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension.” (page 452, left column). Atz et al. continues with: “Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale and exclusively right to left shunting at the ductus arteriosus, **NO should be used with extreme caution, if at all.** We and others have reported **adverse outcomes** in this circumstance.” (page 452, left column) (Examiner added emphasis). Thus, Atz et al. fairly teaches excluding patients with left ventricular dysfunction from inhaled NO treatment because the Examiner interprets “if at all” to mean no treatment and hence exclusion from treatment and consequently any adverse events are reduced. The left ventricular dysfunction is inherently pre-existing and therefore instant claim 1 is anticipated.

Response to arguments:

Applicant asserts that “extreme caution” is not the same as 'excluding' and the recitation of “if at all” is at odds with the data provided. The Examiner has stated clearly

Art Unit: 1613

how the Examiner interpreted 'if at all' to mean no treatment and hence exclusion from treatment and consequently any adverse events are reduced. The rejection over claims reciting elevated PCWP or PCWP > 20 mmg Hg have been withdrawn. However, claim 1 does not recite these limitations and the rejection is maintained.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

Claims 1-19 remain/are rejected under 35 U.S.C. 103(a) as being unpatentable over Atz et al. (Seminars in Perinatology 1997, 21(5), pp 441-455) and Kinsella et al. (The Lancet 1999, 354, 1061-1065) and Bolooki (Clinical Application of the Intra-Aortic Balloon Pump 1998, 3rd Ed. Pp 252-253) and Loh et al. (Circulation 1994, 90, 2780-2785) and The NIH (Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, May 2000, 13 pages).

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Applicant claim, for example:

1. (Presently Amended) A method of reducing the risk of one or more adverse events or serious adverse events in an intended patient population comprising neonates or near-term neonates in need of being treated with inhalation of nitric oxide comprising excluding from such treatment anyone in the intended patient population having pre-existing left ventricular dysfunction.

2. (Presently Amended) ~~The method of claim 1;~~ A method of reducing the risk of one or more adverse events or serious adverse events in an intended patient population comprising neonates or near-term neonates in need of being treated with inhalation of nitric oxide comprising excluding from such treatment anyone in the intended patient population having pre-existing left ventricular dysfunction, wherein anyone in the intended patient population further has a pulmonary capillary wedge pressure greater than 20 mm Hg.

Determination of the scope and content of the prior art

(MPEP 2141.01)

Atz et al. teach methods using inhaled nitric oxide in the neonate with cardiac disease (title and Abstract). Atz et al. teach that: "Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension." (page 452, left column). Atz et al. continues with: "Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale and exclusively right to left shunting at the ductus arteriosus, **NO should be used with extreme caution, if at all.** We and others have reported **adverse outcomes** in this circumstance." (page 452, left column) (Examiner added emphasis). Thus, Atz et al. fairly teaches excluding patients with left ventricular dysfunction from inhaled NO treatment because the Examiner interprets "if at all" to mean no treatment and hence exclusion from treatment. The left ventricular dysfunction is intrinsically pre-existing. The methods disclosed by Atz et al. are interpreted to mean identifying a patient eligible for NO treatment; diagnosing if the patient has left ventricular dysfunction; excluding that patient with left ventricular dysfunction from treatment with NO but treating the patient with NO for other conditions discussed by Atz et al. with inhalation of NO thereby reducing the risk of adverse events associated with the medical treatment. Atz et al. teach neonates with pulmonary hypertension (Abstract and page 442, left column to right column).

Bolooki teaches using intra-aortic balloon pump as well as nitroglycerin and calcium channel blockers in the treatment of left ventricular dysfunction (pages 252-253).

The NIH (Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, May 2000, 13 pages) establishes that inhaled NO therapy is relative contraindicated for patients with severe left ventricular failure and to beware of increased

Art Unit: 1613

left ventricular filling associated with rapid changes in pulmonary pressures (pages 2-3 of 13). Thus, it is a medical mainstream concept that inhaled NO therapy is relative contraindicated for patients with left ventricular dysfunction.

Kinsella et al. teach excluding patients (premature neonates) from inhaled nitric oxide treatment if they have fatal congenital anomalies or congenital heart disease (Abstract and page 1062, Methods). Since left ventricular dysfunction is a congenital heart disease, as acknowledged by Applicant, (see specification [0028]), and it would be pre-existing, then the methods of Kinsella et al. inherently exclude this patient population from the method. The patients also had pulmonary hypertension which would be associated with the cardiac function (Abstract). Thus, one or more adverse events are reduced in the neonates excluded from the method. The neonate must breathe oxygen to survive. Furthermore, if the patients are already excluded then any further limitations on the treatment are truly irrelevant. The intended patient population is inherently at risk of one or more adverse events. Patients are inherently identified for nitric oxide inhalation treatment, diagnosed for congenital heart disease which inherently includes left ventricular dysfunction, and if the patient meets the criteria than treatment with NO is performed thereby reducing the risk of adverse events associated with the treatment. The neonate must breathe oxygen to survive.

Loh et al. teach that inhaled nitric oxide in patients with left ventricular dysfunction may have adverse effects in patients with LV failure (Title and Abstract).

Ascertainment of the difference between the prior art and the claims

(MPEP 2141.02)

1. The difference between the instant application and Atz et al. is that Atz et al. do not expressly teach a method of excluding patients from treatment with a pulmonary capillary wedge pressure greater than 20 mm Hg or using a ventilator for the treatment or idiopathic pulmonary arterial hypertension/congenital heart disease/cardiomyopathy or catheterization characterized by different means. This deficiency in Atz et al. is cured by the teachings of Kinsella et al., Loh et al., The NIH and common sense.

2. The difference between the instant application and Atz et al. is that Atz et al. do not expressly teach: reducing the left ventricular afterload with nitroglycerin, calcium channel blocker or intra-aortic balloon pump such that pulmonary edema is reduced/minimized. This deficiency in Atz et al. is cured by the teachings of Bolooki.

Finding of prima facie obviousness

Rational and Motivation (MPEP 2142-2143)

1. It would have been obvious to one of ordinary skill in the art at the time the claimed invention was made to perform the method of Atz et al. and exclude patients with left ventricular dysfunction wherein the intended patient population is excluded that has a pulmonary capillary wedge pressure greater than 20 mm Hg or using a ventilator for the treatment or idiopathic pulmonary arterial hypertension/congenital heart disease/cardiomyopathy or catheterization characterized by different means, as suggested by Loh et al., the NIH and Kinsella et al., and produce the instant invention.

One of ordinary skill in the art would have been motivated to do this because Atz et al. clearly teach using extreme caution or not using NO at all in the treatment of

Art Unit: 1613

patients with left ventricular dysfunction and the art of Kinsella et al. establishes excluding certain patients from treatment. Furthermore, the NIH teaches that inhaled NO therapy is relative contraindicated for patients with left ventricular dysfunction. **In other words, the art is already well aware and informed that inhaled NO is contraindicated for patients with left ventricular dysfunction, and consequently it is not inventive to exclude that patient population from treatment when the art already suggests it!** Thus it is no stretch of the imagination to exclude patients with left ventricular dysfunction with or without the myriad number of other conditions characterized by various medical parameters claimed by Applicant from inhaled nitric oxide therapy in order to avoid adverse outcomes as taught by Atz et al. which intrinsically include all the adverse events recited by Applicant. The ordinary artisan would err on the side of caution for the benefit of the patient. Such patients intrinsically have a pulmonary capillary wedge pressure of greater than 20 mm Hg. In other words, the teachings of Atz et al. include the patients with left ventricular dysfunction intrinsically that have a pulmonary capillary wedge pressure of greater than 20 mm Hg. Inhaled NO increased the wedge pressure as taught by Loh et al. (see entire document) Furthermore, it is merely a design choice by the ordinary artisan to select a ventilator to administer the gas. This is just common sense. Furthermore, with respect to instant claims 3 and 4, if the patients are already excluded from treatment then any further limitations on the treatment are truly irrelevant.

2. It would have been obvious to one of ordinary skill in the art at the time the claimed invention was made to reducing the left ventricular afterload with nitroglycerin, calcium channel blocker or intra-aortic balloon pump such that pulmonary edema is reduced/minimized, as suggested by Bolooki, and produce the instant invention.

One of ordinary skill in the art would have been motivated to do this because administration of nitroglycerin, calcium channel blocker or intra-aortic balloon pump to treat left ventricular dysfunction is a common technique in the art as taught by Bolooki and intrinsically reduces the left ventricular afterload and reduces pulmonary edema.

In light of the forgoing discussion, the Examiner concludes that the subject matter defined by the instant claims would have been obvious within the meaning of 35 USC 103(a).

From the teachings of the references, it is apparent that one of ordinary skill in the art would have had a reasonable expectation of success in producing the claimed invention. Therefore, the invention as a whole was *prima facie* obvious to one of ordinary skill in the art at the time the invention was made, as evidenced by the references, especially in the absence of evidence to the contrary.

Response to arguments:

Please note that the Declarations of Smith and Baldassarre will be addressed with the arguments below.

Applicant first discusses the INOT22 study designed by international experts in the field of pediatric heart and lung disease. The original NOT22 protocol did not exclude patients with pre-existing LVD. Applicant states that at no time did any member appreciate, recognize or otherwise suggest that the exclusion criteria be amended to exclude study subjects with pre-existing LVD due to an anticipated or predicted risk of adverse events or serious adverse events arising from the use of iNO in patients with pre-existing LVD and/or elevated capillary wedge pressure. This is really irrelevant because:

- 1) the Examiner is not citing INOT22 study as prior art and therefore whatever the panel

Art Unit: 1613

of experts failed to appreciate or recognize is moot; and 2) the preponderance of art cited by the Examiner (in the 103 rejection here as well the art made of record), especially Atz et al., fairly teaches excluding patients with left ventricular dysfunction from inhaled NO treatment because the Examiner interprets “if at all” to mean no treatment and hence exclusion from treatment. Applicant acts surprised that patients with pre-existing LVD were at risk of adverse or serious adverse events from iNO therapy but the art has already established such knowledge. Applicant states that Dr. Baldassarre did not anticipate or predict that patients with pre-existing LVD would be at risk of adverse events or serious adverse events arising from treatment with iNO and that one of skill in the art at the time of the invention would not have predicted or anticipated that patients with pre-existing LVD would be at risk of adverse events or serious adverse events arising from treatment with iNO. This is simply ignoring the art as a whole. This position by Applicant is especially problematic when the art, Loh et al., clearly teaches that patients with pulmonary artery wedge pressure, which is synonymous with the instantly claimed pulmonary capillary wedge pressure, ***of greater than or equal to 18 mm Hg*** had a greater effect of inhaled NO due to the greater degree of reactive pulmonary hypertension present in such patients (page 2784, left column). Loh et al. state: *"Since the degree of reactive pulmonary hypertension is generally related to the severity of hemodynamic compromise in patients with LV failure, it might be anticipated that patients with more severe heart failure will have a more marked hemodynamic response to inhaled NO."* Loh et al. examined this prediction further and verified it (page 2784, left column). Therefore, contrary to Applicant's assertion that “one of skill in the art at the time of the invention would not have predicted or anticipated that patients with pre-existing LVD

Art Unit: 1613

would be at risk of adverse events or serious adverse events arising from treatment with iNO” the art in 1994 already **anticipated** and **predicted** adverse effects in patients with LV failure from inhaled NO (p 2780, Abstract).

Applicant then argues that Loh et al. is directed to adults and not children. This is correct. Applicant and Smith asserts that iNO clinical studies in adults cannot be extrapolated to children, neonates or near-term neonates. Applicant and Smith concludes that the teachings of Loh et al. are irrelevant to the instantly claimed invention.

Respectfully, the Examiner cannot agree. The art is not examined in a vacuum but rather as a whole. The Lipshultz article is a review of current issues in clinical research and teaches that children are not small adults. Applicant and Smith construe this article to mean that iNO clinical studies involving adults cannot be extrapolated to children, neonates or near-term neonates. This is an invalid conclusion. Nowhere in Lipshultz does it say never to extrapolate iNO clinical studies on adults to children with LVD. However, these arguments are moot because the art has already performed iNO therapy on neonates as discussed above and observed adverse effects. In other words, the Examiner gives no weight to the reference of Lipshultz given the preponderance of art as a whole.

Applicant argues that none of the references mentions or recognizes using pre-existing LVD, elevated LVD or PCWP>20 mmHg as exclusionary criteria. Respectfully, the examiner cannot agree because at least Loh et al. teach predicting adverse effects in patients with pulmonary capillary wedge pressure, ***of greater than or equal to 18 mm Hg*** as discussed above. It stands to reason that adults with pulmonary capillary wedge pressure of greater than or equal to 18 mm Hg have adverse effects from iNO and that neonates are subject to adverse effects from iNO then neonates with pulmonary capillary

wedge pressure of greater than or equal to 18 mm Hg are also prone to adverse effects with iNO. It is simply not inventive to exclude those patients at increased risk from iNO therapy when the art already teaches that they are at risk of adverse events. This is not surprising or unexpected given the art as a whole.

Applicant continues to argue that if experts did not recognize or anticipate adverse events associated with the use of iNO in patients with pre-existing LVD then the level of skill is presumptively extraordinary skill and it is that much more surprising and supportive of the non-obviousness of the claims. Respectfully, the Examiner cannot agree given the art as a whole as explained above. The Examiner cannot control what the 'experts' read and apply to their studies but the art clearly teaches adverse effects in neonates from iNO therapy was public knowledge. At most what Applicant has done is practice/confirm what was already known in the art.

Respectfully, after consultation with supervisory patent examiner Brain Kwon and quality assurance specialist Jean Vollano, we are in agreement that these arguments, Declarations and amendments are not persuasive to overcome the rejection.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the

Art Unit: 1613

reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

1. Claims 1-19 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1-19 of copending Application No. 12/820980. Although the conflicting claims are not identical, they are not patentably distinct from each other because the instant subject matter embraces or is embraced by the subject matter of the copending subject matter. Both applications are drawn to methods of reducing one or more adverse events in a patient population by excluding from treatment anyone with pre-existing left ventricular dysfunction.

The copending application does not expressly teach near-term neonates or neonates.

However the copending broadly teaches children patient population which would include neonates and near-term neonates as clearly neonates are children. The instant specification defines 'children' as being 4 weeks old [0023] which would be newborn and hence neonatal.

Therefore one of ordinary skill in the art would have recognized the obvious variation of the instant application over the copending application.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

2. Claims 1-19 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1-20 of copending Application No. 12/821020. Although the conflicting claims are not identical, they are not patentably distinct from each other because the instant subject matter embraces or is embraced by the subject matter of the copending subject matter. Both applications are drawn to methods of reducing one or more adverse events in a patient population by excluding from treatment anyone with pre-existing left ventricular dysfunction.

The copending application does not expressly teach the intended population as having one or more conditions.

However the copending application is drawn to the same patient population which intrinsically has one or more conditions as instantly claimed.

Therefore one of ordinary skill in the art would have recognized the obvious variation of the instant application over the copending application.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

3. Claims 1-19 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1-20 of copending Application No. 12/821041. Although the conflicting claims are not identical, they are not patentably distinct from each other because the instant subject matter embraces or is embraced by the subject matter of the copending subject matter. Both applications are drawn to methods of reducing one or more adverse events in a patient population by excluding from treatment anyone with pre-existing left ventricular dysfunction.

The copending application does not expressly teach the intended population as having one or more conditions.

However the copending application is drawn to the same patient population which intrinsically has one or more conditions as instantly claimed.

Therefore one of ordinary skill in the art would have recognized the obvious variation of the instant application over the copending application.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

Response to arguments:

Applicant will file a terminal disclaimer upon allowance of the instant application. Until that time the claims remain rejected.

Conclusion

No claims are allowed.

Applicant is reminded that for any amendments to the claims (including any new claim) that is not encompassed by the preexamination search and accelerated examination support documents previously filed, applicant is required to provide updated preexamination search and accelerated examination support documents that encompass the amended or new claims at the time of filing the amendment. Failure to provide such updated preexamination search and accelerated examination support documents at the time of filing the amendment will cause the amendment to be treated as not fully responsive and not to be entered. See MPEP § 708.02(a) subsection VIII.D. for more information.

If the reply is not fully responsive, the final disposition of the application may occur later than twelve months from the filing of the application.

Any reply or other papers must be filed electronically via EFS-Web so that the papers will be expeditiously processed and considered. If the papers are not filed electronically via EFS-Web, the final disposition of the application may occur later than twelve months from the filing of the application.

Any reply to this communication filed via EFS-Web must include a document that is filed using the document description of "Accelerated Exam - Transmittal amendment/reply." Applicant is reminded to use proper indexing for documents to avoid any delay in processing of follow on papers. Currently document indexing is not automated in EFS-Web and applicant must select a particular document description for

each attached file. An incorrect document description for a particular file may potentially delay processing of the application. A complete listing of all document codes currently supported in EFS-Web is available at http://www.uspto.gov/ebc/portal/efs/efswweb_document_descriptions.xls.

Any payment of fees via EFS-Web must be accompanied by selection of a proper fee code. An improper fee code may potentially delay processing of the application. Instructions on payment of fees via EFS-Web are available at <http://www.uspto.gov/ebc/portal/efs/quick-start.pdf>.

Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).


A shortened statutory period for reply to this final action is set to expire **THREE MONTHS** from the mailing date of this action. In the event a first reply is filed within **TWO MONTHS** of the mailing date of this final action and the advisory action is not mailed until after the end of the **THREE-MONTH** shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than **SIX MONTHS** from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to ERNST V. ARNOLD whose telephone number is (571)272-8509. The examiner can normally be reached on M-F 7:15-4:45.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Brian Kwon can be reached on 571-272-0581. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Ernst V Arnold/
Primary Examiner, Art Unit 1613

Search Notes 	Application/Control No. 12820866	Applicant(s)/Patent Under Reexamination BALDASSARRE ET AL.
	Examiner ERNST V ARNOLD	Art Unit 1616

SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
inventor name EAST/PALM	8/10/10	eva
EAST 424/718 text limited all databases	8/10/10	eva
google	8/10/10	eva
consultation Brian Kwon SPE 1613 and Jean Vollano QAS	10/24/10	eva

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

--	--

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V Arnold
	Attorney Docket Number	I001-0002USC1

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866
	Filing Date		2010-06-22
	First Named Inventor	James S. Baldassarre	
	Art Unit	1613	
	Examiner Name	Ernst V Arnold	
	Attorney Docket Number	I001-0002USC1	

/E.A./	1	Cuthbertson et al., "UK guidelines for thee use of inhaled nitric oxide therapy in adults ICUs*", Intensive Care Med (1997), 23, Springer-Verlag, 1997, pp#1212-pp#1218	<input type="checkbox"/>
/E.A./	2	Ivy, et al., "Dipyridamole attenuates rebound pulmonary hypertension after inhaled nitric oxide withdrawal in postoperative congenital heart disease", J Thorac Cardiovasc Surg 1998; 115:875-882.	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Ernst Arnold/	Date Considered	10/25/2010
--------------------	----------------	-----------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
 United States Patent and Trademark Office
 Address: COMMISSIONER FOR PATENTS
 P.O. Box 1450
 Alexandria, Virginia 22313-1450
 www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 2913

SERIAL NUMBER 12/820,866	FILING or 371(c) DATE 06/22/2010	CLASS 514	GROUP ART UNIT 1613	ATTORNEY DOCKET NO. 1001-0002USC1		
APPLICANTS James S. Baldassarre, Doylestown, PA; Ralf Rosskamp, Chester, NJ;						
** CONTINUING DATA ***** This application is a CON of 12/494,598 06/30/2009 ABN						
** FOREIGN APPLICATIONS *****						
** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** ** SMALL ENTITY ** 06/24/2010						
Foreign Priority claimed <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	35 USC 119(a-d) conditions met <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	<input type="checkbox"/> Met after Allowance Initials	STATE OR COUNTRY PA	SHEETS DRAWINGS 0	TOTAL CLAIMS 19	INDEPENDENT CLAIMS 2
ADDRESS LEE & HAYES, PLLC 601 W. RIVERSIDE AVENUE SUITE 1400 SPOKANE, WA 99201 UNITED STATES						
TITLE METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION						
FILING FEE RECEIVED 462	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		<input type="checkbox"/> All Fees <input type="checkbox"/> 1.16 Fees (Filing) <input type="checkbox"/> 1.17 Fees (Processing Ext. of time) <input type="checkbox"/> 1.18 Fees (Issue) <input type="checkbox"/> Other _____ <input type="checkbox"/> Credit			

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866	
	Filing Date		2010-06-22	
	First Named Inventor	James S. Baldassarre		
	Art Unit	1613		
	Examiner Name	Ernst V Arnold		
	Attorney Docket Number	I001-0002USC1		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² i	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866
	Filing Date		2010-06-22
	First Named Inventor	James S. Baldassarre	
	Art Unit		1613
	Examiner Name	Ernst V Arnold	
	Attorney Docket Number		I001-0002USC1

1	Comparison of Supplemental Oxygen and Nitric Oxide for Inhalation in the Evaluation of the Reactivity of the Pulmonary Vasculature During Acute Pulmonary Vasodilator Testing, http://clinicaltrials.gov/archive/NCT00626028/2009_01_12 January 12, 2009	<input type="checkbox"/>
2	INO Therapeutics, LLC, "INOflo for Inhalation 800ppm", package leaflet, 2010, 2	<input type="checkbox"/>
3	Notification of Reason for Rejection, mailed 7/30/2010, from Japanese Patent Application No. 2009-157623 (cites foreign references).	<input type="checkbox"/>
4	Yoshida, Kiyoshi, " Well-illustrated Diagnostics and Treatment of Heart Failure" Professor of Kawasaki Medical University, cardiovascular internal medicine CIRCULATION Up-to-Date Vol. 2, No. 4, 2007(343), pp. 23-28	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Christopher P. Rogers, Reg. No. 36,334/	Date Considered	2010-11-03
--------------------	--	-----------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V Arnold
	Attorney Docket Number	I001-0002USC1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature		Date (YYYY-MM-DD)	2010-11-03
Name/Print	Christopher P. Rogers	Registration Number	36,334

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt

EFS ID:	8764697
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Daniel Leo Hayes
Filer Authorized By:	
Attorney Docket Number:	I001-0002USC1
Receipt Date:	03-NOV-2010
Filing Date:	22-JUN-2010
Time Stamp:	18:34:13
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	IDS.pdf	38279 <small>68f2053eaf4ef35bb8c7f02db0053557be360abb</small>	no	4

Warnings:

Information:

This is not an USPTO supplied IDS fillable form					
2	NPL Documents	O86044.pdf	153932 96945d60944cf4e06475c57b2ccf5d35497f2fcf	no	4
Warnings:					
Information:					
3	NPL Documents	O86037.pdf	369742 4a332bd82d6f9a661ba2a15ce0e7b15d484387f	no	5
Warnings:					
Information:					
4	NPL Documents	NQ3600.PDF	200468 a68c776d620b936d03dc2d345e1aff6fa8daa817	no	8
Warnings:					
Information:					
5	NPL Documents	O86041.pdf	727722 40545b06db1277e5c6aa458c60f1a65408c4503a	no	7
Warnings:					
Information:					
Total Files Size (in bytes):			1490143		
<p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p>					



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

Table with 4 columns: APPLICATION NUMBER (12/820,866), FILING OR 371(C) DATE (06/22/2010), FIRST NAMED APPLICANT (James S. Baldassarre), ATTY. DOCKET NO./TITLE (I001-0002USC1)

CONFIRMATION NO. 2913

PUBLICATION NOTICE

49584
LEE & HAYES, PLLC
601 W. RIVERSIDE AVENUE
SUITE 1400
SPOKANE, WA 99201



Title:METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION

Publication No.US-2010-0330206-A1

Publication Date:12/30/2010

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publicly available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

AUTHORIZATION TO ACT IN A REPRESENTATIVE CAPACITY

In re Application of: James S. Baldassarre et al.	
Application No. 12/820,866	
Filed: 06/22/2010	
Title: METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION	
Attorney Docket No. I001-0002USC1	Art Unit: 1613

The practitioner named below is authorized to conduct interviews and has the authority to bind the principal concerned. (Note: pursuant to 37 CFR 10.57(c), a practitioner cannot authorize other registered practitioners to conduct interviews without consent of the client after full disclosure.) Furthermore, the practitioner is authorized to file correspondence in the above-identified application pursuant to 37 CFR 1.34:

Name	Registration Number
Jonathan N. Provoost	44,292
Henry C. Lebowitz	36,196

This is not a Power of Attorney to the above-named practitioner. Accordingly, the practitioner named above does **not** have authority to sign a request to change the correspondence address, a request for an express abandonment, a disclaimer, a power of attorney, or other document requiring the signature of the applicant, assignee of the entire interest or an attorney of record. If appropriate, a separate Power of Attorney to the above-named practitioner should be executed and filed in the United States Patent and Trademark Office.

SIGNATURE of Practitioner of Record

Signature	/Christopher P. Rogers, Reg. No. 36,334/	Date	January 5, 2011
Name	Christopher P. Rogers	Registration No., if applicable	36,334
Telephone	509-944-4785		

This collection of information is required by 1.31, 1.32 and 1.34. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	9170342
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Daniel Leo Hayes/Jennifer Phipps
Filer Authorized By:	Daniel Leo Hayes
Attorney Docket Number:	I001-0002USC1
Receipt Date:	05-JAN-2011
Filing Date:	22-JUN-2010
Time Stamp:	15:52:38
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Miscellaneous Incoming Letter	P39312.PDF	43275 <small>dcd72d6d4e614c47e1c7b5aa6eebc990538b14f</small>	no	1

Warnings:

Information:

Total Files Size (in bytes):

43275

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop After Final Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REPLY AFTER FINAL (37 CFR 1.116)
ACCELERATED EXAM – TRANSMITTAL REPLY

This communication is responsive to the Final Office Action mailed November 2, 2010, setting a shortened statutory period for reply of 3 months.

Applicant respectfully requests entry of this Reply After Final, reconsideration of the pending rejections, and allowance of the application. A listing of the claims and amendments thereof is shown starting at page 2.

Applicant further asserts that this Reply After Final has been diligently filed and that the application is in compliance with MPEP 708.02(a)(IV) After-Final and Appeal Procedures, thus maintaining the application's status as an accelerated application.

Remarks to the pending Office Action begin at page 4.

Amendments to the Claims

Please cancel claims 1-10 and 12-19. In addition, amend claim 11 and add new claims 20-22.

1-10. Canceled.

11. (Twice Amended) A method of reducing the risk of the occurrence, in a patient under the age of 18 ~~being a neonate or near-term neonate~~, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide, said method comprising:

(a) identifying a patient under the age of 18 who is eligible for inhalation of to receive inhaled nitric oxide treatment according to FDA-approved prescribing information;

(b) determining if said eligible patient has pre-existing left ventricular dysfunction ~~evidenced by an elevated pulmonary capillary wedge pressure~~; and,

(c) administering said inhaled nitric oxide medical treatment to said eligible patient if said eligible patient does not have pre-existing left ventricular dysfunction, ~~wherein said patient is excluded from being administered said medical treatment if said patient has pre-existing left ventricular dysfunction~~; and

(d) not administering said inhaled nitric oxide to said eligible patient if said eligible patient has pre-existing left ventricular dysfunction in order to reduce thereby reducing the risk of the occurrence of the adverse event or serious adverse event associated with said inhaled nitric oxide medical treatment.

12-19. Canceled.

20. (New) A method of reducing the risk of one or more adverse events or serious adverse events associated with the use of inhaled nitric oxide in patients under the age of 18, said method comprising:

a. providing a source of pharmaceutically acceptable nitric oxide gas for inhalation to a medical provider;

b. informing the medical provider that inhaled nitric oxide is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood;

c. providing an additional warning to the medical provider, independent of the contraindication for neonates known to be dependent on right-to-left shunting of blood, that inhaled nitric oxide may increase pulmonary wedge pressure leading to pulmonary edema in patients under the age of 18 with pre-existing left ventricular dysfunction.

21. (New) The method of claim 20, further providing an additional warning to the medical provider that independent of the contraindication for right-to-left shunt, patients under the age of 18 who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced serious adverse events.

22. (New) A method of reducing the risk of one or more adverse events or serious adverse events in patients under the age of 18 in need of treatment with inhaled nitric oxide comprising:

a. providing a source of pharmaceutically acceptable nitric oxide gas for inhalation to a medical provider; and

b. informing the medical provider that inhaled nitric oxide may increase pulmonary wedge pressure leading to pulmonary edema in patients with pre-existing left ventricular dysfunction that are eligible to receive inhaled nitric oxide treatment.

23. (New) The method of claim 22, wherein patients eligible to receive inhaled nitric oxide treatment excludes neonates known to be dependent on right-to-left shunting of blood.

REMARKS

Applicant would like to thank Examiner Kwon and Examiner Arnold for providing Applicant an opportunity to discuss the subject matter of the present application during the interview of January 10, 2011, conducted in connection with Applicant's related, co-pending patent applications 12/821,020 and 12/821,041.

Claims 11 and 20-22 are pending in the application. The application contains three independent claims (claims 11, 20 and 22), five total claims, and no multiple dependent claims. As such, the application continues to comply with the 3/20 claim limitation for accelerated applications.

Claim 11 has been amended, and new claims 20-23 have been added to more particularly point out and distinctly claim the subject matter applicant regards as the invention and to address matters discussed during the interview of January 10, 2011. The claims have been amended without prejudice. Each of these claims is believed allowable over the prior art of record for at least the reasons described below.

As discussed at the interview, the prior art cited by the Examiner is addressed to two patient populations that are not the subject of the claimed invention. In particular, some of the disclosures in the cited prior art (e.g., the "NIH reference," and Loh et al., as cited in the Office Action mailed November 2, 2010) are directed to potential effects of inhaled nitric oxide on adults with left ventricular dysfunction due primarily to ischemic cardiomyopathy.

Other disclosures in the cited prior art are directed to potential effects of inhaled nitric oxide on a second class of patients - neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus (Atz et al., page 452). At the time of the instant invention, it was widely recognized by those of skill in the art that this class of patients should not be given inhaled NO therapy. In fact, this contraindication has been present on the prescribing label for nitric oxide since its introduction into the

marketplace. Consequently, patients with this specific condition were, of course, excluded from the INOT22 study that resulted in the discovery that is the subject of the presently claimed invention.

In contrast to the prior art references cited by the Examiner, the claimed invention relates to an important discovery in a third patient population - pediatric patients with pre-existing left ventricular dysfunction who are eligible to receive inhaled nitric oxide treatment (i.e., those not dependent on a right-to-left shunting of blood). As explained during the interview, those of ordinary skill in the art, prior to the instant invention, would not have found it obvious to withhold inhaled NO treatment from this class of patients based on the prior art cited by the Examiner in the Office Action mailed November 2, 2010, because the etiology and pathophysiology of the left ventricular dysfunction present in these three patient populations is markedly different. In fact, the members of the INOT22 Screening Committee who designed the study and the approximately 18 Institutional Review Boards and 4 national Health Authorities who reviewed and approved the study prior to its initiation – failed to predict that any untoward effects would be caused by the administration of inhaled NO in this third patient population.

Turning now to the specific language of the claims, amended claim 11 and new claims 20-23 are each limited to patients under the age of 18 and accordingly are not anticipated or rendered obvious by the prior art cited by the Examiner in the Office Action mailed November 2, 2010.

In addition, claim 11 is limited to patients eligible to receive inhaled nitric oxide treatment. To those skilled in the art, this patient population does not include neonates dependent on right-to-left shunt, since it was and is well known that inhaled nitric oxide is contraindicated for such patients. This is demonstrated not only by Atz et al. cited by the Examiner (see, e.g., Atz at 452: "We and others have reported adverse outcomes in this circumstance), but also by the contraindication clearly stated on the FDA-approved label for inhaled nitric oxide (see label section 4: "Contraindications"). Thus,

claim 11 does not include within its scope the neonate patients described by Atz et al. in column 452 of their paper who are not, to begin with, eligible to receive inhaled nitric oxide.

Similarly, new claim 20 expressly calls out this distinction between the patient population addressed by Atz et al., as to which the potential dangers of inhaled nitric oxide were well known in the prior art, and the distinct patient population that is the subject of the claimed invention. In particular, part (b) of the claim refers to the contraindication contained within the prescribing label for inhaled nitric oxide (see section 4, Contraindications). As noted above, this part of the claim embodies the disclosure of Atz et al., with respect to the treatment of neonates known to be dependent on right-to-left shunting of blood through a patent ductus arteriosus. Conversely, part (c) of claim 20 pertains to the novel and non-obvious finding that resulted from the INOT22 study, i.e., the new warning added to the Warnings and Precautions section of the prescribing label for inhaled nitric oxide (see page 1, right column). Claim 20(c) expressly states that the warning is independent from the known contraindication pertaining to neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus. Accordingly, the warning claimed in part (c) of claim 20 is not directed to the neonates described by Atz et al., as to whom the treatment is already contraindicated. Relatedly, claim 21 includes specific reference to the other warning added to the prescribing label for inhaled nitric oxide in Section 5.4 (see page 2, right hand column) arising from the INOT22 Study.

Support for the amendments and new claims is found in the specification of the application, as filed, including the original claims as filed and paragraphs [0007], [0020], and [0023] of the specification. Notably, the reference in claims 11 and 22 to patients "eligible to receive inhaled nitric oxide treatment" is original language in claim 11 as filed and is also found in paragraph [0007] of the application as filed. In addition, with respect to claim 20, both the contraindication for neonates dependent on right to left shunting of blood recited in part (b) of the claim and the warning recited in part (c) of the

claim are expressly found in the prescribing label for inhaled nitric oxide incorporated by reference in the specification at paragraph [0020] (copy attached as Appendix A).

In light of the above, Applicant respectfully submits that the application as amended is in condition for allowance and respectfully requests the same. Examiner Arnold is invited to contact Chief Patent Counsel for the patent owner, Jonathan Provoost (Reg. No. 44, 292) at 908-238-6392 to discuss any of the amendments or remarks set forth above.

No fees are believed to be due with this submission. Please apply any necessary charges or credits to deposit account **12-0769**, referencing Attorney Docket No. I001-0002USC1.

Respectfully submitted,



/Jonathan N. Provoost, Reg. No. 44,292/
Jonathan N. Provoost
Attorney for Applicant and Assignee
Associate General Counsel
Ikaria
6 Route 173
Clinton, NJ 08809
Direct phone: (908) 238-6392
Cell: (908) 391-3440
Fax (legal dept.): (908) 238-6773
jonathan.provoost@ikaria.com

Dated: January 14, 2011

APPENDIX A

INOMax[®] (nitric oxide) for inhalation

HIGHLIGHTS OF PRESCRIBING INFORMATION

These highlights do not include all the information needed to use INOMax safely and effectively. See full prescribing information for INOMax.

INOMax (nitric oxide) for inhalation
Initial U.S. Approval: 1999

RECENT MAJOR CHANGES

Warnings and Precautions, Heart Failure (5.4) 8/2009

INDICATIONS AND USAGE

INOMax is a vasodilator, which, in conjunction with ventilatory support and other appropriate agents, is indicated for the treatment of term and near-term (>34 weeks gestation) neonates with hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension, where it improves oxygenation and reduces the need for extracorporeal membrane oxygenation (1.1).

Monitor for PaO₂, methemoglobin, and inspired NO₂ during INOMax administration (1.1).

Utilize additional therapies to maximize oxygen delivery (1.1).

DOSAGE AND ADMINISTRATION

Dosage: The recommended dose of INOMax is 20 ppm, maintained for up to 14 days or until the underlying oxygen desaturation has resolved (2.1).

Administration:

- INOMax must be delivered via a system which does not cause generation of excessive inhaled nitrogen dioxide (2.2).
- Do not discontinue INOMax abruptly (2.2).

DOSAGE FORMS AND STRENGTHS

INOMax (nitric oxide) is a gas available in 100 ppm and 800 ppm concentrations.

CONTRAINDICATIONS

Neonates known to be dependent on right-to-left shunting of blood (4).

WARNINGS AND PRECAUTIONS

Rebound: Abrupt discontinuation of INOMax may lead to worsening oxygenation and increasing pulmonary artery pressure (5.1).

Methemoglobinemia: Methemoglobin increases with the dose of nitric oxide; following discontinuation or reduction of nitric oxide, methemoglobin levels return to baseline over a period of hours (5.2).

Elevated NO₂ Levels: NO₂ levels should be monitored (5.3).

Heart Failure: In patients with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary capillary wedge pressure leading to pulmonary edema (5.4).

ADVERSE REACTIONS

Methemoglobinemia and elevated NO₂ levels are dose dependent adverse events. Worsening oxygenation and increasing pulmonary artery pressure occur if INOMax is discontinued abruptly. Other adverse reactions that occurred in more than 5% of patients receiving INOMax in the CIRRT study were: thrombocytopenia, hypokalemia, bilirubinemia, atelectasis, and hypotension (6).

To report SUSPECTED ADVERSE REACTIONS, contact INO Therapeutics at 1-877-566-9466 and <http://www.inomax.com/> or FDA at 1-800-FDA-1088 or www.fda.gov/medwatch.

DRUG INTERACTIONS

Nitric oxide donor agents: Nitric oxide donor compounds, such as prilocaine, sodium nitropruside, and nitroglycerin, when administered as oral, parenteral, or topical formulations, may have an additive effect with INOMax on the risk of developing methemoglobinemia (7).

Revised: August 2009

FULL PRESCRIBING INFORMATION: CONTENTS*

1. INDICATIONS AND USAGE
 - 1.1 Treatment of Hypoxic Respiratory Failure
2. DOSAGE AND ADMINISTRATION
 - 2.1 Dosage
 - 2.2 Administration
3. DOSAGE FORMS AND STRENGTHS
4. CONTRAINDICATIONS
5. WARNINGS AND PRECAUTIONS
 - 5.1 Rebound
 - 5.2 Methemoglobinemia
 - 5.3 Elevated NO₂ Levels
 - 5.4 Heart Failure
6. ADVERSE REACTIONS
 - 6.1 Clinical Trials Experience
 - 6.2 Post-Marketing Experience
7. DRUG INTERACTIONS
8. USE IN SPECIFIC POPULATIONS
 - 8.1 Pregnancy
 - 8.2 Labor and Delivery
 - 8.3 Nursing Mothers
 - 8.4 Pediatric Use
 - 8.5 Geriatric Use

9. OVERDOSAGE
10. DESCRIPTION
11. CLINICAL PHARMACOLOGY
 - 11.1 Mechanism of Action
 - 11.2 Pharmacodynamics
 - 11.3 Pharmacokinetics
 - 11.4 Pharmacokinetics: Uptake and Distribution
 - 11.5 Pharmacokinetics: Metabolism
 - 11.6 Pharmacokinetics: Elimination
12. NONCLINICAL TOXICOLOGY
 - 12.1 Carcinogenesis, Mutagenesis, Impairment of Fertility
13. CLINICAL STUDIES
 - 13.1 Treatment of Hypoxic Respiratory Failure (HRF)
 - 13.2 Ineffectiveness in Adult Respiratory Distress Syndrome (ARDS)
14. HOW SUPPLIED/STORAGE AND HANDLING

*Sections or subsections omitted from the full prescribing information are not listed.

FULL PRESCRIBING INFORMATION

1 INDICATIONS AND USAGE

1.1 Treatment of Hypoxic Respiratory Failure

INOmax® is a vasodilator, which, in conjunction with ventilatory support and other appropriate agents, is indicated for the treatment of term and near-term (>34 weeks) neonates with hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension, where it improves oxygenation and reduces the need for extracorporeal membrane oxygenation.

Utilize additional therapies to maximize oxygen delivery. In patients with collapsed alveoli, additional therapies might include surfactant and high-frequency oscillatory ventilation.

The safety and effectiveness of inhaled nitric oxide have been established in a population receiving other therapies for hypoxic respiratory failure, including vasodilators, intravenous fluids, bicarbonate therapy, and mechanical ventilation. Different dose regimens for nitric oxide were used in the clinical studies [see Clinical Studies (14)].

Monitor for PaO₂, methemoglobin, and inspired NO₂ during INOmax administration.

2 DOSAGE AND ADMINISTRATION

2.1 Dosage

Term and near-term neonates with hypoxic respiratory failure

The recommended dose of INOmax is 20 ppm. Treatment should be maintained up to 14 days or until the underlying oxygen desaturation has resolved and the neonate is ready to be weaned from INOmax therapy.

An initial dose of 20 ppm was used in the NINOS and CIRGI trials. In CIRGI, patients whose oxygenation improved with 20 ppm were dose-reduced to 5 ppm as tolerated at the end of 4 hours of treatment. In the NINOS trial, patients whose oxygenation failed to improve on 20 ppm could be increased to 80 ppm, but those patients did not then improve on the higher dose. As the risk of methemoglobinemia and elevated NO₂ levels increases significantly when INOmax is administered at doses >20 ppm, doses above this level ordinarily should not be used.

2.2 Administration

The nitric oxide delivery systems used in the clinical trials provided operator-determined concentrations of nitric oxide in the breathing gas, and the concentration was constant throughout the respiratory cycle. INOmax must be delivered through a system with these characteristics and which does not cause generation of excessive inhaled nitrogen dioxide. The INOvent® system and other systems meeting these criteria were used in the clinical trials. In the ventilated neonate, precise monitoring of inspired nitric oxide and NO₂ should be instituted, using a properly calibrated analysis device with alarms. The system should be calibrated using a precisely defined calibration mixture of nitric oxide and nitrogen dioxide, such as INOcal®. Sample gas for analysis should be drawn before the Y-piece, proximal to the patient. Oxygen levels should also be measured.

In the event of a system failure or a wall-outlet power failure, a backup battery power supply and reserve nitric oxide delivery system should be available.

Do not discontinue INOmax abruptly, as it may result in an increase in pulmonary artery pressure (PAP) and/or worsening of blood oxygenation (PaO₂). Deterioration in oxygenation and elevation in PAP may also occur in children with no apparent response to INOmax. Discontinue/wean cautiously.

3 DOSAGE FORMS AND STRENGTHS

Nitric oxide is a gas available in 100 ppm and 800 ppm concentrations.

4 CONTRAINDICATIONS

INOmax is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood.

5 WARNINGS AND PRECAUTIONS

5.1 Rebound

Abrupt discontinuation of INOmax may lead to worsening oxygenation and increasing pulmonary artery pressure.

5.2 Methemoglobinemia

Methemoglobinemia increases with the dose of nitric oxide. In clinical trials, maximum methemoglobin levels usually were reached

approximately 8 hours after initiation of inhalation, although methemoglobin levels have peaked as late as 40 hours following initiation of INOmax therapy. In one study, 13 of 37 (35%) of neonates treated with INOmax 80 ppm had methemoglobin levels exceeding 7%. Following discontinuation or reduction of nitric oxide, the methemoglobin levels returned to baseline over a period of hours.

5.3 Elevated NO₂ Levels

In one study, NO₂ levels were <0.5 ppm when neonates were treated with placebo, 5 ppm, and 20 ppm nitric oxide over the first 48 hours. The 80 ppm group had a mean peak NO₂ level of 2.6 ppm.

5.4 Heart Failure

Patients who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced similar adverse events (e.g., pulmonary edema).

6 ADVERSE REACTIONS

Because clinical trials are conducted under widely varying conditions, adverse reaction rates observed in the clinical trials of a drug cannot be directly compared to rates in the clinical trials of another drug and may not reflect the rates observed in practice. The adverse reaction information from the clinical studies does, however, provide a basis for identifying the adverse events that appear to be related to drug use and for approximating rates.

6.1 Clinical Trials Experience

Controlled studies have included 325 patients on INOmax doses of 5 to 80 ppm and 251 patients on placebo. Total mortality in the pooled trials was 11% on placebo and 9% on INOmax, a result adequate to exclude INOmax mortality being more than 40% worse than placebo.

In both the NINOS and CIRGI studies, the duration of hospitalization was similar in INOmax and placebo-treated groups.

From all controlled studies, at least 6 months of follow-up is available for 276 patients who received INOmax and 212 patients who received placebo. Among these patients, there was no evidence of an adverse effect of treatment on the need for rehospitalization, special medical services, pulmonary disease, or neurological sequelae.

In the NINOS study, treatment groups were similar with respect to the incidence and severity of intracranial hemorrhage, Grade IV hemorrhage, periventricular leukomalacia, cerebral infarction, seizures requiring anticonvulsant therapy, pulmonary hemorrhage, or gastrointestinal hemorrhage.

The table below shows adverse reactions that occurred in at least 5% of patients receiving INOmax in the CIRGI study with event rates >5% and greater than placebo event rates. None of the differences in these adverse reactions were statistically significant when inhaled nitric oxide patients were compared to patients receiving placebo.

Table 1:
Adverse Reactions in the CIRGI Study

Adverse Event	Placebo (n=89)	Inhaled NO (n=97)
Hypotension	9 (10%)	13 (13%)
Withdrawal	9 (10%)	12 (12%)
Atelectasis	8 (9%)	9 (9%)
Hematuria	5 (6%)	8 (8%)
Hyperglycemia	6 (7%)	8 (8%)
Sepsis	2 (2%)	7 (7%)
Infection	3 (3%)	6 (6%)
Obtund	2 (2%)	5 (5%)
Celulitis	0 (0%)	5 (5%)

6.2 Post-Marketing Experience

The following adverse reactions have been identified during post-approval use of INOmax. Because these reactions are reported voluntarily from a population of uncertain size, it is not always possible to estimate their frequency reliably or to establish a causal relationship to drug exposure. The listing is alphabetical: dose errors associated with the delivery system; headaches associated with environmental exposure of INOmax in hospital staff; hypotension associated with acute withdrawal of the drug; hypoxemia associated with acute withdrawal of the drug; pulmonary edema in patients with CREST syndrome.

7 DRUG INTERACTIONS

No formal drug-interaction studies have been performed, and a clinically significant interaction with other medications used in the treatment of hypoxic respiratory failure cannot be excluded based on the available data. iNOmax has been administered with tolatidine, dopamine, dobutamine, steroids, surfactant, and high-frequency ventilation. Although there are no study data to evaluate the possibility, nitric oxide donor compounds, including sodium nitroprusside and nitroglycerin, may have an additive effect with iNOmax on the risk of developing methemoglobinemia. An association between prilocaine and an increased risk of methemoglobinemia, particularly in infants, has specifically been described in a literature case report. This risk is present whether the drugs are administered as oral, parenteral, or topical formulations.

8 USE IN SPECIFIC POPULATIONS

8.1 Pregnancy

Pregnancy Category C

Animal reproduction studies have not been conducted with iNOmax. It is not known if iNOmax can cause fetal harm when administered to a pregnant woman or can affect reproductive capacity. iNOmax is not intended for adults.

8.2 Labor and Delivery

The effect of iNOmax on labor and delivery in humans is unknown.

8.3 Nursing Mothers

Nitric oxide is not indicated for use in the adult population, including nursing mothers. It is not known whether nitric oxide is excreted in human milk.

8.4 Pediatric Use

Nitric oxide for inhalation has been studied in a neonatal population (up to 14 days of age). No information about its effectiveness in other age populations is available.

8.5 Geriatric Use

Nitric oxide is not indicated for use in the adult population.

10 OVERDOSAGE

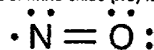
Overdosage with iNOmax will be manifest by elevations in methemoglobin and pulmonary toxicities associated with inspired NO_2 . Elevated NO_2 may cause acute lung injury. Elevations in methemoglobinemia reduce the oxygen delivery capacity of the circulation. In clinical studies, NO_2 levels >3 ppm or methemoglobin levels >7% were treated by reducing the dose of, or discontinuing, iNOmax.

Methemoglobinemia that does not resolve after reduction or discontinuation of therapy can be treated with intravenous vitamin C, intravenous methylene blue, or blood transfusion, based upon the clinical situation.

11 DESCRIPTION

iNOmax (nitric oxide gas) is a drug administered by inhalation. Nitric oxide, the active substance in iNOmax, is a pulmonary vasodilator. iNOmax is a gaseous blend of nitric oxide and nitrogen (0.08% and 99.92%, respectively for 800 ppm; 0.01% and 99.99%, respectively for 100 ppm). iNOmax is supplied in aluminum cylinders as a compressed gas under high pressure (2000 pounds per square inch gauge [psig]).

The structural formula of nitric oxide (NO) is shown below:



12 CLINICAL PHARMACOLOGY

12.1 Mechanism of Action

Nitric oxide is a compound produced by many cells of the body. It relaxes vascular smooth muscle by binding to the heme moiety of cytosolic guanylate cyclase, activating guanylate cyclase and increasing intracellular levels of cyclic guanosine 3',5'-monophosphate, which then leads to vasodilation. When inhaled, nitric oxide selectively dilates the pulmonary vasculature, and because of efficient scavenging by hemoglobin, has minimal effect on the systemic vasculature.

iNOmax appears to increase the partial pressure of arterial oxygen (PaO_2) by dilating pulmonary vessels in better ventilated areas of the lung, redistributing pulmonary blood flow away from lung regions with low ventilation/perfusion (V/Q) ratios toward regions with normal ratios.

12.2 Pharmacodynamics

Effects on Pulmonary Vascular Tone in PPHN

Persistent pulmonary hypertension of the newborn (PPHN) occurs as a primary developmental defect or as a condition secondary to other diseases such as meconium aspiration syndrome (MAS), pneumonia, sepsis, hyaline membrane disease, congenital diaphragmatic hernia (CDH), and pulmonary hypoplasia. In these states, pulmonary vascular resistance (PVR) is high, which results in hypoxemia secondary to right-to-left shunting of blood through the patent ductus arteriosus and foramen ovale. In neonates with PPHN, iNOmax improves oxygenation (as indicated by significant increases in PaO_2).

12.3 Pharmacokinetics

The pharmacokinetics of nitric oxide has been studied in adults.

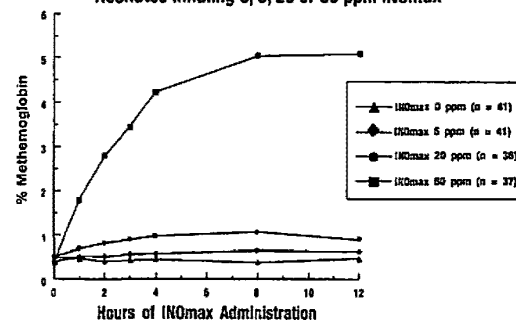
12.4 Pharmacokinetics: Uptake and Distribution

Nitric oxide is absorbed systemically after inhalation. Most of it traverses the pulmonary capillary bed where it combines with hemoglobin that is 60% to 100% oxygen-saturated. At this level of oxygen saturation, nitric oxide combines predominantly with oxyhemoglobin to produce methemoglobin and nitrate. At low oxygen saturation, nitric oxide can combine with deoxyhemoglobin to transiently form nitrosylhemoglobin, which is converted to nitrogen oxides and methemoglobin upon exposure to oxygen. Within the pulmonary system, nitric oxide can combine with oxygen and water to produce nitrogen dioxide and nitrite, respectively, which interact with oxyhemoglobin to produce methemoglobin and nitrate. Thus, the end products of nitric oxide that enter the systemic circulation are predominantly methemoglobin and nitrate.

12.5 Pharmacokinetics: Metabolism

Methemoglobin disposition has been investigated as a function of time and nitric oxide exposure concentration in neonates with respiratory failure. The methemoglobin (MetHb) concentration-time profiles during the first 12 hours of exposure to 0, 5, 20, and 80 ppm iNOmax are shown in Figure 1.

Figure 1:
Methemoglobin Concentration – Time Profiles
Neonates inhaling 0, 5, 20 or 80 ppm iNOmax



Methemoglobin concentrations increased during the first 8 hours of nitric oxide exposure. The mean methemoglobin level remained below 1% in the placebo group and in the 5 ppm and 20 ppm iNOmax groups, but reached approximately 5% in the 80 ppm iNOmax group. Methemoglobin levels >7% were attained only in patients receiving 80 ppm, where they comprised 35% of the group. The average time to reach peak methemoglobin was 10 ± 9 (SD) hours (median, 8 hours) in these 13 patients, but one patient did not exceed 7% until 40 hours.

12.6 Pharmacokinetics: Elimination

Nitrate has been identified as the predominant nitric oxide metabolite excreted in the urine, accounting for >70% of the nitric oxide dose inhaled. Nitrate is cleared from the plasma by the kidney at rates approaching the rate of glomerular filtration.

13 NONCLINICAL TOXICOLOGY

13.1 Carcinogenesis, Mutagenesis, Impairment of Fertility

No evidence of a carcinogenic effect was apparent, at inhalation exposures up to the recommended dose (20 ppm), in rats for 20 hr/day for up to two years. Higher exposures have not been investigated.

Nitric oxide has demonstrated genotoxicity in Salmonella (Ames Test), human lymphocytes, and after *in vivo* exposure in rats. There are no animal or human studies to evaluate nitric oxide for effects on fertility.

14 CLINICAL STUDIES

14.1 Treatment of Hypoxic Respiratory Failure (HRF)

The efficacy of INOmax has been investigated in term and near-term newborns with hypoxic respiratory failure resulting from a variety of etiologies. Inhalation of INOmax reduces the oxygenation index (OI= mean airway pressure in cm H₂O × fraction of inspired oxygen concentration [FIO₂] × 100 divided by systemic arterial concentration in mm Hg [PaO₂]) and increases PaO₂ [see *Clinical Pharmacology* (12.1)].

NINOS Study

The Neonatal Inhaled Nitric Oxide Study (NINOS) group conducted a double-blind, randomized, placebo-controlled, multicenter trial in 235 neonates with hypoxic respiratory failure. The objective of the study was to determine whether inhaled nitric oxide would reduce the occurrence of death and/or initiation of extracorporeal membrane oxygenation (ECMO) in a prospectively defined cohort of term or near-term neonates with hypoxic respiratory failure unresponsive to conventional therapy. Hypoxic respiratory failure was caused by meconium aspiration syndrome (MAS; 49%), pneumonia/sepsis (21%), idiopathic primary pulmonary hypertension of the newborn (PPHN; 17%), or respiratory distress syndrome (RDS; 11%). Infants ≤14 days of age (mean, 1.7 days) with a mean PaO₂ of 46 mm Hg and a mean oxygenation index (OI) of 43 cm H₂O / mm Hg were initially randomized to receive 100% O₂ with (n=114) or without (n=121) 20 ppm nitric oxide for up to 14 days. Response to study drug was defined as a change from baseline in PaO₂ 30 minutes after starting treatment (full response = >20 mm Hg, partial = 10–20 mm Hg, no response = <10 mm Hg). Neonates with a less than full response were evaluated for a response to 80 ppm nitric oxide or control gas. The primary results from the NINOS study are presented in Table 2.

Table 2:
Summary of Clinical Results from NINOS Study

	Control (n=121)	NO (n=114)	P value
Death or ECMO*†	77 (64%)	52 (46%)	0.006
Death	20 (17%)	16 (14%)	0.60
ECMO	66 (55%)	44 (39%)	0.014

* Extracorporeal membrane oxygenation

† Death or need for ECMO was the study's primary end point

Although the incidence of death by 120 days of age was similar in both groups (NO, 14%; control, 17%), significantly fewer infants in the nitric oxide group required ECMO compared with controls (39% vs. 55%, p = 0.014). The combined incidence of death and/or initiation of ECMO showed a significant advantage for the nitric oxide treated group (46% vs. 64%, p = 0.006). The nitric oxide group also had significantly greater increases in PaO₂ and greater decreases in the OI and the alveolar-arterial oxygen gradient than the control group (p<0.001 for all parameters). Significantly more patients had at least a partial response to the initial administration of study drug in the nitric oxide group (66%) than the control group (26%, p<0.001). Of the 125 infants who did not respond to 20 ppm nitric oxide or control, similar percentages of NO-treated (18%) and control (20%) patients had at least a partial response to 80 ppm nitric oxide for inhalation or control drug, suggesting a lack of additional benefit for the higher dose of nitric oxide. No infant had study drug discontinued for toxicity. Inhaled nitric oxide had no detectable effect on mortality. The adverse events collected in the NINOS trial occurred at similar incidence rates in both treatment groups [see *Adverse Reactions* (6.1)]. Follow-up exams were performed at 18–24 months for the infants enrolled in this trial. In the infants with available follow-up, the two treatment groups were similar with respect to their mental, motor, audiologic, or neurologic evaluations.

CINRGI Study

This study was a double-blind, randomized, placebo-controlled, multicenter trial of 186 term and near-term neonates with pulmonary hypertension and hypoxic respiratory failure. The primary objective of the study was to determine whether INOmax would reduce the receipt

of ECMO in these patients. Hypoxic respiratory failure was caused by MAS (35%), idiopathic PPHN (30%), pneumonia/sepsis (24%), or RDS (8%). Patients with a mean PaO₂ of 54 mm Hg and a mean OI of 44 cm H₂O / mm Hg were randomly assigned to receive either 20 ppm INOmax (n=97) or nitrogen gas (placebo; n=89) in addition to their ventilatory support. Patients who exhibited a PaO₂>60 mm Hg and a pH < 7.55 were weaned to 5 ppm INOmax or placebo. The primary results from the CINRGI study are presented in Table 3.

Table 3:
Summary of Clinical Results from CINRGI Study

	Placebo	INOmax	P value
ECMO*†	51/89 (57%)	30/97 (31%)	<0.001
Death	5/89 (6%)	3/97 (3%)	0.48

* Extracorporeal membrane oxygenation

† ECMO was the primary end point of this study

Significantly fewer neonates in the INOmax group required ECMO compared to the control group (31% vs. 57%, p<0.001). While the number of deaths were similar in both groups (INOmax, 3%; placebo, 6%), the combined incidence of death and/or receipt of ECMO was decreased in the INOmax group (33% vs. 58%, p<0.001).

In addition, the INOmax group had significantly improved oxygenation as measured by PaO₂, OI, and alveolar-arterial gradient (p<0.001 for all parameters). Of the 97 patients treated with INOmax, 2 (2%) were withdrawn from study drug due to methemoglobin levels >4%. The frequency and number of adverse events reported were similar in the two study groups [see *Adverse Reactions* (6.1)].

14.2 Ineffective in Adult Respiratory Distress Syndrome (ARDS) ARDS Study

In a randomized, double-blind, parallel, multicenter study, 385 patients with adult respiratory distress syndrome (ARDS) associated with pneumonia (46%), surgery (33%), multiple trauma (26%), aspiration (23%), pulmonary contusion (18%), and other causes, with PaO₂/FIO₂ <250 mm Hg despite optimal oxygenation and ventilation, received placebo (n=193) or INOmax (n=192), 5 ppm, for 4 hours to 28 days or until weaned because of improvements in oxygenation. Despite acute improvements in oxygenation, there was no effect of INOmax on the primary endpoint of days alive and off ventilator support. These results were consistent with outcome data from a smaller dose ranging study of nitric oxide (1.25 to 80 ppm). INOmax is not indicated for use in ARDS.

16 HOW SUPPLIED/STORAGE AND HANDLING

INOmax (nitric oxide) is available in the following sizes:

Size D	Portable aluminum cylinders containing 353 liters at STP of nitric oxide gas in 800 ppm concentration in nitrogen (delivered volume 344 liters) (NDC 64693-002-01)
Size D	Portable aluminum cylinders containing 353 liters at STP of nitric oxide gas in 100 ppm concentration in nitrogen (delivered volume 344 liters) (NDC 64693-001-01)
Size 88	Aluminum cylinders containing 1963 liters at STP of nitric oxide gas in 800 ppm concentration in nitrogen (delivered volume 1918 liters) (NDC 64693-002-02)
Size 88	Aluminum cylinders containing 1963 liters at STP of nitric oxide gas in 100 ppm concentration in nitrogen (delivered volume 1918 liters) (NDC 64693-001-02)

Store at 25°C (77°F) with excursions permitted between 15–30°C (59–86°F) [see USP Controlled Room Temperature].

Occupational Exposure

The exposure limit set by the Occupational Safety and Health Administration (OSHA) for nitric oxide is 25 ppm, and for NO₂ the limit is 5 ppm.

INO Therapeutics
6 Route 173 West
Clinton, NJ 08809
USA

© 2009 INO Therapeutics

SPC-0303 V:4.0

Electronic Acknowledgement Receipt

EFS ID:	9237230
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Kayla D. Brant/Anna Goforth
Filer Authorized By:	Kayla D. Brant
Attorney Docket Number:	I001-0002USC1
Receipt Date:	14-JAN-2011
Filing Date:	22-JUN-2010
Time Stamp:	16:06:43
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		P80022.PDF	1941125 <small>3f41b64b443e4984f706349a238fb102b127cbcd</small>	yes	12

Multipart Description/PDF files in .zip description		
Document Description	Start	End
Accelerated Exam - Transmittal amendment/reply	1	1
Claims	2	3
Applicant Arguments/Remarks Made in an Amendment	4	12

Warnings:

Information:

Total Files Size (in bytes):

1941125

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 12/820,866		Filing Date 06/22/2010		<input type="checkbox"/> To be Mailed			
APPLICATION AS FILED – PART I											
(Column 1)			(Column 2)			SMALL ENTITY <input checked="" type="checkbox"/>		OR		OTHER THAN SMALL ENTITY	
FOR		NUMBER FILED	NUMBER EXTRA		RATE (\$)	FEE (\$)	OR		RATE (\$)	FEE (\$)	
<input checked="" type="checkbox"/> BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A	N/A		N/A	82			N/A		
<input type="checkbox"/> SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A	N/A		N/A				N/A		
<input type="checkbox"/> EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A	N/A		N/A				N/A		
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 = *			X \$ =		OR		X \$ =		
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 = *			X \$ =		OR		X \$ =		
<input type="checkbox"/> APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))											
* If the difference in column 1 is less than zero, enter "0" in column 2.											
APPLICATION AS AMENDED – PART II					SMALL ENTITY		OR		OTHER THAN SMALL ENTITY		
(Column 1)			(Column 2)		(Column 3)			SMALL ENTITY		OTHER THAN SMALL ENTITY	
AMENDMENT	01/14/2011	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 4	Minus	** 20	= 0	X \$26 =	0	OR	X \$ =		
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X \$110 =	0	OR	X \$ =		
	<input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))										
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE		OR		TOTAL ADD'L FEE	
						0					
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =		
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =		
	<input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))										
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE		OR		TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.											
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".											
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".											
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.											
						Legal Instrument Examiner: /GLORIA TRAMMELL/					

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/820,866	06/22/2010	James S. Baldassarre	I001-0002USC1	2913
49584	7590	02/23/2011	EXAMINER	
LEE & HAYES, PLLC 601 W. RIVERSIDE AVENUE SUITE 1400 SPOKANE, WA 99201			ARNOLD, ERNST V	
			ART UNIT	PAPER NUMBER
			1613	
			NOTIFICATION DATE	DELIVERY MODE
			02/23/2011	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

lhpto@leehayes.com

Notice of References Cited	Application/Control No. 12/820,866	Applicant(s)/Patent Under Reexamination BALDASSARRE ET AL.	
	Examiner ERNST V. ARNOLD	Art Unit 1613	Page 1 of 1

U.S. PATENT DOCUMENTS

*	Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A US-			
	B US-			
	C US-			
	D US-			
	E US-			
	F US-			
	G US-			
	H US-			
	I US-			
	J US-			
	K US-			
	L US-			
	M US-			

FOREIGN PATENT DOCUMENTS

*	Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N				
	O				
	P				
	Q				
	R				
	S				
	T				

NON-PATENT DOCUMENTS

*	Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
U	Figure from Dr. Green's presentation given 1/10/11; 1 page.
V	
W	
X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Advisory Action Before the Filing of an Appeal Brief	Application No. 12/820,866	Applicant(s) BALDASSARRE ET AL.	
	Examiner ERNST V. ARNOLD	Art Unit 1613	

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

THE REPLY FILED 14 January 2011 FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.

1. The reply was filed after a final rejection, but prior to or on the same day as filing a Notice of Appeal. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. The reply must be filed within one of the following time periods:

- a) The period for reply expires 3 months from the mailing date of the final rejection.
b) The period for reply expires on: (1) the mailing date of this Advisory Action, or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.

Examiner Note: If box 1 is checked, check either box (a) or (b). ONLY CHECK BOX (b) WHEN THE FIRST REPLY WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. The Notice of Appeal was filed on _____. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. The proposed amendment(s) filed after a final rejection, but prior to the date of filing a brief, will not be entered because
(a) They raise new issues that would require further consideration and/or search (see NOTE below);
(b) They raise the issue of new matter (see NOTE below);
(c) They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or
(d) They present additional claims without canceling a corresponding number of finally rejected claims.

NOTE: See Continuation Sheet. (See 37 CFR 1.116 and 41.33(a)).

4. The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).
5. Applicant's reply has overcome the following rejection(s): _____.
6. Newly proposed or amended claim(s) _____ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).
7. For purposes of appeal, the proposed amendment(s): a) will not be entered, or b) will be entered and an explanation of how the new or amended claims would be rejected is provided below or appended.
The status of the claim(s) is (or will be) as follows:
Claim(s) allowed: _____.
Claim(s) objected to: _____.
Claim(s) rejected: 1-19.
Claim(s) withdrawn from consideration: _____.

AFFIDAVIT OR OTHER EVIDENCE

8. The affidavit or other evidence filed after a final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).
9. The affidavit or other evidence filed after the date of filing a Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing a good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).
10. The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. The request for reconsideration has been considered but does NOT place the application in condition for allowance because:
See Continuation Sheet.
12. Note the attached Information *Disclosure Statement*(s). (PTO/SB/08) Paper No(s). 11/3/10
13. Other: PTO 892.

/Ernst V Arnold/
Primary Examiner, Art Unit 1613

Continuation of 3. NOTE: Applicant has changed the scope of the patient population from neonate or near term neonate to under the age of 18. This is a new patient population that requires further search and consideration. One of Applicant's arguments has been that treatment of mature adults cannot be directly correlated to treatment for children but by amending the claims to include a patient 17.99 years of age, which is essentially a mature adult, then the claims need to be re-evaluated in consideration of this new patient population. Atz clearly teaches that pulmonary edema can occur in adults with left ventricular dysfunction who are administered NO (page 452, left column of Atz). Thus, at least the reference of Atz needs to be reconsidered with respect to the new limitations. Also, parts (b) and (c) of claim 20 are directed to neonates but the patients are under the age of 18 which include 17.99 year olds and by Applicant's own arguments, what applies to neonates is different than what applies to mature individuals, which a 17.99 year old person is. What does a warning about neonates have to do with a 17.99 year old mature individual? It appears to be incongruous to the Examiner and possibly a 35 USC 112 second paragraph problem. Furthermore, iNO is already known to increase the capillary wedge pressure as taught by Loh. So, new claim 20 does not appear to be in condition for allowance. Amdended claim 11 also has the patient under the age of 18 and is not allowable. Applicant directed the Examiner to [0020] which incorporates by reference the label on iNOmax. The label states that the neonates known to be dependent on right to left shunting of blood are contraindicated and this appears to be a proper incorporation by reference and not new matter.

Continuation of 11. does NOT place the application in condition for allowance because: Applicant's proposed amendments create numerous problems including requiring further search and consideration as discussed above. Applicant asserts that Atz teaches right to left shunting of blood which is part (b) of the claim 20. Applicant asserts that part (c) of claim 20 is not directed to the neonates described by Atz et al. but a new patient population discovered by Applicant. Respectfully, this is not distinguishing. As discussed during the interview of 1/10/11, Dr. Greene discussed that the Atz is directed to right to left shunting of blood in patent ductus arteriosus (See attached Figure provided during the interview). The instant claims are directed to increases in pulmonary wedge pressure which is already known in the art as taught by Loh and discussed above. Furthermore, Atz also teaches left to right shunting at the foramen ovale in newborns with left ventricular dysfunction and that iNO should be used with extreme caution, if at all with these patients (page 452, left column Atz). Thus, Atz is not limited to right to left shunting as found in ductus arteriosus. Consequently, it remains obvious to exclude patients with left ventricular dysfunction from iNO therapy because of the inherent risk of adverse and serious adverse effects. Respectfully, the Examiner consulted with his supervisor and has tried to find language to be copacetic with our informative discussion during the interview but cannot at this time find adequate language supported in the specification as filed. Respectfully, the claims remain rejected for the reasons of record and those provided above.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866	
	Filing Date		2010-06-22	
	First Named Inventor	James S. Baldassarre		
	Art Unit	1613		
	Examiner Name	Ernst V Arnold		
	Attorney Docket Number	I001-0002USC1		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² i	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866
	Filing Date		2010-06-22
	First Named Inventor	James S. Baldassarre	
	Art Unit		1613
	Examiner Name	Ernst V Arnold	
	Attorney Docket Number		I001-0002USC1

/E.A./	1	Comparison of Supplemental Oxygen and Nitric Oxide for Inhalation in the Evaluation of the Reactivity of the Pulmonary Vasculature During Acute Pulmonary Vasodilator Testing, http://clinicaltrials.gov/archive/NCT00626028/2009_01_12 January 12, 2009	<input type="checkbox"/>
/E.A./	2	INO Therapeutics, LLC, "INOflo for Inhalation 800ppm", package leaflet, 2010, 2	<input type="checkbox"/>
/E.A./	3	Notification of Reason for Rejection, mailed 7/30/2010, from Japanese Patent Application No. 2009-157623 (cites foreign references).	<input type="checkbox"/>
/E.A./	4	Yoshida, Kiyoshi, " Well-illustrated Diagnostics and Treatment of Heart Failure" Professor of Kawasaki Medical University, cardiovascular internal medicine CIRCULATION Up-to-Date Vol. 2, No. 4, 2007(343), pp. 23-28	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Christopher P. Rogers, Reg. No. 36,334/	Date Considered	2010-11-03
--------------------	--	-----------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

/Ernst Arnold/

02/14/2011

Do Not Enter
/EA/
2/14/11

Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop After Final Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REPLY AFTER FINAL (37 CFR 1.116)
ACCELERATED EXAM – TRANSMITTAL REPLY

This communication is responsive to the Final Office Action mailed November 2, 2010, setting a shortened statutory period for reply of 3 months.

Applicant respectfully requests entry of this Reply After Final, reconsideration of the pending rejections, and allowance of the application. A listing of the claims and amendments thereof is shown starting at page 2.

Applicant further asserts that this Reply After Final has been diligently filed and that the application is in compliance with MPEP 708.02(a)(IV) After-Final and Appeal Procedures, thus maintaining the application's status as an accelerated application.

Remarks to the pending Office Action begin at page 4.

Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop After Final Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REPLY AFTER FINAL (37 CFR 1.116)
ACCELERATED EXAM – TRANSMITTAL REPLY

This communication is responsive to the Advisory Action mailed Feb. 23, 2011 and the Final Office Action mailed November 2, 2010, setting a shortened statutory period for reply of 3 months.

Applicant respectfully requests entry of this 2nd Reply After Final, reconsideration of the pending rejections, and allowance of the application. A listing of the claims and amendments thereof is shown starting at page 2.

Applicant further asserts that this 2nd Reply After Final has been diligently filed and that the application is in compliance with MPEP 708.02(a)(IV) After-Final and Appeal Procedures, thus maintaining the application's status as an accelerated application.

Remarks to the pending Office Action begin at page 3.

Amendments to the Claims

Please cancel claims 1-10 and 12-19.

1-10. Canceled.

11. (Twice Amended) A method of reducing the risk of the occurrence, in a ~~patient~~ a neonate or near-term neonate patients, of one or more ~~adverse events or~~ adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide, said method comprising:

(a) identifying a neonate or near-term neonate patient eligible to receive inhaled nitric oxide treatment according to FDA-approved prescribing information, wherein said neonate or near-term neonate patient is not eligible to receive inhaled nitric oxide treatment if he or she is dependent on right-to-left shunting of blood at the patent ductus arteriosus;

(b) determining if said eligible patient has pre-existing left ventricular dysfunction ~~evidenced by an elevated pulmonary capillary wedge pressure;~~ and,

(c) administering said inhaled nitric oxide ~~medical treatment~~ to said eligible patient if said eligible patient does not have pre-existing left ventricular dysfunction, ~~wherein said patient is excluded from being administered said medical treatment if said patient has pre-existing left ventricular dysfunction;~~ and

(d) not administering said inhaled nitric oxide to said eligible patient if said eligible patient has pre-existing left ventricular dysfunction in order to reduce thereby reducing the risk of the occurrence of the a serious adverse event associated with said inhaled nitric oxide ~~medical~~ treatment.

12-19. Canceled.

REMARKS

Claims 1-10 and 12-19 have been cancelled. Claim 11 has been amended. Allowance of the present application in light of the above amendments and the following remarks is respectfully requested.

Applicants would like to thank Examiner Arnold for the comments and discussion provided in the Advisory Action of February 23, 2011, and Examiner Kwon and Examiner Arnold for providing Applicant an opportunity to discuss the subject matter of the present application during the interview of January 10, 2011, conducted in connection with Applicants' related, co-pending patent applications 12/821,020 and 12/821,041.

Following the interview, Applicants submitted a response to the Final Office Action in which they sought to amend and add claims that highlighted the distinctions between the present invention and the prior art discussed at the January 10 interview. In response, the Examiner issued an Advisory Action indicating that those amendments did not put the application in condition for allowance and would require additional searching of the prior art. Accordingly, Applicants' January 14th Amendment was not entered.

It was certainly not Applicants intention to expand the scope of the claimed subject matter in a way that would require additional searching, but rather simply to present claims that reflected Applicants' understanding of the discussion at the interview. Applicants remain hopeful that there remains agreement with respect to the underlying fact that the INO22 study resulted in a significant medical invention not taught in the prior art and that the question presented is how appropriately to claim that invention. With this as background, Applicant respectfully submits this second after final response in an attempt to address the specific points made by the Examiner in the Advisory Action.

Applicant sought to establish three points during the January 10, 2011 Interview:

1. That the present invention is not directed to neonates reliant on right-to-left shunting of blood at the patent ductus arteriosus because it was already well known in the art at the time of the INO22 study that such patients were ineligible to receive inhaled nitric oxide treatment. This is demonstrated by the Atz et al. article cited by the Examiner and the original FDA label for inhaled nitric oxide issued by the FDA which specifically states that inhaled nitric oxide is contraindicated for this patient population. Rather, the invention claimed in the present application is directed to pediatric patients with pre-existing left ventricular dysfunction that are not reliant on such right-to-left shunting.

2. That the risk of increased adverse events and serious adverse events from administering inhaled nitric oxide to pediatric patients that are not reliant on right-to-left shunting, represented a highly surprising result to those skilled in the art, as demonstrated, e.g., by the fact that it was not recognized or considered by any of the 18 independent review boards (IRBs) at medical institutions in the United States and abroad as a risk to be considered in the original protocol for the INO22 study.

3. That the references cited by the Examiner are directed solely either (a) to neonates reliant on right-to-left shunting (e.g., Atz et al.); or (b) to adults suffering from an entirely different category of left ventricular dysfunction than the type that affects children. Adults with LVD suffer from diastolic dysfunction (stiff, non-compliant heart that cannot fill properly) caused by ischemic cardiomyopathy (heart failure due to coronary artery disease and resultant partial cardiac muscle death) and idiopathic dilated cardiomyopathy. By contrast, children with LVD suffer from systolic dysfunction (soft flabby heart that cannot push blood out) caused by congenital (structural) defects or cardiomyopathies (muscle diseases). For this reason, there were no existing concerns about left ventricular dysfunction in children or neonates until the INOT 22 study was analyzed and understood despite the known teachings of Loh and others with respect to adults.

It is respectfully submitted that if the above three points are agreed, the only barrier to allowance of the present application is identifying claim language that both the Examiner and Applicant agree captures the distinction between the claimed invention and the prior art and would not require an additional search of the prior art. The claim amendments above are an attempt to present such language and, for the reasons described below, are believed to address the concerns raised by the Examiner in the Advisory Action.

The Examiner raises two concerns in the Advisory Action. First, the Examiner states that amending the claims from neonates to patients under the age of 18 raises new obviousness issues and would require additional search. In particular, the Examiner contends that a pediatric patient just under 18 years of age will be medically equivalent to an adult just over 18 years of age. Consequently, the Examiner concludes, a prior art reference such as Loh relating to adult patients may render obvious a claim that covers patients who are just short of their 18th birthday.

Applicants respectfully disagree with the Examiner's arguments on this point. The adults at issue in the Loh reference had an average age of 52 +/- 3 years and suffered from ischemic cardiomyopathy (heart failure due to coronary artery disease and resultant partial cardiac muscle death) and idiopathic dilated cardiomyopathy, which resulted in systolic left ventricular failure. These are symptoms of older adults, and Loh's teachings would not be understood as referring to an "adult" of age 18, and certainly not to a pediatric patient.

Nevertheless, to facilitate the present prosecution, the claims presented in this second after-Final amendment are directed to neonates, and (without prejudice to Applicants' right to submit further amendments in the future in this or related applications), Applicant has not attempted in this response to amend the claims to cover patients under the age of 18.

Second, the Examiner contends that Atz et al. is not limited to patients with right-to-left shunting of blood at the patent ductus arteriosus but also allegedly refers to patients with extreme left-to-right shunting at the foramen ovale in newborns with left ventricular dysfunction. It is respectfully submitted that the Examiner is simply incorrect in his reading of Atz et al. on this point.

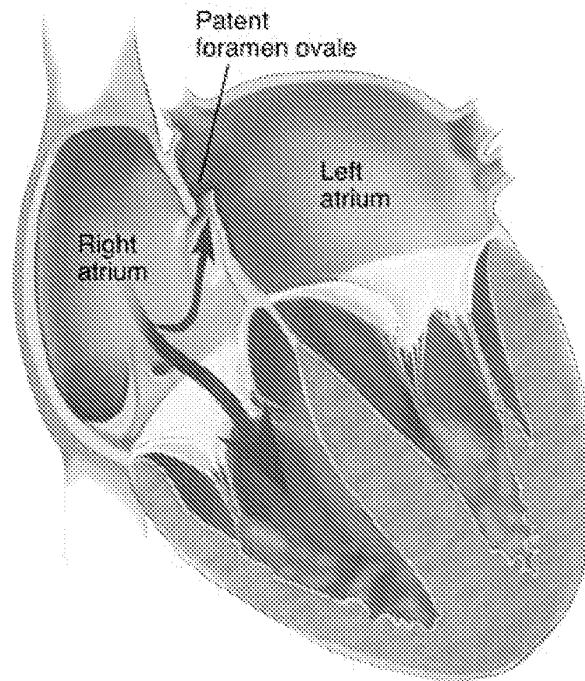
Atz et al., page 452, states in pertinent part:

*“A different, but related phenomenon may be operative in the newborn with severe left ventricular dysfunction and pulmonary hypertension. In these patients, the systemic circulation may depend in part on the ability of the right ventricle to sustain cardiac output through a right-to-left shunt across the patent ductus arteriosus. Selective pulmonary vasodilation may redirect the right ventricular output to the lungs and away from the systemic circulation. Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale **and** exclusively right to left shunting at the ductus arteriosus, NO should be used with extreme caution. (emphasis added)”*

With all due respect, the operative key word is “**and**.” The Examiner seems to be interpreting Atz et al. as describing two separate conditions, “predominantly left to right shunting at the foramen ovale” and “exclusively right to left shunting at the ductus arteriosus.” That is simply not a correct reading of Atz et al. Atz et al. is referring to a single condition, one in which patients exhibit a right to left shunt across the patent ductus arteriosus and a left-to-right shunt at the foramen ovale.

Left-to-right shunt at the foramen ovale is not, in and of itself, a form of LVD. Indeed, a foramen ovale is not even located or associated with a left or right ventricle. Rather, as shown in Figure 1 below, a foramen ovale is an unintended opening between the right and left atrium.

Figure 1



In particular, prior to birth, the fetal heart utilizes the foramen ovale as a means for blood to pass from the right atrium directly into the left atrium. This “bypass” allows fetal blood to circumvent the nonfunctional fetal lungs, while the fetus obtains its oxygen from the placenta. A layer of tissue called the septum primum acts as a valve over the foramen ovale during fetal development. After birth, the pressure in the pulmonary circulatory system drops, thus causing the foramen ovale to close entirely. In certain instances, the foramen ovale may not entirely seal after birth. In this case, elevation of pressure in the pulmonary circulatory system (i.e., pulmonary hypertension due to various causes) can cause the foramen ovale to remain open. This is known as a patent foramen ovale. Indeed, the use of inhaled nitric oxide to decrease pulmonary hypertension is known to be a successful treatment for right-to-left shunting through a

patent foramen ovale (see *Right-to-Left shunting through a patent foramen ovale in right ventricular infarction: improvement of hypoxemic and hemodynamics with inhaled nitric oxide*; Fessler MB et al, J Clin Anesth. 2003 Aug; 15(5): 371-4).

By contrast, it has long been known that the use of inhaled nitric oxide is contraindicated in patients dependent on right-to-left shunt across the patent ductus arteriosus. Atz implies that the risk may be even greater if the newborn patient has **both** a dependency on right-to-left shunt across the patent ductus arteriosus **combined with** left to right shunt at the foramen ovale. In other words, Atz et al. is describing neonates with predominantly left-to-right shunting at the foramen ovale **and** exclusively right-to-left shunting at the ductus arteriosus, which is a subset of the well-known broader contraindication for the use of iNO in neonates (i.e., newborns) dependent on right-to-left shunt across the patent ductus arteriosus. But Atz et al. teaches nothing about patients with left-to-right shunt at the foramen ovale, in and of itself. This condition is neither a contraindication for inhaled nitric oxide (rather inhaled nitric oxide is used to treat it in specific instances), nor is it considered to be representative of “left ventricular dysfunction” (rather it is a defect of the atrium, not a ventricle).

Support for the amendments and new claims is found in the specification of the application, as filed, including the original claims as filed and paragraphs [0007], [0020], [0023] and [0052] of the specification. Notably, the reference in claim 22 to patients “eligible to receive inhaled nitric oxide treatment” is original language in claim 11 as filed and is also found in paragraph [0007] of the application as filed. In addition, with respect to claim 20, both the contraindication for neonates dependent on right to left shunting of blood recited in part (b) of the claim and the warning recited in part (c) of the claim are expressly found in the prescribing label for inhaled nitric oxide incorporated by reference in the specification at paragraph [0020] (copy attached as Appendix A).

In light of the above, Applicant respectfully submits that the application as amended is in condition for allowance and respectfully requests the same. Examiner Arnold is invited to contact Chief Patent Counsel for the patent owner, Jonathan

Provoost (Reg. No. 44,292) at 908-238-6392 to discuss any of the amendments or remarks set forth above.

The application as amended contains one independent claim, one total claim, and no multiple dependent claims. As such, the application continues to comply with the 3/20 claim limitation for accelerated applications.

No fees are believed to be due with this submission. Please apply any necessary charges or credits to deposit account **12-0769**, referencing Attorney Docket No. I001-0002USC1.

Respectfully submitted,

/Jonathan N. Provoost, Reg. No. 44,292/
Jonathan N. Provoost
Attorney for Applicant and Assignee
Associate General Counsel
Ikaria
6 Route 173
Clinton, NJ 08809
Direct phone: (908) 238-6392
Cell: (908) 391-3440
Fax (legal dept.): (908) 238-6773
jonathan.provoost@ikaria.com

Dated: March 1st, 2011

Electronic Patent Application Fee Transmittal

Application Number:	12820866
Filing Date:	22-Jun-2010
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Filer:	Beatrice L. Koempel-Thomas/Anna Goforth
Attorney Docket Number:	I001-0002USC1

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 1 month with \$0 paid	2251	1	65	65

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				65

Electronic Acknowledgement Receipt

EFS ID:	9563947
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Beatrice L. Koempel-Thomas/Anna Goforth
Filer Authorized By:	Beatrice L. Koempel-Thomas
Attorney Docket Number:	I001-0002USC1
Receipt Date:	01-MAR-2011
Filing Date:	22-JUN-2010
Time Stamp:	18:04:48
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$65
RAM confirmation Number	5066
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
-----------------	----------------------	-----------	----------------------------------	------------------	------------------

1		PO3587.PDF	125298	yes	9
			dd3db582f0bd1e70889bcacc648a65106578cae2		
Multipart Description/PDF files in .zip description					
		Document Description	Start	End	
		Accelerated Exam - Transmittal amendment/reply	1	1	
		Claims	2	2	
		Applicant Arguments/Remarks Made in an Amendment	3	9	
Warnings:					
Information:					
2	Fee Worksheet (PTO-875)	fee-info.pdf	30641	no	2
			0245d31d5ea766d2292cf53f81b6883c87b1bb8		
Warnings:					
Information:					
Total Files Size (in bytes):			155939		
<p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p>					

Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop After Final Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REPLY AFTER FINAL (37 CFR 1.116)
ACCELERATED EXAM – TRANSMITTAL REPLY

This communication is responsive to the Examiner Interview of March 3, 2011, and the Advisory Action mailed Feb. 23, 2011.

Applicant respectfully requests entry of this 3rd Reply After Final, reconsideration of the pending rejections, and allowance of the application. A listing of the claims and amendments thereof is shown starting at page 2.

Applicant further asserts that this 3rd Reply After Final has been diligently filed and that the application is in compliance with MPEP 708.02(a)(IV) After-Final and Appeal Procedures, thus maintaining the application's status as an accelerated application.

Remarks to the pending Office Action begin at page 3.

Amendments to the Claims

Please cancel claims 1-10 and 12-19.

1-10. Canceled.

11. (Twice Amended) A method of reducing the risk of the occurrence, in a ~~patient~~ a neonate or near-term neonate patients, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide, said method comprising:

(a) identifying a patient ~~eligible for~~ in need of inhaled nitric oxide treatment; ~~;~~

~~(b) determining~~ identifying if said patient has a first condition, said first condition being pre-existing left ventricular dysfunction evidenced by an elevated pulmonary capillary wedge pressure dependency on right-to-left shunting of blood at the patent ductus arteriosus; and,

(c) further identifying if said patient has a second condition, said second condition being pre-existing left ventricular dysfunction, independent and separate from whether said patient has right-to-left shunting of blood at the patent ductus arteriosus; and

(d) administering said inhaled nitric oxide medical treatment to said patient if said patient does not have the first condition or the second condition. pre-existing left ventricular dysfunction, wherein said patient is excluded from being administered said medical treatment if said patient has pre-existing left ventricular dysfunction;

~~thereby reducing the risk of the occurrence of the a serious adverse event associated with said medical treatment.~~

12-19. Canceled.

REMARKS

Claims 1-10 and 12-19 have been cancelled. Claim 11 has been amended. Allowance of the present application in light of the above amendments and the following remarks is respectfully requested.

Applicants would like to thank Examiner Arnold for the comments and discussion provided in the Examiner interview of March 3, 2011.

Based on the discussion during the interview, Applicants have attempted to amend claim 11 to reflect the agreement reached during the interview. In sum, amended claim 11 more clearly distinguishes between the step of identifying patients depending on right-to-left shunting of blood at the patent ductus arteriosus, and with respect to the present invention, further identifying patients with pre-existing left ventricular dysfunction, independent of whether such patients have right-to-left shunting of blood at the patent ductus arteriosus.

To reiterate, the prior art (Atz et al., page 452) discloses the well known contraindication (also found on the prescribing information of INOMAX®, submitted with prior communications) that neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus should not be administered inhaled nitric oxide. Indeed, at the time of the invention, it was widely recognized by those of skill in the art that this class of patients should not be given inhaled NO therapy. In contrast to the prior art and the contraindication, the claimed invention relates to an important discovery of an elevated risk for the use of inhaled NO within a newly identified and separate patient population - pediatric patients with pre-existing left ventricular dysfunction, independent and separate from those dependent on a right-to-left shunting of blood.

Turning to the specific language of amended claim 11, step (b) relates to identifying patients who are dependent on right-to-left shunting of blood at the patent ductus arteriosus – i.e., the prior art. Conversely, step (c) separately and independently from (b), relates to the nature of the invention – i.e., further identifying patients with pre-existing left ventricular dysfunction, independently of those captured in step (b). Finally, as discovered during INOT22, step (d) relates to excluding from treatment with inhaled nitric oxide, those patients found to have either (b) or (c).

Support for the amendments and new claims is found in the specification of the application, as filed, including the original claims as filed and paragraphs [0007], [0020], [0023] and [0052] of the specification.

In light of the above, Applicant respectfully submits that the application as amended is in condition for allowance and respectfully requests the same. Examiner Arnold is invited to contact Chief Patent Counsel for the patent owner, Jonathan Provoost (Reg. No. 44,292) at 908-238-6392 to discuss any of the amendments or remarks set forth above.

The application as amended contains one independent claim, one total claim, and no multiple dependent claims. As such, the application continues to comply with the 3/20 claim limitation for accelerated applications.

No fees are believed to be due with this submission. Please apply any necessary charges or credits to deposit account **12-0769**, referencing Attorney Docket No. I001-0002USC1.

Respectfully submitted,

/Jonathan N. Provoost, Reg. No. 44,292/
Jonathan N. Provoost
Attorney for Applicant and Assignee
Associate General Counsel
Ikaria
6 Route 173
Clinton, NJ 08809
Direct phone: (908) 238-6392
Cell: (908) 391-3440
Fax (legal dept.): (908) 238-6773
jonathan.provoost@ikaria.com

Dated: March 3, 2011

Electronic Acknowledgement Receipt

EFS ID:	9583338
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Beatrice L. Koempel-Thomas/Anna Goforth
Filer Authorized By:	Beatrice L. Koempel-Thomas
Attorney Docket Number:	I001-0002USC1
Receipt Date:	03-MAR-2011
Filing Date:	22-JUN-2010
Time Stamp:	18:40:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		PP6196.PDF	73564 <small>23a96980f3cb2b0425b65d6b7a69a6769cfe10dd</small>	yes	5

Multipart Description/PDF files in .zip description		
Document Description	Start	End
Amendment After Final	1	1
Claims	2	2
Applicant Arguments/Remarks Made in an Amendment	3	5

Warnings:

Information:

Total Files Size (in bytes):	73564
-------------------------------------	-------

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 12/820,866		Filing Date 06/22/2010		<input type="checkbox"/> To be Mailed			
APPLICATION AS FILED – PART I					SMALL ENTITY <input checked="" type="checkbox"/> OR OTHER THAN SMALL ENTITY						
(Column 1)		(Column 2)			(Column 3)		(Column 4)				
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)			
<input type="checkbox"/> BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A		N/A			
<input type="checkbox"/> SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A		N/A			
<input type="checkbox"/> EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =		OR X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		X \$ =		OR X \$ =			
<input type="checkbox"/> APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))											
* If the difference in column 1 is less than zero, enter "0" in column 2.											
APPLICATION AS AMENDED – PART II					SMALL ENTITY <input type="checkbox"/> OR OTHER THAN SMALL ENTITY						
(Column 1)		(Column 2)		(Column 3)		(Column 4)		(Column 5)			
AMENDMENT	03/03/2011	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 1	Minus	** 20	= 0	X \$26 =	0	OR	X \$ =		
	Independent (37 CFR 1.16(h))	* 1	Minus	***3	= 0	X \$110 =	0	OR	X \$ =		
	<input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))										
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE		0	OR	TOTAL ADD'L FEE	
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =		
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =		
	<input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))										
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE			OR	TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.											
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".											
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".											
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.											
						Legal Instrument Examiner: /MARISSA R. BLYTHER/					

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
 If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/820,866	06/22/2010	James S. Baldassarre	I001-0002USC1	2913
49584	7590	03/25/2011	EXAMINER	
LEE & HAYES, PLLC 601 W. RIVERSIDE AVENUE SUITE 1400 SPOKANE, WA 99201			ARNOLD, ERNST V	
			ART UNIT	PAPER NUMBER
			1613	
			NOTIFICATION DATE	DELIVERY MODE
			03/25/2011	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

lhpto@leehayes.com

Advisory Action Before the Filing of an Appeal Brief	Application No. 12/820,866	Applicant(s) BALDASSARRE ET AL.	
	Examiner ERNST ARNOLD	Art Unit 1613	

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

THE REPLY FILED 03 March 2011 FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.

1. The reply was filed after a final rejection, but prior to or on the same day as filing a Notice of Appeal. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. The reply must be filed within one of the following time periods:

- a) The period for reply expires 4 months from the mailing date of the final rejection.
b) The period for reply expires on: (1) the mailing date of this Advisory Action, or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.

Examiner Note: If box 1 is checked, check either box (a) or (b). ONLY CHECK BOX (b) WHEN THE FIRST REPLY WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. The Notice of Appeal was filed on _____. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. The proposed amendment(s) filed after a final rejection, but prior to the date of filing a brief, will not be entered because
(a) They raise new issues that would require further consideration and/or search (see NOTE below);
(b) They raise the issue of new matter (see NOTE below);
(c) They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or
(d) They present additional claims without canceling a corresponding number of finally rejected claims.

NOTE: See Continuation Sheet. (See 37 CFR 1.116 and 41.33(a)).

4. The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).
5. Applicant's reply has overcome the following rejection(s): _____.
6. Newly proposed or amended claim(s) _____ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).
7. For purposes of appeal, the proposed amendment(s): a) will not be entered, or b) will be entered and an explanation of how the new or amended claims would be rejected is provided below or appended.
The status of the claim(s) is (or will be) as follows:
Claim(s) allowed: _____.
Claim(s) objected to: _____.
Claim(s) rejected: 1-19.
Claim(s) withdrawn from consideration: _____.

AFFIDAVIT OR OTHER EVIDENCE

8. The affidavit or other evidence filed after a final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).
9. The affidavit or other evidence filed after the date of filing a Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing a good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).
10. The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. The request for reconsideration has been considered but does NOT place the application in condition for allowance because:
See Continuation Sheet.
12. Note the attached Information *Disclosure Statement*(s). (PTO/SB/08) Paper No(s). _____.
13. Other: _____.

/Ernst V Arnold/
Primary Examiner, Art Unit 1613

Continuation of 3. NOTE: The term 'patent ductus arteriosus' is not in the specification as filed and appears to be new matter.

Continuation of 11. does NOT place the application in condition for allowance because: After consultation with a quality assurance specialist, it has been determined that: 1) the amendment raise issues of proper incorporation by reference of essential subject matter; 2) raises the issue of a need for applicant to UPDATE both their search and examination support documents; 3) requires additional search by the Examiner; 4) requires modification of existing rejections; 5) does not simplify issues for appeal; and 6) does not place the case in immediate condition for allowance.

Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop After Final Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REPLY AFTER FINAL (37 CFR 1.116)
ACCELERATED EXAM – TRANSMITTAL REPLY

This communication is responsive to the Examiner Interview of March 3, 2011, and the Advisory Action mailed Feb. 23, 2011.

Applicant respectfully requests entry of this 3rd Reply After Final, reconsideration of the pending rejections, and allowance of the application. A listing of the claims and amendments thereof is shown starting at page 2.

Applicant further asserts that this 3rd Reply After Final has been diligently filed and that the application is in compliance with MPEP 708.02(a)(IV) After-Final and Appeal Procedures, thus maintaining the application's status as an accelerated application.

Remarks to the pending Office Action begin at page 3.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<p style="text-align: center;">Request for Continued Examination (RCE) Transmittal</p> <p>Address to: Mail Stop RCE Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450</p>	Application Number	12/820,866
	Filing Date	6/22/2010
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001 - 0002USC1

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
 Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See Instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. **Submission required under 37 CFR 1.114** Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).
- a. Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.
- i. Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ii. Other _____
- b. Enclosed
- i. Amendment/Reply
- ii. Affidavit(s)/ Declaration(s)
- iii. Information Disclosure Statement (IDS)
- iv. Other Accelerated exam support docs

2. **Miscellaneous**

- a. Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of _____ months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)
- b. Other _____

3. **Fees**

- The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.
 The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any overpayments, to Deposit Account No. 12-0769.
- a. The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any overpayments, to Deposit Account No. 12-0769.
- i. RCE fee required under 37 CFR 1.17(e)
- ii. Extension of time fee (37 CFR 1.136 and 1.17)
- iii. Other _____
- b. Check in the amount of \$ _____ enclosed
- c. Payment by credit card (Form PTO-2038 enclosed) Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

Signature	/Christopher P. Rogers, RegNo 36334/	Date	May 2, 2011
Name (Print/Type)	Christopher P. Rogers	Registration No.	36,334

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop RCE, Commissioner for Patents, P. O. Box 1450, Alexandria, VA 22313-1450 or facsimile transmitted to the U.S. Patent and Trademark Office on the date shown below.

Signature	Filed via EFS WEB	
Name (Print/Type)		Date

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop RCE, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
 If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO)	
Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1613
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

UPDATED ACCELERATED EXAMINATION SUPPORT DOCUMENT

Commissioner for Patents
 PO Box 1450
 Alexandria, VA 22313-1450

Sir:

This Updated Accelerated Examination Support Document (AESD) is submitted in support of the Petition for Accelerated Examination filed herewith.

Pending claims 20-27 are shown starting at page 2 herein.

Consideration and grant of the Petition to Accelerate Examination is respectfully requested.

CLAIMS

20. A method of reducing the risk of the occurrence, in a neonate or near-term neonate patient, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide, said method comprising:

(a) identifying a patient in need of inhaled nitric oxide treatment;

(b) identifying if said patient has a first condition, said first condition being where the patient is known to be dependent on right-to-left shunting of blood;

(c) further identifying if said patient has a second condition, said second condition being pre-existing left ventricular dysfunction, independent and separate from whether said patient is dependent on right-to-left shunting of blood; and

(d) administering said inhaled nitric oxide treatment to said patient if said patient does not have the first condition or the second condition.

21. A method of reducing the risk of one or more adverse events or serious adverse events associated with the use of inhaled nitric oxide in term or near-term neonate patients, said method comprising:

a. providing a source of pharmaceutically acceptable nitric oxide gas for inhalation to a medical provider;

b. informing the medical provider of a first risk factor, said first risk factor being that nitric oxide is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood; and,

c. informing the medical provider of a second risk factor, said second risk factor being independent and separate from said first risk factor, said second risk factor being that in patients with elevated pulmonary capillary wedge pressure, inhaled nitric oxide may increase pulmonary wedge pressure leading to pulmonary edema.

22. The method of claim 20 wherein the patients have an elevated pulmonary capillary wedge pressure greater than or equal to 20 mg Hg.

23. The method of claim 20 wherein the neonate patients are receiving inhaled nitric oxide for the treatment of hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension.

24. The method of claim 20 wherein the source of inhaled nitric oxide is a pressurized cylinder containing nitric oxide and one or more inert gases.

25. A method of reducing the risk of one or more adverse events or serious adverse events associated with the use of inhaled nitric oxide in term or near-term neonates, said method comprising:

a. providing a source of pharmaceutically acceptable nitric oxide gas for inhalation to a medical provider;

b. informing the medical provider of a first risk factor, said first risk factor being that nitric oxide is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood; and,

c. informing the medical provider of a second risk factor, said second risk factor being independent and separate from first risk factor, wherein said second risk factor being that in children with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary wedge pressure leading to pulmonary edema.

26. The method of claim 25 wherein children with pre-existing left ventricular dysfunction are characterized by a condition selected from the group consisting of elevated pulmonary capillary wedge pressure, diastolic dysfunction, hypertensive cardiomyopathy, systolic dysfunction, ischemic cardiomyopathy, viral cardiomyopathy, idiopathic cardiomyopathy, autoimmune disease related cardiomyopathy, drug-related cardiomyopathy, toxin-related cardiomyopathy, structural heart disease, valvular heart disease and congenital heart disease.

27. The method of claim 25 wherein children with pre-existing left ventricular dysfunction are characterized by systolic dysfunction and a pulmonary capillary wedge pressure of greater than or equal to 20 mg Hg.

9(A) References Deemed Most Closely Related

An Information Disclosure Statement in compliance with 37 CFR 1.98 has been filed herewith citing each of the following references deemed most closely related to the subject matter of the claims.

List of Most Closely Related References

Rosenberg, Adam A., Inhaled nitric oxide in the premature infant with severe hypoxemic respiratory failure: A time for caution, J Pediatr 1998;133:720-2. ("Rosenberg").

Ichinose, F. et al., Inhaled Nitric Oxide: A Selective Pulmonary Vasodilator: Current Uses and Therapeutic Potential, Circulation 2004;109;3106-3111. ("Ichinose").

Konduri GG et al., A randomized trial of early versus standard inhaled nitric oxide therapy in term and near-term newborn infants with hypoxic respiratory failure, Pediatrics 2004;113;559-564. ("Konduri").

Soto, FJ et al., Cardiopulmonary Hemodynamics in Pulmonary Hypertension: Pressure Tracings, Waveforms, and More, Advances in Pulmonary Hypertension, Winter 08-09, Vol. 7, No. 4, pp. 386-393. ("Soto").

Malloy R., Nitric Oxide Weaning, RT: For Decision Makers in Respiratory Care (December 2000). ("Malloy").

Delivery of Inhaled Nitric Oxide Therapy through an Adult or Pediatric Nasal Cannula, UTMB Respiratory Care Services (2005). ("UTMB Procedure").

Fraisse A et al., Doppler echocardiographic predictors of outcome in newborns with persistent pulmonary hypertension, Cardiol Young 2004; 14:277-283. ("Fraisse").

9(B) Identification of Limitations Disclosed by References

Rosenberg is a review article of a selection of then-published studies concerning inhaled nitric oxide in premature infants with severe hypoxemic respiratory failure. No

new studies or data is reported. As such, Rosenberg is concerned with respiratory failure as opposed to heart failure.

Ichinose is a review article concerning inhaled nitric oxide being a selective pulmonary vasodilator. Ichinose reviews current uses and discusses the therapeutic potential of inhaled nitric oxide. No new studies or data is reported.

Konduri reports the results of a randomized trial that enrolled neonates born at \geq 34 weeks gestation. The authors concluded that inhaled nitric oxide (iNO) improved oxygenation but does not reduce the incidence of ECMO/mortality when initiated at an oxygenation index of 15-25 compared to initiation at >25 in-term and near-term neonates with respiratory failure. (See Abstract).

Soto is a continuing medical education paper concerning cardiopulmonary hemodynamics in patients with pulmonary hypertension. Under the heading "Vasodilator challenge," Soto discusses a patient receiving iNO resulting in increased PCWP and V wave pressure upon vasodilation. (See p. 389). The findings point to LVD being the likely cause of pulmonary hypertension in the patient.

Malloy is an article pointing out that iNO is contraindicated in neonates dependent on right-to-left shunting of blood.

UTMB Procedure includes guidelines for iNO therapy. Under the heading "Indications", it discloses that iNO is indicated for use in term and near-term neonates with hypoxic respiratory failure associated with various conditions.

Fraisse discusses a study involving neonates with persistent pulmonary hypertension. The authors concluded that "an exclusively left-to-right shunt across the atrial septum increases the risk of failing to respond to nitric oxide." (P. 282 left column). Fraisse is concerned with the "predictive features of echocardiography in persistent pulmonary hypertension of the newborn." (Id. at right column).

9(C) Detailed Explanation of Patentability

Independent claim 20 involves identifying the first condition (right-to-left shunt) and the second condition (pre-existing LVD). Independent claims 21 and 25 involve informing the medical provider of the first and second risk factors (right-to-left shunt and pre-existing LVD). Claim 20 has the additional step (d) of administering iNO if the patient does not have right-to-left shunt or pre-existing LVD. Claims 21 and 25 have the additional step (a) of providing NO gas for inhalation.

None of the references disclose an increased risk of adverse events or severe adverse events associated with iNO treatment in a pediatric patient population (comprising neonates and near-term neonates) that have been diagnosed as having pre-existing left ventricular dysfunction (LVD), separate and independent from the known contraindication of iNO for neonates dependent on right-to-left shunting of blood.

Thus, claims 20-27 are patentably novel and nonobvious over the new prior art set forth herein at least because it fails to disclose or render obvious the increased risk of adverse events or serious adverse events associated with iNO treatment in a pediatric population.

9(D) Concise Statement of Utility

The instantly claimed invention is eligible subject matter under 35 USC 101 for patentable utility in that the claims are generally directed to a method of reducing the risk of adverse events and serious adverse events in patients in need of being treated with inhaled nitric oxide.

9(E) Showing of Support under 35 USC 112, First Paragraph

Support for the new claims is found in the specification of the application, as filed, including the original claims as filed and paragraphs [0007], [0011], [0014], [0020], [0023] and [0052] of the specification. In addition, with respect to the contraindication for neonates dependent on right to left shunting of blood, this language is expressly found in the prescribing information for inhaled nitric oxide, incorporated by reference in the specification at paragraph [0020], and as per the amendment to the specification above, this language is now expressly included in paragraph [0020].

9(F) Identification of References Disqualified as Prior Art under 35 USC 103(c)

None of the cited references are disqualified as prior art under 35 USC 103(c).

Respectfully Submitted,

/Christopher P. Rogers, RegNo 36,334/

Date: May 2, 2011

Christopher P. Rogers
Lee & Hayes PLLC
601 W. Riverside Ave.
Suite 1400
Spokane, WA 99201
(509)944-4785

UNITED STATES PATENT & TRADEMARK OFFICE	
Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop Amendment
 Commissioner for Patents
 P.O. Box 1450
 Alexandria, VA 22313-1450

REPLY AMENDMENT 37 CFR 1.111(a)
ACCELERATED EXAM – TRANSMITTAL REPLY

This communication is responsive to the Final Office Action mailed November 2, 2010, setting a shortened statutory period for reply of 3 months.

Applicant respectfully requests entry of this Reply Amendment, reconsideration of the pending rejections, and allowance of the application.

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims beginning on page 3 of this paper.

The **Remarks** begin on page 6 of this paper.

Amendments to the Specification

Please amend paragraph [0020] as follows:

[0020] INOmax® (nitric oxide) for inhalation was approved for sale in the United States by the U.S. Food and Drug Administration (“FDA”) in 1999. Nitric oxide, the active substance in INOmax®, is a selective pulmonary vasodilator that increases the partial pressure of arterial oxygen (PaO₂) by dilating pulmonary vessels in better ventilated areas of the lung, redistributing pulmonary blood flow away from the lung regions with low ventilation/perfusion (V/Q) ratios toward regions with normal ratios. INOmax® significantly improves oxygenation, reduces the need for extracorporeal oxygenation and is indicated to be used in conjunction with ventilatory support and other appropriate agents. The current FDA-approved prescribing information for INOmax® is incorporated herein by reference in its entirety. Section 4 of the prescribing information, Contraindications, states that INOmax® is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood.

Amendments to the Claims

Please cancel claims 1-19. Please add new claims 20-27.

1-19. Canceled.

20. (New) A method of reducing the risk of the occurrence, in a neonate or near-term neonate patient, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide, said method comprising:

- (a) identifying a patient in need of inhaled nitric oxide treatment;
- (b) identifying if said patient has a first condition, said first condition being where the patient is known to be dependent on right-to-left shunting of blood;
- (c) further identifying if said patient has a second condition, said second condition being pre-existing left ventricular dysfunction, independent and separate from whether said patient is dependent on right-to-left shunting of blood; and
- (d) administering said inhaled nitric oxide treatment to said patient if said patient does not have the first condition or the second condition.

21. (New) A method of reducing the risk of one or more adverse events or serious adverse events associated with the use of inhaled nitric oxide in term or near-term neonate patients, said method comprising:

- a. providing a source of pharmaceutically acceptable nitric oxide gas for inhalation to a medical provider;
- b. informing the medical provider of a first risk factor, said first risk factor being that nitric oxide is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood; and,
- c. informing the medical provider of a second risk factor, said second risk factor being independent and separate from said first risk factor, said second risk factor being

that in patients with elevated pulmonary capillary wedge pressure, inhaled nitric oxide may increase pulmonary wedge pressure leading to pulmonary edema.

22. (New) The method of claim 20 wherein the patients have an elevated pulmonary capillary wedge pressure greater than or equal to 20 mg Hg.

23. (New) The method of claim 20 wherein the neonate patients are receiving inhaled nitric oxide for the treatment of hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension.

24. (New) The method of claim 20 wherein the source of inhaled nitric oxide is a pressurized cylinder containing nitric oxide and one or more inert gases.

25. (New) A method of reducing the risk of one or more adverse events or serious adverse events associated with the use of inhaled nitric oxide in term or near-term neonates, said method comprising:

- a. providing a source of pharmaceutically acceptable nitric oxide gas for inhalation to a medical provider;
- b. informing the medical provider of a first risk factor, said first risk factor being that nitric oxide is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood; and,
- c. informing the medical provider of a second risk factor, said second risk factor being independent and separate from first risk factor, wherein said second risk factor being that in children with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary wedge pressure leading to pulmonary edema.

26. (New) The method of claim 25 wherein children with pre-existing left ventricular dysfunction are characterized by a condition selected from the group consisting of elevated pulmonary capillary wedge pressure, diastolic dysfunction, hypertensive cardiomyopathy, systolic dysfunction, ischemic cardiomyopathy, viral

cardiomyopathy, idiopathic cardiomyopathy, autoimmune disease related cardiomyopathy, drug-related cardiomyopathy, toxin-related cardiomyopathy, structural heart disease, valvular heart disease and congenital heart disease.

27. (New) The method of claim 25 wherein children with pre-existing left ventricular dysfunction are characterized by systolic dysfunction and a pulmonary capillary wedge pressure of greater than or equal to 20 mm Hg.

REMARKS

In the specification, paragraph [0020] was amended to include language from the INOMAX® prescribing information, which was expressly incorporated by reference within paragraph [0020] of the original specification. The language added to paragraph [0020] is material previously incorporated by reference and the amendment to paragraph [0020] contains no new matter (see 37 CFR 1.57(f) and MPEP 608.01(p)).

Claims 1-19 have been canceled.

New claims 20 – 27 have been added. In particular, new claim 20 is analogous to claim 11, as presented in the 4th After Final Reply of March 3rd, 2011, subsequent to a discussion with Examiner Arnold on March 3, 2011. Support for the new claims is found in the specification of the application, as filed, including the original claims as filed and paragraphs [0007], [0011], [0014], [0020], [0023] and [0052] of the specification. In addition, with respect to the contraindication for neonates dependent on right to left shunting of blood, this language is expressly found in the prescribing information for inhaled nitric oxide, incorporated by reference in the specification at paragraph [0020], and as per the amendment to the specification above, this language is now expressly included in paragraph [0020].

The amendments and new claims address matters discussed during the Examiner Interview conducted on January 10, 2011, a discussion with Examiner Arnold on March 3, 2011, and Advisory Actions of February 23, 2011 and March 25, 2011.

Applicant submits that the amendments herein are in compliance with revised 37 CFR 1.121.

On March 3rd, after a telephone conference with Examiner Arnold, Applicants submitted a 4th Reply After Final seeking to amend a single claim (claim 11) that would

distinguish the present invention from the prior art. In response, on March 25, 2011 the Examiner issued an Advisory Action indicating that the March 3, 2011, amendments did not put the application in condition for allowance due to the fact that the term “patent ductus arteriosus” was not found in the original specification. To redress this objection, the term “patent ductus arteriosus” is not presented within new claims 20-27. Further, the Examiner noted that the amendments require an update to the search and examination support documents. Accordingly, with this Request for Continuation, applicants include an updated Accelerated Examination Support Document.

Applicants remain hopeful that there remains agreement with respect to the underlying fact that the INO22 study resulted in a significant medical invention not taught in the prior art and that the question presented is how appropriately to claim that invention.

Applicant sought to establish three points during the January 10, 2011, interview:

1. That the present invention is not directed to neonates reliant on right-to-left shunting of blood at the patent ductus arteriosus because it was already well known in the art at the time of the INO22 study that such patients were ineligible to receive inhaled nitric oxide treatment. This is demonstrated by the Atz et al. article cited by the Examiner and the original FDA label for inhaled nitric oxide issued by the FDA which specifically states that inhaled nitric oxide is contraindicated for this patient population. Rather, the invention claimed in the present application is directed to pediatric patients with pre-existing left ventricular dysfunction that are not reliant on such right-to-left shunting.

2. That the risk of increased adverse events and serious adverse events from administering inhaled nitric oxide to pediatric patients that are not reliant on right-to-left shunting, represented a highly surprising result to those skilled in the art, as demonstrated, e.g., by the fact that it was not recognized or considered by any of the 18

independent review boards (IRBs) at medical institutions in the United States and Europe, nor two independent National Health Authorities (the US FDA and the European Medicines Agency) as a risk to be considered in the original protocol for the INO22 study.

3. That the references cited by the Examiner are directed solely either (a) to neonates reliant on right-to-left shunting (e.g., Atz et al.); or (b) to adults suffering from an entirely different category of left ventricular dysfunction than the type that affects children. Adults with LVD suffer from diastolic dysfunction (stiff, non-compliant heart that cannot fill properly) caused by ischemic cardiomyopathy (heart failure due to coronary artery disease and resultant partial cardiac muscle death) and idiopathic dilated cardiomyopathy. By contrast, children with LVD suffer from systolic dysfunction (soft flabby heart that cannot push blood out) caused by congenital (structural) defects or cardiomyopathies (muscle diseases). For this reason, there were no existing concerns about left ventricular dysfunction in children or neonates until the INOT 22 study was analyzed and understood despite the known teachings of Loh and others with respect to adults.

It is respectfully submitted that if the above three points are agreed, the only barrier to allowance of the present application is identifying claim language that both the Examiner and Applicant agree captures the distinction between the claimed invention and the prior art. With this background, applicant respectfully submits that the new claims presented herein are believed to address the concerns raised by the Examiner in the in the Advisory Action of March 25, 2011.

As amended, claims 20-27 more clearly distinguish between the step of identifying neonates depending on right-to-left shunting of blood at the patent ductus arteriosus, and with respect to the present invention, further identifying patients with pre-existing left ventricular dysfunction, independent of whether such patients have right-to-left shunting of blood at the patent ductus arteriosus. To further clarify this

distinction, dependent claim 26 further limits the claimed definition of pre-existing left ventricular dysfunction in children to only include children characterized by a condition selected from the group consisting of elevated pulmonary capillary wedge pressure, diastolic dysfunction, hypertensive cardiomyopathy, systolic dysfunction, ischemic cardiomyopathy, viral cardiomyopathy, idiopathic cardiomyopathy, autoimmune disease related cardiomyopathy, drug-related cardiomyopathy, toxin-related cardiomyopathy, structural heart disease, valvular heart disease and congenital heart disease. Dependent claim 27 limits the claimed definition of pre-existing left ventricular dysfunction to children with pre-existing left ventricular dysfunction are characterized by systolic dysfunction and a pulmonary capillary wedge pressure of greater than or equal to 20 mg Hg.

Final Office Action of November 2, 2010

Rejections Under 35 USC § 102(b)

Former claim 1 was rejected as being anticipated by the NIH Clinical Center, Department Policy and Procedure Manual for the Critical Care therapy and Respiratory Care Section; Nitric Oxide Therapy, 2000 (hereinafter the "NIH Manual") and Atz, et al., Seminars in Perinatology, 1997 (hereinafter "Atz").

"Anticipation" under 35 USC102 requires that a rejection must be based on a single prior art reference. For a claim to be anticipated, each claim element must be disclosed, either expressly or inherently, in a single prior art reference, and the claimed arrangement or combination of those elements must also be disclosed, either expressly or inherently, in that same prior art reference.

In particular, the Examiner states that the NIH Manual contains a relative contraindication to the use of inhaled nitric oxide in severe left ventricular failure and that such contraindication applies to the treatment of term or near term neonates. During the interview of January 10, 2011, Applicants provided an email from Dr. Dennis

T. Brown, Section Chief, at the NIH Hospital in Bethesda, Maryland, to Jeffrey R. Smith, Esq, an attorney and expert witness at the firm representing Applicant, confirming that the NIH manual reference is limited to the use of inhaled nitric oxide therapy in adult patients being treated in the intensive care unit (a reproduction of the email is attached in Appendix A) and that the NIH Hospital does not contain a neonatal intensive care unit for the treatment of adults. Further, applicants highlight the fact that section 5.0 of the NIH Manual, Contraindications (both absolute and relative contraindications), is virtually an exact duplicate of the same Contraindications (both absolute and relative contraindications) described in B.H. Cuthbertson, P. Dellinger, O.L., Dyar, T.E. Evens, et al., *UK guidelines for the use of inhaled nitric oxide therapy in adult ICUs*. *Intensive Care Med* (1997) 23:1212-1218 (see page 1216, Table 1), which is cited in Section 19.0 References of the NIH Manual. Thus, the NIH Manual describes the risks associated with the use of iNO in adult patients, not patients under the age of 18 (e.g., non-adults).

Atz, page 452, states in pertinent part:

“Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension. In adults with ischemic cardiomyopathy, sudden pulmonary vasodilation may occasionally unload the right ventricle sufficiently to increase pulmonary blood flow and harmfully augment preload in a compromised left ventricle. The attendant increase in left atrial pressure may produce pulmonary edema. ... A different, but related phenomenon may be operative in the newborn with severe left ventricular dysfunction and pulmonary hypertension. In these patients, the systemic circulation may depend in part on the ability of the right ventricle to sustain cardiac output through a right-to-left shunt across the patent ductus arteriosus. Selective pulmonary vasodilation may redirect the right ventricular output to the lungs and away from the systemic circulation. Therefore, in newborns with severe left ventricular dysfunction, predominantly left

to right shunting at the foramen ovale and exclusively right to left shunting at the ductus arteriosus, NO should be used with extreme caution.”

Thus, Atz describes two distinct phenomenon – (i) the potential effects of inhaled nitric oxide in adults, and (ii) the potential effects of inhaled nitric oxide in newborns dependent on right-to-left shunt across the patent ductus arteriosus.

A. Adults

Atz and the NIH Manual describe the potential effects of inhaled nitric oxide on a first patient population, adults with left ventricular dysfunction due primarily to ischemic or hypertensive cardiomyopathy. As explained during the interviews, adult patients are clearly distinct from children due to the fact that the etiology and pathophysiology of the left ventricular dysfunction present in non-adult patients is markedly different from adult patients (systolic vs. diastolic dysfunction). Accordingly, adults are not clinically analogous to children, particularly with respect to left ventricular dysfunction.

In particular, it should be noted that left ventricular dysfunction comes in two broad types: diastolic dysfunction (stiff, non-compliant heart that cannot fill properly) or systolic dysfunction (soft flabby heart that cannot push blood out). As detailed in the accompanying declaration of Dr. Douglas A. Greene, in children, left-sided ventricular dysfunction is generally associated with a soft, overly elastic heart that cannot push blood out, resulting in impaired emptying (“systolic dysfunction”). Conversely, in adults, left-sided ventricular dysfunction is generally ischemic or hypertensive in origin, and is associated with a stiff, non-compliant left ventricle that cannot fill properly (“diastolic dysfunction”). Because of this important clinical and etiological distinction, one would not expect an elevated risk of pulmonary edema or cardiac complications when using inhaled nitric oxide in children with impaired left ventricular dysfunction. For this reason,

there were no existing concerns about left ventricular dysfunction in children until the INOT 22 study was analyzed.

B. Neonates with Right-to-Left Shunt

In addition, Atz is further directed to the potential effects of inhaled nitric oxide in a second, distinct patient population – neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus. As discussed during the interview of January 10, 2011, pre-existing left ventricular dysfunction, as enumerated in the claims, does not include neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus. In particular, patent ductus arteriosus is a congenital disorder in the heart wherein the ductus arteriosus of a neonate (a vascular connection between the pulmonary artery and the aortic arch that allows most of the blood from the right ventricle to bypass the fetus lungs) fails to close naturally after birth (see paragraph 12 of the Declaration of Dr Greene). This condition is very specific and rather uncommon; it has essentially no clinical or physiologic overlap with any other condition discussed in this patent application. At the time of the instant invention, it was widely recognized by those of skill in the art that neonates dependent on right-to-left shunting of blood should not be treated with inhaled nitric oxide (see paragraph 14 of the Declaration of Dr Greene). In fact, this contraindication has been presented in the prescribing information (sometimes referred to as the drug “label”) for INOMAX® (nitric oxide) for inhalation, since the approval of the drug by the FDA in December 1999 (see Section 4 of the INOMAX Prescribing Information – Attached hereto as Appendix B). Consequently, patients with this specific condition, were, of course, excluded from the INOT22 study that resulted in the discovery that is the subject of the presently claimed invention (see paragraph 20 of the Declaration of Dr Greene). Moreover, in 2009, based on the findings from the INOT22 study, the FDA approved the addition of the following new warnings to the INOMAX® prescribing information, independent of the existing contraindication for neonates dependent on right-to-left shunting of blood:

“Heart Failure: In patients with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary capillary wedge pressure leading to pulmonary edema” and “5.4 Heart Failure: Patients who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced serious adverse events (e.g., pulmonary edema).”

One would have to suppose that the FDA would not add new warnings and precautions to the label of a drug that essentially restate a known contraindication already existing on the approved drug label. Indeed, the new FDA-approved warnings for the use of nitric oxide are clinically distinct from the existing, original INOMAX contraindication disclosed by Atz, with respect to neonates with right-to-left shunt.

In contrast to Atz, the NIH Manual and other prior art references cited by the Examiner, the claimed invention relates to an important discovery in a **third patient population**--non-adult patients (i.e., children and neonates) with pre-existing left ventricular dysfunction who are eligible to receive inhaled nitric oxide treatment (i.e., those not dependent on a right-to-left shunting of blood). As discussed during the interview of January 10, 2011, adult patents are clearly distinct from children due to the fact that the etiology and pathophysiology of the left ventricular dysfunction present in non-adult patients markedly different from adult patients. Further, the pre-existing left ventricular dysfunction in non-adult patients, as claimed in the present invention, is clinically distinct from the pathophysiology within neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus.

Again, to anticipate a claim, a single prior art reference must be enabled and teach each and every element of the claimed invention. In this case, the NIH manual and Atz (with respect to the adult disclosure within Atz) fail to anticipate the claimed invention in that the prior art only discloses a risk associated with the use of inhaled

nitric oxide in adults. In contrast, the present claims are limited to neonates and children, a patient population that is clinically differentiated from adults. With respect to the disclosure in Atz regarding the use of iNO in neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus, the claimed invention pertains to a separate and distinct clinical condition, independent from neonates dependent on right-to-left shunting of blood, such clinical condition being pre-existing LVD. Dependent claims further define LVD to clinical conditions known to those skilled in the art as conditions clinically different from dependency on right-to-left shunting of blood (e.g., systolic dysfunction and elevated PCWP).

Rejection and withdrawal of the anticipation rejections in view of Atz and the NIH manual are respectfully requested.

Rejections Under 35 USC § 103(a)

The Examiner rejected claims 1-19 under 35 USC § 103(a) as being obvious over five different references. In addition to Atz and the NIH Manual, the Examiner further sites Kinsella et al. (The Lancet 1999, 354 1061-1065), Bolooki (Clinical Application of the Intra-Aortic Balloon Pump 1998, 3rd Ed. pp 252-253) and Loh et al. (Circulation 1994, 90, 2780-2785).

Section 35 USC 103 states that “a patent may not be obtained ... if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.”. The foundation for any determination of obviousness is dependent on the facts of each case and is subject to the factual inquiries announced by the Supreme Court in *Graham v. John Deere*, 383 U.S.1 (1966): (i) the scope and content of the prior art, (ii) differences between the claimed invention and the prior art, (iii) the level of ordinary skill in the art, and secondary indicia of nonobviousness.

As explained previously, Atz and the NIH manual describe the use and potential risks of inhaled nitric oxide therapy in adults, a patient population clinically distinct from the patients enumerated in new claims 20-27. Further, Atz describes the well known contraindication with regard to the use of inhaled nitric oxide in neonates dependent on right-to-left shunting of blood through a patent ductus arteriosus.

Kinsella discloses a double blind study that evaluated 80 premature infants with severe hypoxic respiratory failure. The exclusion criteria was "fatal congenital anomalies or congenital heart disease (except atrial and ventricular septal defects) and the study noted the rate and severity of intracranial hemorrhage, pulmonary hemorrhage, duration of ventilation and chronic lung disease. Kinsella described the potential adverse effects of inhaled nitric oxide on platelet adhesion and the attendant risks of intracranial hemorrhage. Kinsella concluded that low dose iNO improved oxygenation and decreased the need for mechanical ventilation, as well as lowered the frequency of chronic lung disease, but did not improve survival in severely hypoxic neonates. Kinsella is silent with respect to the use of inhaled nitric oxide in non-adult patents having pre-existing left ventricular dysfunction.

Bolooki describes uses of an intra-aortic balloon pump in adult patients, as well as nitroglycerin and calcium channel blockers in the treatment of left ventricular dysfunction (pages 252-253). Bolooki is silent respect to the use of inhaled nitric oxide in non-adult patients.

Loh is a study of 19 adult patients with an average age of 52 +/- 3 years suffering from ischemic cardiomyopathy (heart failure due to coronary artery disease and resultant partial cardiac muscle death) and idiopathic dilated cardiomyopathy, which resulted in diastolic left ventricular (LV) failure. The patients also had reactive pulmonary artery hypertension (HTN) secondary to LV failure. The patients were identified as having heart failure due to LV dysfunction as classified by adult NYHA

classifications (class III and class IV). The study found that in patients with heart failure due to LV dysfunction, inhalation of nitric oxide causes a decrease in the pulmonary vascular resistance associated with an increase in LV filling pressure. Unlike the claimed invention, Loh does not disclose the use of inhaled nitric oxide in children, a patient population clinically distinct from those treated in Loh and fails to suggest or anticipated an elevated risk for the use of inhaled nitric oxide in children subject to distinct cardiac myopathies than those possessed by the adult patient in the Loh study.

As described herein, contrary to the prior art references cited by the Examiner, the claimed invention relates to an important discovery in non-adult patients with pre-existing left ventricular dysfunction who are eligible to receive inhaled nitric oxide treatment (i.e., those not dependent on a right-to-left shunting of blood). As explained during the interviews, and in the accompanying Declaration of Dr. Douglas A. Greene, those of ordinary skill in the art, prior to the instant invention, would not have found it obvious to withhold inhaled NO treatment from the claimed patient population because the etiology and pathophysiology of left ventricular dysfunction present in adult patient populations and neonates with right-to-left shunt is markedly different from the non-adult patients of the claimed invention. In fact, as described in greater detail below, the members of the INOT22 Screening Committee who designed the study and the approximately 18 Institutional Review Boards and 2 National Health Authorities who reviewed and approved the study prior to its initiation, would have been aware of the cited prior art, yet failed to predict that any untoward effects would be caused by the administration of inhaled NO within the claimed patient population.

The INOT22 Study

The INOT22 study, entitled "Comparison of supplemental oxygen and nitric oxide for inhalation plus oxygen in the evaluation of the reactivity of the pulmonary vasculature during acute pulmonary vasodilatory testing" was conducted both to assess the safety and effectiveness of INOMAX® as a diagnostic agent in patients undergoing

assessment of pulmonary hypertension (primary endpoint), and to confirm the hypothesis that iNO is selective for the pulmonary vasculature (secondary endpoint).

Upon final analysis of the INOT22 study results, applicants discovered that rapidly decreasing the pulmonary vascular resistance, via the administration of iNO to a patient in need of such treatment, may be detrimental to patients with concomitant, pre-existing left ventricular dysfunction (LVD).

The INOT22 study was an open, prospective, randomized, multi-center, controlled diagnostic trial, with an expected total enrollment of a minimum of 150 patients, in approximately 18 study sites in the US and Europe over approximately 2 years. The expected patient population for enrollment into the INOT22 trial were subjects between the ages of four (4) weeks and eighteen (18) years undergoing diagnostic right heart catheterization scheduled to include pulmonary vasodilation testing to assess pulmonary vasoreactivity. The anticipated study population were subjects with idiopathic pulmonary arterial hypertension, congenital heart disease with pulmonary hypertension and cardiomyopathies.

The INOT22 study was established and designed by the study sponsor, INO Therapeutics LLC (INOT) and a Steering Committee comprising internationally recognized experts in the field of pediatric heart and lung disease.

The original INOT22 protocol contained the following inclusion and exclusion criteria:

Inclusion Criteria

The patient must meet the following criteria:

1. Have any one of the three disease categories:

a. Idiopathic Pulmonary Arterial Hypertension

*i. PAPm >25mmHg at rest, PCWP ≤ 15mmHG, and PVRI > 3 u.m²
or diagnosed clinically with no previous catheterization*

- b. CHD with pulmonary hypertension repaired and unrepaired,
 - i. PAPm >25mmHg at rest, and PVRI > 3 u.m² or diagnosed clinically with no previous catheterization**
 - c. Cardiomyopathy
 - i. PAPm >25mmHg at rest, and PVRI > 3 u.m² or diagnosed clinically with no previous catheterization**
- 2. Schedule to undergo right heart catheterization to assess pulmonary vasoreactivity by acute pulmonary vasodilation testing.*
 - 3. Males or females, ages 4 weeks to 18 years, inclusive*
 - 4. Signed IRB/IEC approved informed consent (and assent if applicable).*

Exclusion Criteria

The patient will be excluded from enrollment if any of the following are true:

- 1. Focal pulmonary infiltrates on chest radiograph.*
- 2. Diagnosed with severe obstructive or restrictive pulmonary disease that is significantly contributing to the patient's pulmonary hypertension.*
- 3. Received treatment with nitric oxide for inhalation within 30 days prior to study initiation, are on other investigation medications, nitroglycerin, sodium nitroprusside, sildenafil, other PDE-5 inhibitors, or prostacyclin.*
- 4. Pregnant (urine HCG +).*

The original INOT22 investigational plan and study protocol were further reviewed and approved by the Institutional Review Board (IRB) and/or Independent Ethics Committee (IEC) at each of the participating study institutions, including review by the principal investigator within each study institution.

At no time did any member of the Steering Committee, INOT, nor any member of an IRB, IEC, or individual principal investigator, appreciate, recognize or otherwise suggest that the exclusion criteria be amended to exclude study subjects (i.e., children) with pre-existing left ventricular dysfunction, due to an anticipated or predicted risk of adverse events or serious adverse events arising from the use of iNO within these patients.

After initiation and enrollment of the first 24 subject in INOT22, there were 5 serious adverse events – a rate much higher than expected based on prior clinical experience. Each of these 5 SAEs were cardiovascular events, and included pulmonary edema, cardiac arrest and hypotension (low blood pressure).

Thereafter, in February 2005, INOT and the Steering Committee convened to review the unexpected SAEs described above, and upon review and discussion, expressed concern that the unexpected SAEs may be due to the administration of iNO in subjects having pre-existing LVD. Accordingly, based upon a review of the SAE cases, the exclusion criteria of the INOT22 protocol was amended to thereafter exclude subjects with pre-existing LVD. For the purpose of the study, the exclusion criteria was amended to exclude subjects from enrollment if the subjects demonstrated an elevated pulmonary capillary wedge pressure (PCWP), defined within the study as subjects having a PCWP greater than 20 mmHg. All study sites were notified immediately. The exclusion criteria was amended as follows:

Exclusion Criteria

The patient will be excluded from enrollment if any of the following are true:

- 1. Focal pulmonary infiltrates on chest radiograph.*
- 2. Diagnosed with severe obstructive or restrictive pulmonary disease that is significantly contributing to the patient's pulmonary hypertension.*

3. *Received treatment with nitric oxide for inhalation within 30 days prior to study initiation, are on other investigation medications, nitroglycerin, sodium nitroprusside, sildenafil, other PDE-5 inhibitors, or prostacyclin.*
4. *Pregnant (urine HCG +).*
5. **Baseline PCWP > 20 mmHg.**

Upon conclusion of the INOT22 study and completion of the final study report, INOT noted that subsequent to excluding patients with pre-existing LVD, the rate of serious adverse events (including serious adverse events associated with heart failure) was significantly reduced. There were 5 SAEs amongst the first 24 subjects of this type prior to the additional exclusion criteria, but only 2 SAEs amongst the last 80 subjects in the study after the additional exclusion. Furthermore, there were 2 SAEs amongst the 4 subjects with evidence of pre-existing LVD, but only 5 SAEs amongst the 120 subjects without evidence of LVD.

Therefore, based on this unexpected finding, on February 25, 2009, INO Therapeutics LLC (owner of NDA 20845) submitted a label supplement to the US Food and Drug Administration (FDA) seeking to amend the prescribing information for INOMAX® to include a warning statement for physicians such that the use of iNO in patients with pre-existing LVD could cause serious adverse events, such as pulmonary edema. On August 28, 2009, the FDA approved the INOMAX® label supplement to include the following new information:

WARNINGS AND PRECAUTIONS

Heart Failure: In patients with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary capillary wedge pressure leading to pulmonary edema (5.4).

5 WARNINGS AND PRECAUTIONS

5.4 Heart Failure: Patients who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced serious adverse events (e.g., pulmonary edema).

Thereafter, similar warnings were added to the INOMAX label worldwide, such as Japan, Europe, Canada and Australia.

Person of Ordinary Skill in the Art

As is well known, the determination of obviousness, while a question of law, is based on underlying factual inquiries that include the level of ordinary skill in the pertinent art. Factors that may be considered are (i) the educational level of the inventor, (ii) the type of problems encountered in the art, (iii) prior art solutions to those problems; (iv) the rapidity with which innovations are made; (v) the sophistication of the technology; and (vi) the education level of active workers in the field. Applicant notes that the members of the Steering Committee were retained because they were well recognized **experts** in the field, not because they were considered to have “ordinary skill in the art”. Thus, although the Steering Committee did not predict or anticipate the risk of adverse events or serious adverse events associated with the use of iNO in study subjects with pre-existing LVD, this level of anticipation is not representative of those of ordinary skill in the art, but rather of those of presumptively **extraordinary** skill. Thus, it is all that much more surprising, and supportive of the non-obviousness of the claims, that the Steering Committee, INOT, the various Institutional Review Board (IRB) and/or Independent Ethics Committee (IEC) and the individual Principal Investigators, upon review of the original INOT22 protocol, and in view of prior art cited by the Examiner, did not predict or anticipate the risk of adverse events or serious adverse events associated with the use of iNO in non-adult patients with preexisting LVD.

Accordingly, as evidenced and supported by the findings of the INOT22 study which gave rise to the present invention, in view of the prior art, one skilled in the art at

the time of the invention would not have predicted or anticipated that pediatric patients with pre-existing LVD would be at risk of experiencing adverse events or serious adverse events arising from treatment with inhaled nitric oxide. Indeed, as described above, not only was the invention not obvious to one of ordinary skill, but even those of extraordinary skill (i.e., those directly involved in the development and analysis of the INOT22 clinical trial) failed to appreciate the unexpected clinical risks and undesirable clinical outcomes giving rise to the present invention. Importantly, based on prior clinical experience and knowledge of the prior art, these experts predicted the opposite outcome – that the use of iNO in children with pre-existing LVD would not raise an undesired safety risk. Clearly, if such a risk would have been obvious, one of the many skilled medical professionals expert in the field of pediatric cardiology that reviewed the original INOT22 protocol would have noted a predicted increased risk in the claimed patient population. Put simply, they did not. As further support of the non-obviousness of the invention, in view of the prior art, Applicants point out that the senior author of Atz, Dr. David Wessel, was a member of the Steering Committee that designed the original INOT22 protocol. As an author of the Atz reference and the disclosures therein, Dr. Wessel did not predict or anticipate that non-adult patients with pre-existing LVD would be at increased risk of experiencing adverse events or serious adverse events arising from the treatment with inhaled nitric oxide.

Therefore, the documented chain of decisions regarding the original development and subsequent amendment of the INOT22 protocol provides direct evidence of the exact perspective and clinical reasoning of a person skilled in the art (or in this instance, those of extraordinary skill) at the time of the invention. The piecing together of multiple prior art references, without support for doing so, fails to establish the obviousness of the present invention in view of the overwhelming evidence to the contrary presented herein.

In light of the above, Applicant respectfully submits that the application, as amended is in condition for allowance and respectfully requests the same. Examiner Arnold is invited to contact Chief Patent Counsel for the patent owner, Jonathan Provoost (Reg. No. 44, 292) at 908-238-6392 to discuss any of the amendments or remarks set forth above.

Please apply any additional necessary charges or credits to deposit account **12-0769**, referencing Attorney Docket No. I001-0002USC1.

Respectfully submitted,

/Jonathan N. Provoost, Reg. No. 44,292/
Jonathan N. Provoost
Attorney for Applicant and Assignee
Associate General Counsel
Ikaria
6 Route 173
Clinton, NJ 08809
Direct phone: (908) 238-6392
Cell: (908) 391-3440
Fax (legal dept.): (908) 238-6773
jonathan.provoost@ikaria.com

Dated: May 2, 2011

APPENDIX A

From: Brown, Dennis (NIH/CC/CCMD) [E] [mailto:DBrown@cc.nih.gov]
Sent: Wednesday, December 29, 2010 11:27 AM
To: Jeffrey Smith
Cc: Allen, Sarah (NIH/CC/CCMD) [E]
Subject: RE: NIH Policy/ Procedure

Jeff,

Sorry for the delay in responding to you. We have a process in place for outside inquiries and I wanted to make sure I was in compliance. The answers to your questions are as follows:

So, just to make sure that I am not way off base in my analysis of this document, can you provide me with some direction?

Specifically:

(1) Is this document used as a policy and procedure for RT's in the MICU, giving them guidelines in the delivery of iNO to adult patients?

Yes. This is a policy/procedure in place to provide direction to respiratory therapists in the implementation of NO in the MICU to adult patients in the ICU.

(2) Does the Clinical Center (for which the attached policy pertains) have a neonatal ICU?

No. The Clinical Center at the National Institutes of Health does not have a neonatal ICU nor do we care for neonates.

Once again I apologize for the delay. Hopefully the information will provide you with the requested clarification.

Dennis T. Brown

Section Chief, CTRCS, CCMD, CC
National Institutes of Health
Critical Care Medicine Department
Critical Care Therapy and Respiratory Care Section
10 Center Drive Bldg. 10 CRC Rm. 4-5551
Bethesda, Maryland 20892
Main Office: 301-496-0758
Desk: 301-435-2348
Cell: 301-807-0904
FAX: 301-402-9030

From: Jeffrey Smith [mailto:JeffreyS@LeeHayes.com]
Sent: Tuesday, December 21, 2010 12:49 PM
To: Brown, Dennis (NIH/CC/CCMD) [E]
Cc: Allen, Sarah (NIH/CC/CCMD) [E]
Subject: NIH Policy/ Procedure
Importance: High

Hi Dennis:

Last week I contacted Sarah Allen regarding a question about an NIH policy dealing with iNO (see my email to her below). She contacted me this morning and felt like you would be the appropriate contact regarding the request below. I have reattached the document in question.

Thanks for your help. Please let me know if you have any questions. I can be reached at my office, (509-944-4786) or via email.

Have a great day.

Jeff
Jeffrey R. Smith, Esq.
Corporate Practice Group
Life Science Practice Group
(509) 944.4786
jeffreys@leehayes.com

APPENDIX B

UNITED STATES PATENT AND TRADEMARK OFFICE	
Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	22-JUN-2010
Title of Application	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor	JAMES S. BALDASSARRE
Assignee	IKARIA, INC.
Group Art Unit	1616
Examiner	ARNOLD, ERNST V.
Attorney Docket Number	1001-0002USC1

Mail Stop Amendment
 Commissioner for Patents
 P.O. Box 1450
 Alexandria, VA 22313-1450

DECLARATION OF DOUGLAS A. GREENE, M.D.
UNDER 37 C.F.R. § 1.132

I, Douglas A. Greene, do hereby declare the following:

1. I currently hold the position of Executive Vice President and Head, Research and Development at INO Therapeutics LLC (“INO”). A copy of my *curriculum vitae* is attached as **Exhibit 1**.

2. I received an undergraduate degree in biology (*cum laude*) from Princeton University in 1966 and a doctoral degree in medicine (M.D.) from Johns Hopkins School of Medicine in 1970.

3. I spent the next thirty years of my medical career (1970-2000) practicing and teaching medicine at some of America’s foremost academic medical centers, including Johns Hopkins, Penn, Pitt, and the University of Michigan. At Michigan, I was a full professor of internal medicine, director of the Michigan Diabetes Research and Training Center, and chief of the Division of Endocrinology and Metabolism.

4. In 2000, I left Michigan to join Merck as Executive Vice President in charge of clinical sciences and product development. In this role, I supervised and directly managed all clinical research at Merck Research Laboratories, among other duties.

5. In 2003, I left Merck for Sanofi-Aventis, where I became a Senior Vice President and Chief Medical Officer. My duties at Sanofi-Aventis included overseeing all aspects of pre-clinical and clinical regulatory development of the company's products and overseeing all medical aspects of the company's US business.

6. In 2010, I joined INO, where – as noted above – I am presently Executive Vice President and Head of Research and Development.

7. INO markets pharmaceutical grade nitric oxide (NO) gas under the brand name INOmax[®]. INOmax[®] is administered to patients using INO's proprietary INOvent[®] and INOmax[®] DS devices.

8. INOmax[®] was approved for sale in the United States by the U.S. Food and Drug Administration ("FDA") in 1999 for the treatment of term and near-term (≥ 34 weeks gestational age) neonates with hypoxic respiratory failure ("HRF") associated with clinical or echocardiographic evidence of pulmonary hypertension, a condition also known as persistent pulmonary hypertension in the newborn ("PPHN"). From 2000 to the present, INO has been selling INOmax[®] throughout the United States, Canada and certain other overseas markets.

9. In addition to the approved indication, physicians employ INOmax[®] to treat or prevent pulmonary hypertension and improve blood oxygen levels in a variety of other clinical settings, including in both pediatric and adult patients suffering from acute respiratory distress syndrome ("ARDS"), pediatric and adult patients undergoing cardiac or transplant surgeries, pediatric and adult patients for testing to diagnose reversible pulmonary hypertension, and in pediatric patients with congenital diaphragmatic hernia. In most, if not all, of these applications, INOmax[®] acts by preventing or treating reversible pulmonary vasoconstriction, and improves pulmonary gas exchange.

10. The mechanism of action of INOmax[®] - the selective relaxation of pulmonary blood vessels - is particularly relevant to the transition of the newborn from the fetal to the neonatal environment. During *in utero* development, the fetal lungs are not filled with air. Accordingly, the fetus obtains oxygen from the mother across the placenta into the systemic circulation, whereas the circulation through the lungs is largely shut down because the pulmonary vessels are tightly constricted. Instead of the blood being pumped from the right side of the heart through the fetal lungs and then returning to the left side of the heart to be pumped to the rest of the body, as it is normally after birth, blood from the right side of the fetal heart bypasses the fetal lungs through a patent ductus arteriosus, a blood vessel connecting the outflow of the right heart directly to the systemic circulation.

11. In addition to the patent ductus arteriosus, the fetal heart contains a second anatomical distinction from the neonatal heart - the foramen ovale - as a means for fetal blood to circumvent the nonfunctional fetal lungs while the fetus obtains its oxygen from the placenta. The foramen ovale is a "hole" located in the wall that separates the right and left atria of the heart. The foramen ovale is usually covered by a flap of tissue known as the septum primum, which is located on the inner wall of the left atrium. The septum primum and the foramen ovale together act as a one-way valve that permits blood to be shunted from the right atrium, where blood pressure is usually high due to the high vascular resistance present in the non-functional fetal lungs, into the left atrium for distribution to the body via the left ventricle. As discussed below, nonclosure of a patent foramen ovale after birth, as well as other forms of congenital heart disease, are often associated with a large persistently patent ductus arteriosus.

12. After birth, the pressure in the pulmonary circulatory system drops, reducing the right atrial pressure below that of the left atrium. This shift in pressure causes the septum primum to close off the foramen ovale, and this flap of tissue eventually becomes incorporated into the intra-atrial wall. In certain instances, however, the foramen ovale may remain open or "patent" after birth. In one such case, elevation of pressure in the pulmonary circulatory system (i.e.: pulmonary hypertension due to various causes) can prevent the pressure shift that leads to the closure of the foramen ovale. This condition is known as patent foramen ovale, and the use

of inhaled nitric oxide to decrease pulmonary hypertension is known to be a successful treatment for right-to-left shunting through a patent foramen ovale.¹

13. At birth, the ductus arteriosus closes and pulmonary vessels relax, thereby redirecting the outflow of the right heart to the now oxygenated lungs, with oxygenated blood then returning to the left side of the heart to be pumped to the rest of the body from the left ventricle. However, in some instances, neonates are born with severe congenital heart disease involving the left ventricle, wherein the left side of the heart lacks the ability to pump blood to the rest of the body. In these instances, a ductus arteriosus that remains open or “patent” is actually beneficial, and in fact is life-saving when combined with pulmonary hypertension, because the reverse pressure created by the pulmonary hypertension creates a right-to-left shunt through the patent ductus arteriosus, thereby permitting the right ventricle to pump oxygenated blood directly to the systemic circulation to maintain organ function; simply put, the patent ductus arteriosus permits the right ventricle to subsume the role of nonfunctional left ventricle in circulating blood to the body. In these circumstances, stealing blood circulation away from the ductus arteriosus would be potentially fatal, and significantly, pulmonary vasoconstriction is also absolutely essential for survival in order to divert sufficient blood from the right heart through the patent ductus arteriosus to the systemic circulation, thus bypassing the non-functional left side of the heart to maintain life. The terminology to describe this situation is “neonates dependent upon right-to-left shunting of blood” for survival.

14. Administration of inhaled nitric oxide (iNO) in the context of such right-to-left shunting would be catastrophic, because reducing or eliminating the pulmonary vasoconstriction would permit blood to be diverted to the lungs and away from the patent ductus arteriosus.² Accordingly, an absolute contraindication for the use of iNO in babies dependent upon right-to-

¹ See Fessler MB et al., *Right-to-left shunting through a patent foramen ovale in right ventricular infarction: improvement of hypoxemic and hemodynamics with inhaled nitric oxide*. J. Clin. Anesth. 15: 371-4, 1993, at 371.

² See, e.g., Atz AM, Wessel DL. *Inhaled nitric oxide in the neonate with cardiac disease*. Sem. Perinatol. 21:441-455, 1997, at 452.

left shunting of blood has been contained in the INOmax[®] prescribing information since the original approval of INOmax[®] by the FDA in December, 1999.³

15. Pulmonary engorgement also occurs in adults with serious left-sided heart disease due to coronary artery disease (“ischemic cardiomyopathy”), hypertensive heart disease (“hypertensive cardiomyopathy”) or obstructive valvular disease or other conditions that similarly restrict the inflow of blood to the left side of the heart such that engorgement of the pulmonary blood vessels ensues. It is important to note that restriction of left-sided inflow is particularly prominent in the above cardiomyopathies, and is described as diastolic dysfunction.⁴ Diastolic dysfunction is extremely common in adult heart disease, especially in the elderly, but is extremely rare in childhood heart disease, which is generally caused by either congenital malformations or viral infections.⁵

16. To summarize, in adults, left-sided ventricular dysfunction is generally ischemic or hypertensive in origin, and is associated with a stiff, non-compliant left ventricle that cannot

³ See, Exhibit 2, section 4, Prescribing Information, INOMAX.

⁴ See “Diastolic Dysfunction” American Heart Association “Learn and Live” website visited April 13, 2011: “The heart contracts and relaxes with each heartbeat. The contraction part of this cycle is called **systole** (SIS'-to-le). The relaxation portion is called **diastole** (di-AS'-to-le). In some people with heart failure, the contraction function is normal but there's impaired relaxation of the heart. This affects the heart's lower, pumping chambers (the ventricles) specifically. If the relaxation part of the cycle is abnormal, it's called diastolic (di"as-TOL'-ik) dysfunction. Because the ventricle doesn't relax normally, the pressure in it increases and exceeds what's normal as blood for the next heartbeat. (It's harder for all of the blood to go into the ventricle.) This can cause increased pressure and fluid in the blood vessels of the lungs. (This is called pulmonary congestion.) It can also cause increased pressure and fluid in the blood vessels coming back to the heart. (This is called systemic congestion.) People with certain types of cardiomyopathy (kar"-de-o-my-OP'-ah-the) may also have diastolic dysfunction.”

⁵ Diastolic dysfunction in children has been described in rare genetic diseases such as Marfan's syndrome [that directly affects the elasticity of connective tissue of the heart and elsewhere], Kawasaki's disease [that creates cardiac ischemia similar to that in adult ischemic cardiomyopathy] or sickle cell disease [that produces fibrotic scars in the myocardium].

fill properly (“diastolic dysfunction”). In contrast, in children, left-sided ventricular dysfunction is generally not of ischemic or hypertensive in origin and is not associated with impaired filling, but rather is associated with a soft, overly elastic heart that cannot push blood out, resulting in impaired emptying (“systolic dysfunction”). Thus, adult left ventricular diastolic dysfunction, but not childhood left ventricular systolic dysfunction, would lead to pulmonary vascular engorgement, requiring caution in the use of iNO.

17. Since the approval of iNO in December 1999, iNO has from time-to-time sponsored, supported or otherwise facilitated - under its own FDA Investigational New Drug (IND) application or IND applications filed by other investigators - clinical research exploring the efficacy and safety of iNO in clinical contexts outside the approved indication for PPHN. The results of these investigations are submitted to the FDA and are often published in the medical literature. In May 2004, following detailed consultations with an expert steering committee composed of leading world authorities in pediatric heart and lung disease,⁶ iNO initiated a multinational randomized controlled 150-patient study entitled “Comparison of Supplemental Oxygen and Nitric Oxide for Inhalation Plus Oxygen in the Evaluation of the Reactivity of the Pulmonary Vasculature During Acute Pulmonary Vasodilator Testing” (“INOT22”). Prior to its initiation, the INOT22 study was reviewed and approved by the Institutional Review Board (IRB) and/or Independent Ethics Committee (IEC) at each of the 18 participating study institutions, and by two independent National Health Authorities (the U.S. FDA and the European Medicines Agency (EMA)). At no time did any of the members of these boards, committees or agencies counsel against giving inhaled nitric oxide to the proposed patient population because of the risk of severe adverse events in pediatric patients (i.e., children) with left ventricular dysfunction.

18. INOT22 was designed and purposed to compare the diagnostic utility of short-term (10 minute) inhalation of iNO alone, iNO plus oxygen (“O₂”) or O₂ alone to children between the ages of 4 weeks and eighteen years with either idiopathic pulmonary arterial

⁶ The steering committee included Dr. David Wessel of the Department of Cardiology, Children's Hospital and the Department of Pediatrics, Harvard Medical School.

hypertension, congenital heart disease with pulmonary arterial hypertension, or childhood forms of cardiomyopathy undergoing diagnostic right heart catheterization and acute pulmonary vasodilatation testing to assess pulmonary vasoreactivity. The rationale for INOT22 were: (1) that in patients with right ventricular failure and lung disorders, the prognosis and course of treatment are determined by acute pulmonary vasodilatation testing (APVT); (2) a reduction in the mean pulmonary artery pressure and pulmonary vascular resistance with acute vasodilator treatment may be used to predict therapeutic efficacy of long-term vasodilator medication; and (3) APVT is also used to evaluate patients being considered for heart or heart/lung transplantation; elevated pulmonary artery pressures and pulmonary vascular resistance place a strain on the right ventricle leading to an increased risk of perioperative morbidity and mortality due to right heart failure post heart transplant. Accordingly, the primary objective of INOT22 was to compare the number of patients who exhibited reversible pulmonary hypertension (vasoreactivity) in response to iNO or iNO plus and oxygen as compared to 100% oxygen alone.

19. Under the direction of the expert steering committee, inclusion and exclusion criteria were established that were intended to ensure the safe use of iNO during the conduct of the study. For example, patients dependent on right-to-left shunting and thereby contraindicated for iNO treatment were not included. Patients also were excluded if they had focal pulmonary infiltrates on chest radiograph, a diagnosis of severe obstructive or restrictive pulmonary disease that significantly contributed to the patient's pulmonary hypertension, had received treatment with iNO within 30 days prior to study initiation or were on other investigational medications, nitroglycerin, sodium nitroprusside, sildenafil, other PDE-5 inhibitors, or prostacyclin, or were pregnant.

20. However, since the inclusion criteria included congenital heart disease or cardiomyopathy, many of the patients had, by design, significant childhood heart disease. This was not considered to pose a significant risk by the experts on the steering committee (1) based on the exclusion of right-to-left shunt-dependent patients, (2) based on prior extensive safe experience with iNO in pediatric patients with congenital heart disease or cardiomyopathy by the

investigators and published in the medical literature,⁷ and (3) the very different nature of non-ischemic non-hypertensive childhood heart disease from the ischemic or hypertensive adult form marked by diastolic dysfunction.

21. Surprisingly and unexpectedly, severe adverse events including pulmonary edema and death were noted during the early phase of the study, and the study was stopped. Analysis of the cases revealed that the patients suffering severe adverse events had severe left ventricular dysfunction, largely due to viral cardiomyopathy, and exhibited during their right-sided cardiac catheterizations an increased pulmonary capillary wedge pressure ("PCWP") of greater than 20 mm Hg, indicative of elevated pressures in the upper chamber of the left side of the heart (the left atrium).

22. To determine if there was a correlation between the severe adverse events and the left ventricular dysfunction of the patients that had suffered them, a protocol amendment was submitted to FDA to exclude – on an ongoing basis - patients with severe left ventricular dysfunction with a PCWP greater than 20 mm Hg from further enrollment in the study. The study was then completed. On analyzing the data from the study, the inventors concluded that a correlation did, in fact, exist between the severe adverse events that had occurred during the study and the left ventricular dysfunction of the patients that had suffered them. Accordingly, INO subsequently requested that the FDA add an additional warning to the product labeling for INOmax concerning use of the drug within patients with left ventricular dysfunction. The FDA agreed and included an additional warning in section 5.4 and the Warnings and Precautions section of the INOmax prescribing information (in the US and worldwide).⁸

23. Competent practitioners would understand that the warnings included in section 5.4 and the Warnings and Precautions section of the INOmax prescribing information are intended as a separate warning generally applicable to all patients with left ventricular dysfunction and not limited to those patients having left ventricular dysfunction that also rely on

⁷ See Atz AM et al. *Combined effects of nitric oxide and oxygen during acute pulmonary vasodilator testing*. J. Amer. Coll. Cardio. 33:813-819, 1999, at 814, 818.

⁸ See **EXHIBIT 2**.

right to left shunting of blood. This second category of patients is the subject of a separate section of the US Package Insert which expressly provides that INOmax is contraindicated for patients with this condition. The fact that administration of INOmax would be harmful to patients dependent on right to left shunting of blood has been well known for many years as demonstrated by several of the references that are of record in the present case including [e.g., Atz AM, Wessel DL. *Inhaled nitric oxide in the neonate with cardiac disease*. Sem. Perinatol. 21:441-455, 1997].

24. Furthermore, no competent practitioner would understand the separate warnings in section 5.4 and the Warnings and Precautions section of the INOmax prescribing information, or the disclosure in the present application of the potential for severe adverse events in patients with left ventricular dysfunction as referring to patients dependent on right to left shunting of blood, since it has long been known that the use of INOmax is contraindicated in such patients. Rather, the competent practitioner would understand the additional warnings added at section 5.4 and within the Warnings and Precautions section of the INOmax prescribing information, and the disclosure in the present application of the potential for severe adverse events in patients with left ventricular dysfunction, as a distinct and separate warning and disclosure that administration of INOmax to patients with left ventricular dysfunction generally (even those not dependent on right to left shunting of blood) may result in serious adverse events.

Applicant : Baldassarre et al
Serial No. : 12/820,866
Filed : 22JUN10
Page : 10 of 10

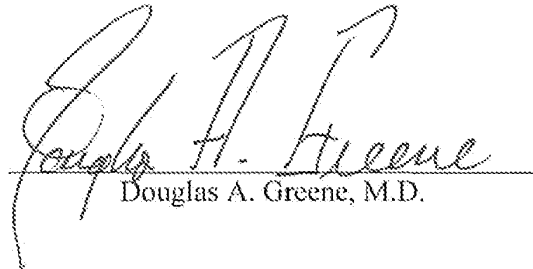
Attorney's Docket No.: 1001-0002USC1

25. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the '359 patent.

26.

Dated

April 29, 2011



Douglas A. Greene, M.D.

Applicant : Baldassarre et al
Serial No. : 12/820,866
Filed : 22JUN10
Page : 11 of 10

Attorney's Docket No.: I001-0002USC1

EXHIBIT 1

CURRICULUM VITAE

PERSONAL DATA

Name: Douglas Alan Greene, M.D.

EDUCATION

High School Columbia High School, South Orange, NJ, 1962
Undergraduate Princeton University, Princeton, NJ, BA Biology(cum laude), 1962-1966
Graduate/Professional Johns Hopkins School of Medicine, Baltimore, MD, M.D., 1966-1970

POSTDOCTORAL TRAINING

Medical Internship: Department of Medicine, Johns Hopkins, Baltimore, MD, 1970-1971
Medical Residency: Department of Medicine, Johns Hopkins, Baltimore, MD, 1971-1972
Fellowship: Medical Fellowship, Department of Medicine, Johns Hopkins University, School of Medicine, Baltimore, MD, 1970-1972

Post-doctoral Research Fellow, Diabetes, George S. Cox Medical Research Institute; Hospital of the University of Pennsylvania, Philadelphia, PA (Dr. Albert I. Winegrad, preceptor), 1972-1975

Medical Fellowship, Department of Medicine, University of Pennsylvania, School of Medicine, Philadelphia, PA, 1972-1975

NON-ACADEMIC EMPLOYMENT

2000-2003 Executive Vice President, Clinical Sciences and Product Development (CSPD), Merck Research Laboratories, Rahway, New Jersey, and Corporate Officer, Merck, Inc. Supervised and directly managed all clinical research, regulatory affairs, clinical and non-clinical quality assurance and pharmaco-vigilance at Merck Research Laboratories.

2003-2006 Vice President, Head Corporate Regulatory Development, Sanofi-Aventis, Bridgewater, NJ. Overseeing all aspects of corporate regulatory development of all pre-clinical and clinical development projects/life-cycle products in Research & Development.

2006-2009 Senior Vice President, Chief Medical Officer, Sanofi-Aventis, Bridgewater, NJ. Overseeing medical, regulatory, pharmacovigilance, risk management, education and medical communications for US region, Member US Executive Committee, Member Committee Operational de Development, International Clinical Development.

2009-present Senior Vice President, Senior Scientific Advisor, Sanofi-Aventis, Bridgewater, New Jersey. Member Corporate Portfolio Valuation Process and Drug Development Committees. The position at the interface between the Research and Development and Pharmaceutical Operations is responsible for providing key scientific and medical guidance for sanofi-aventis' scientific strategy within U.S. and global contexts to enhance the quality and effectiveness of the company's research and product portfolio, including assessment and guidance of internal R&D product pipeline and franchise portfolio and external commercial and academic innovation opportunities.

ACADEMIC APPOINTMENTS

- | | |
|--------------|--|
| 1975-1980 | Assistant Professor of Medicine, University of Pennsylvania, School of Medicine, Philadelphia, Pennsylvania |
| 1980-1986 | Associate Professor of Medicine, Director, General Clinical Research Center and Diabetes Research Laboratories, University of Pittsburgh, School of Medicine |
| 1986-2000 | Professor of Internal Medicine, Director, Michigan Diabetes Research and Training Center, University of Michigan School of Medicine |
| 1991-2000 | Chief, Division of Endocrinology & Metabolism, University of Michigan School of Medicine |
| 2000-Present | Adjunct Professor, Internal Medicine, Division of Endocrinology & Metabolism, University of Michigan, School of Medicine |

SELECTED SCIENTIFIC ACTIVITIES

- | | |
|-----------|---|
| 1988-1994 | Chairman, Endocrinologic and Metabolic Drug Advisory Board, Food and Drug Administration, Washington D.C (Chair, 1990-1994) |
| 1994-2000 | Chairman, Merck Scientific Board of Advisors |

SELECTED SCIENTIFIC PRIZES AND AWARDS

- | | |
|------|---|
| 1986 | First Annual Raymond A. and Robert L. Kroc Lecturer, Eisenhower Medical Center, Palm Springs, California |
| 1987 | Moore Award, The American Association of Neuropathologists, Seattle, Washington |
| 1987 | Carol Sinicki Manuscript Award (The Diabetes Educator), American Association of Diabetes Educators, Chicago, Illinois |
| 1988 | Kellion Lecture, International Diabetes Federation, Sydney, Australia |
| 1989 | Banting and Best Lecture, Toronto General Hospital, Toronto, Canada |
| 1994 | Charles H. Best Lecturer, Toronto Diabetes Association, Toronto, Canada |
| 1996 | Invited Speaker, Seventy-fifth Anniversary Celebrating the Discovery of Insulin, Toronto, Canada |
| 1996 | First Alan Robinson Lecturer, University of Pittsburgh |
| 1998 | Outstanding Foreign Investigator Award, Japan Society of Diabetic Complications |

SELECTED BIBLIOGRAPHY

Peer-Reviewed Publications (Selected from over 170 peer-reviewed articles):

1. Greene DA, DeJesus PV, Winegrad AI: Effect of insulin and dietary Myo-Inositol on impaired peripheral motor nerve conduction velocity in acute streptozotocin diabetes. *J. Clin. Invest.* 55:1326-1336, 1975.
2. Winegrad AI, Greene DA: Diabetic polyneuropathy: The importance of insulin deficiency, hyperglycemia and alterations in myoinositol metabolism in its pathogenesis. *N. Engl. J. Med.* 295:1416-1420, 1976.
3. Greene DA, Lattimer SA: Sodium- and energy dependent uptake of myo-inositol by rabbit peripheral nerve. Competitive inhibition by glucose and lack of an insulin effect. *J. Clin. Invest.* 70:1009-1018, 1982.
4. Greene DA, Lattimer SA: Impaired rat sciatic nerve sodium-potassium ATPase in acute streptozocin diabetes and its correlation by dietary myo-inositol supplementation. *J. Clin. Invest.* 72:1058-1063, 1983.
5. Greene DA, Lattimer SA: Impaired energy utilization and Na-K-ATPase in diabetic peripheral nerve. *Am. J. Physiol.* 246:E311-E318, 1984.
6. Greene DA, Yagihashi S, Lattimer SA, Sima AAF: Nerve Na⁺+K⁺-ATPase, conduction and myo-inositol in the insulin deficient BB rat. *Am J Physiol* 247:E534-E539, 1984.
7. Greene DA, Lattimer SA: Protein kinase C agonists acutely normalize decreased ouabain-inhibitable respiration in diabetic rabbit nerve: Implications for [Na,K]-ATPase regulation and diabetic complications. *Diabetes* 35:242-245, 1986.
8. Sima AAF, Lattimer SA, Yagihashi S, Greene DA: 'Axo-glial dysjunction' a novel structural lesion that accounts for poorly-reversible slowing of nerve conduction in the spontaneously diabetic BB-rat. *J. Clin. Invest.* 77:474-484, 1986.
9. Greene DA: A sodium-pump defect in diabetic peripheral nerve corrected by sorbinil administration: Relationship to myo-inositol metabolism and nerve conduction slowing. *Metabolism* 35:60-66, 1986.
10. Greene DA, Mackway AM: Decreased myo-inositol content and Na⁺-K⁺-ATPase activity in superior cervical ganglion of STZ-diabetic rat and prevention by aldose reductase inhibition. *Diabetes* 35:1106-1108, 1986.
11. Carroll PB, Thornton BM, Greene DA: Glutathione redox state is not the link between polyol pathway activity and diminished (Na,K)-ATPase activity in experimental diabetic neuropathy. *Diabetes* 35:1282-1285, 1986.
12. Greene DA, Lattimer SA, Sima AAF: Sorbitol, phosphoinositides and the sodium-potassium ATPase in the pathogenesis of diabetic complications. *N. Engl. J. Med.* 316:599-606, 1987.
13. Greene DA, Chakrabarti S, Lattimer SA, Sima AAF: Role of sorbitol accumulation and myo-inositol depletion in paranodal swelling of large myelinated nerve fibers in the insulin-deficient spontaneously diabetic bio-breeding rat: Reversal by insulin replacement, an aldose reductase inhibitor, and myo-inositol. *J. Clin. Invest.* 79:1479-1485, 1987.

14. Sima AAF, Nathaniel V, Bril V, McEwen TAJ, Greene DA: Histopathological heterogeneity of neuropathy in insulin-dependent and non-insulin-dependent diabetes, and demonstration of axo-glial dysjunction in human diabetic neuropathy. *J. Clin. Invest.* 81:349-364, 1988.
15. Greene DA, Lattimer SA, Sima AAF: Perspectives in diabetes: Are disturbances of sorbitol, phosphoinositide, and $\text{Na}^+\text{-K}^+\text{-ATPase}$ regulation involved in pathogenesis of diabetic neuropathy? *Diabetes* 37:688-693, 1988.
16. Greene DA, Lattimer SA, Sima AA: Pathogenesis and prevention of diabetic neuropathy. *Diabetes Metab Rev* 4:201-221, 1988.
17. Lattimer SA, Sima AAF, Greene DA: In Vitro correction of impaired $\text{Na}^+\text{-K}^+\text{-ATPase}$ in diabetic nerve by protein kinase C agonists. *Am. J. Physiol.* 256 (Endocrinol. Metab. 19):E264-E269, 1989.
18. Greene DA, Lattimer SA, Sima AAF: Pathogenesis of diabetic neuropathy: Role of altered phosphoinositide metabolism. *CRC Critical Reviews in Neurobiology* (J. Nelson, ed., CRC Press, Inc.), pp. 143-219, 1989.
19. Greene DA, Lattimer SA, Carroll PB, Fernstrom JD, Finegold DN: A defect in sodium-dependent amino acid uptake in diabetic rabbit peripheral nerve: Correction by an aldose reductase inhibitor or myo-inositol administration. *J. Clin. Invest.* 85:1657-1665, 1990.
20. Greene DA, Sima AF, Pfeifer MA, Albers JW. Diabetic Neuropathy. *Annu Rev Med* 41:303-317, 1990.
21. Sima AAF, Prashar A, Zhang W-X, Chakrabarti S, Greene DA: Preventive effect of long-term aldose reductase inhibition (Ponalrestat) on nerve conduction and sural nerve structure in the spontaneously diabetic bio-breeding rat. *J. Clin. Invest.* 85:1410-1420, 1990.
22. Kim J, Kyriazi H, Greene DA: Normalization of (Na,K)-ATPase activity in an isolated membrane fraction from sciatic nerves of streptozotocin-diabetic rats by dietary myo-inositol supplementation in vivo or protein kinase C agonists in vitro. *Diabetes* 40:558-567, 1991.
23. Stevens MJ, Lattimer SA, Kamijo M, Van Huysen C, Sima AAF, Greene DA: Osmotically induced nerve taurine depletion in experimental diabetes: An hypothetical mediator of painful neuropathy. *Diabetologia* 36:608-614, 1993.
24. Henry DN, Del Monte M, Greene DA, Killen PD: Altered aldose reductase gene regulation in cultured human retinal pigment epithelial cells. *J. Clin. Invest.* 92:617-623, 1993.
25. The DCCT Research Group: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N. Eng. J. Med.* 329:977-986, 1993.
26. Thomas TP, Feldman EL, Nakamura J, Kato K, Lien M, Stevens MJ, Greene DA: Ambient glucose and aldose reductase-induced myo-inositol depletion modulate basal and carbachol-stimulated inositol phospholipid metabolism and diacylglycerol accumulation in human retinal pigment epithelial cells in culture. *Proc. Natl. Acad. Sci. USA* 90:9712-9716, 1993.
27. Thomas TP, Porcellati F, Kato K, Stevens MJ, Sherman WR, Greene DA: Effects of glucose on sorbitol pathway activation, cellular redox, and metabolism of myo-inositol, phosphoinositide and

- diacylglycerol in cultured human retinal pigment epithelial cells. *J. Clin. Invest.* 93:2718-2724, 1994.
28. Stevens MJ, Dananberg J, Feldman EL, Lattimer SA, Kamijo M, Thomas TP, Shindo H, Sima AAF, Greene, DA: The linked roles of nitric oxide, aldose reductase and (NA⁺,K⁺)-ATPase in the slowing of nerve conduction in the streptozotocin diabetic rat. *J. Clin. Invest.* 94:853-859, 1994.
 29. Feldman EL, Stevens MJ, Thomas PK, Brown MB, Canal N, Greene DA: A practical two-step quantitative clinical and electrophysiological assessment for the diagnosis and staging of diabetic neuropathy. *Diabetes Care* 17:1281-1289, 1994.
 30. The DCCT Research Group: The effect of intensive treatment of diabetes on nerve conduction measures in the DCCT. *Annals of Neuro.* 38:869-880, 1995.
 31. Stevens MJ, Feldman EL, Greene DA: The aetiology of diabetic neuropathy: The combined roles of metabolic and vascular defects. *Diabetic Medicine* 12:566-579, 1995.
 32. Shindo H, Thomas TP, Larkin DD, Karihaloo AK, Inada H, Onaya T, Stevens MJ, Greene DA: Modulation of basal nitric oxide-dependent cyclic-GMP production by ambient glucose, myo-inositol, and protein kinase C in SH-SY5Y human neuroblastoma cells. *J Clin Invest* 97:736-745, 1996.
 33. Sima AAF, Ristic H, Merry A, Kamijo M, Lattimer SA, Stevens MJ, Greene DA: Primary preventive and secondary interventional effects of acetyl-L-carnitine on diabetic neuropathy in the bio-breeding Worcester rat. *J Clin Invest* 97:1900-1907, 1996.
 34. Karihaloo A, Kato K, Greene DA, Thomas TP: Protein kinase and cytosolic calcium modulation of myo-inositol transport in cultured retinal pigment epithelial cells. *Am J Physiol* 273:C671-678, 1997.
 35. The DCCT Research Group: Effect of intensive therapy on residual β -cell function in patients with Type I diabetes in the DCCT: A randomized, controlled trial. *Ann Int Med* 128:517-523, 1998.
 36. The DCCT Research Group: The effect of intensive diabetes therapy on measures of autonomic nervous system function in the DCCT. *Diabetologia* 41:416-423, 1998.
 37. Porcellati F, Hlaing T, Togawa M, Stevens MJ, Larkin DD, Hosaka Y, Glover TW, Henry DN, Greene DA, Killen PD: Human Na⁺-myo-inositol cotransporter gene: alternate splicing generates diverse transcripts. *Am J Physio.* 274: C1215-C1225, 1998.
 38. Porcellati F, Hosaka Y, Hlaing T, Togawa M, Larkin DD, Karihaloo A, Stevens MJ, Killen PD, Greene DA: alternate splicing in human Na⁺-MI cotransporter gene yields differentially regulated transport isoforms. *Am J Physiol* 276:1325-1337, 1999.
 39. Greene DA, Stevens MJ, Obrosova I, Feldman EL. Glucose-induced oxidative stress and programmed cell death in diabetic neuropathy. *European Journal of Pharmacology* 375:217-223, 1999.
 40. Greene DA, Arezzo JC, Brown MB: Effect of aldose reductase inhibition on nerve conduction and morphometry in diabetic neuropathy. *Neurology* 53:580-591, 1999.

41. Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group: Retinopathy and nephropathy in patients with type 1 diabetes four years after a trial of intensive therapy. *N Engl J Med* 342:381-389, 2000.
42. Sundkvist G, Dahlin LB, Nilsson H, Eriksson KP, Lingarde F, Rosen I, Lattimer SA, Sima AAF, Sullivan KA, Greene DA: Sorbitol and myo-inositol levels and morphology of sural nerve in relation to peripheral nerve function and clinical neuropathy in men with diabetic, impaired, and normal glucose tolerance. *Diabetic Medicine* 17:259-268, 2000.
43. Stevens MJ, Obrosova I, Cao X, Van Huysen C, Greene DA: Effects of DL-alpha-lipoic acid on peripheral nerve conduction, blood flow, energy metabolism and oxidative stress in experimental diabetic neuropathy. *Diabetes* 49:1006-1015, 2000.
44. Obrosova IG, Fathallah L, Greene DA: Early changes in lipid peroxidation and antioxidative defense in diabetic rat retina: effect of DL-alpha-lipoic acid. *Eur J Pharmacol* 398:139-146, 2000.
45. White NH, Cleary PA, Dahms W, Goldstein D, Malone J, Tamborlane WV; Diabetes Control and Complications Trial (DCCT)/Epidemiology of Diabetes Interventions and Complications (EDIC) Research Group: Beneficial effects of intensive therapy of diabetes during adolescence: outcomes after the conclusion of the Diabetes Control and Complications Trial (DCCT). *J Pediatr* 139:804-812, 2001.
46. Perkins BA, Greene DA, Bril V: Glycemic control is related to the morphological severity of diabetic sensorimotor polyneuropathy. *Diabetes Care* 24: 748-752, 2001.
47. Moller DE, Greene DA: Peroxisome proliferators-activated receptor (PPAR) gamma agonists for diabetes. *Adv Protein Chem* 56:181-212, 2001.
48. Obrosova IG, Van Huysen C, Fathallah L, Cao XC, Greene DA, Stevens MJ: An aldose reductase inhibitor reverses early diabetes-induced changes in peripheral nerve function, metabolism, and antioxidative defense. *FASEB J* 16:123-125, 2002.
49. Pop-Busui R, Marinescu V, Van Huysen C, Li F, Sullivan K, Greene DA, Larkin D, Stevens MJ: Dissection of metabolic, vascular, and nerve conduction interrelationships in experimental diabetic neuropathy by cyclooxygenase inhibition and acetyl-L-carnitine administration. *Diabetes* 51: 2619-2628, 2002.
50. Viberti G, Kahn SE, Greene DA, Herman WH, Zinman B, Holman RR, Haffner SM, Levy D, Lachin JM, Berry RA, Heise MA, Jones NP, Freed MI: A diabetes outcome progression trial (ADOPT): an international multicenter study of the comparative efficacy of rosiglitazone, glyburide, and metformin in recently diagnosed type 2 diabetes. *Diabetes* 25:1737-1743, 2002.
51. The Writing Team for the Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group: Effect of intensive therapy on the microvascular complications of type 1 diabetes mellitus. *JAMA* 287:2563-2569, 2002.

Applicant : Baldassarre et al
Serial No. : 12/820,866
Filed : 22JUN10
Page : 12 of 10

Attorney's Docket No.: I001-0002USC1

EXHIBIT 2

INOMax[®] (nitric oxide) for inhalation

HIGHLIGHTS OF PRESCRIBING INFORMATION

These highlights do not include all the information needed to use INOMax safely and effectively. See full prescribing information for INOMax.

INOMax (nitric oxide) for inhalation
Initial U.S. Approval: 1999

RECENT MAJOR CHANGES

Warnings and Precautions, Heart Failure (5.4) 8/2009

INDICATIONS AND USAGE

INOMax is a vasodilator, which, in conjunction with ventilatory support and other appropriate agents, is indicated for the treatment of term and near-term (>34 weeks gestation) neonates with hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension, where it improves oxygenation and reduces the need for extracorporeal membrane oxygenation (1.1).

Monitor for PaO₂, methemoglobin, and inspired NO₂ during INOMax administration (1.1).

Utilize additional therapies to maximize oxygen delivery (1.1).

DOSE AND ADMINISTRATION

Dosage: The recommended dose of INOMax is 20 ppm, maintained for up to 14 days or until the underlying oxygen desaturation has resolved (2.1).

Administration:

- INOMax must be delivered via a system which does not cause generation of excessive inhaled nitrogen dioxide (2.2).
- Do not discontinue INOMax abruptly (2.2).

DOSE FORMS AND STRENGTHS

INOMax (nitric oxide) is a gas available in 100 ppm and 800 ppm concentrations.

CONTRAINDICATIONS

Neonates known to be dependent on right-to-left shunting of blood (4).

WARNINGS AND PRECAUTIONS

Rebound: Abrupt discontinuation of INOMax may lead to worsening oxygenation and increasing pulmonary artery pressure (5.1).

Methemoglobinemia: Methemoglobin increases with the dose of nitric oxide; following discontinuation or reduction of nitric oxide, methemoglobin levels return to baseline over a period of hours (5.2).

Elevated NO₂ Levels: NO₂ levels should be monitored (5.3).

Heart Failure: In patients with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary capillary wedge pressure leading to pulmonary edema (5.4).

ADVERSE REACTIONS

Methemoglobinemia and elevated NO₂ levels are dose dependent adverse events. Worsening oxygenation and increasing pulmonary artery pressure occur if INOMax is discontinued abruptly. Other adverse reactions that occurred in more than 5% of patients receiving INOMax in the CIRRI study were: thrombocytopenia, hypokalemia, bilirubinemia, atelectasis, and hypotension (6).

To report SUSPECTED ADVERSE REACTIONS, contact INO Therapeutics at 1-877-566-9466 and <http://www.inomax.com/> or FDA at 1-800-FDA-1088 or www.fda.gov/medwatch.

DRUG INTERACTIONS

Nitric oxide donor agents: Nitric oxide donor compounds, such as prilocaine, sodium nitroprusside, and nitroglycerin, when administered as oral, parenteral, or topical formulations, may have an additive effect with INOMax on the risk of developing methemoglobinemia (7).

Revised: August 2009

FULL PRESCRIBING INFORMATION: CONTENTS*

1. INDICATIONS AND USAGE
 - 1.1 Treatment of Hypoxic Respiratory Failure
2. DOSE AND ADMINISTRATION
 - 2.1 Dosage
 - 2.2 Administration
3. DOSE FORMS AND STRENGTHS
4. CONTRAINDICATIONS
5. WARNINGS AND PRECAUTIONS
 - 5.1 Rebound
 - 5.2 Methemoglobinemia
 - 5.3 Elevated NO₂ Levels
 - 5.4 Heart Failure
6. ADVERSE REACTIONS
 - 6.1 Clinical Trials Experience
 - 6.2 Post-Marketing Experience
7. DRUG INTERACTIONS
8. USE IN SPECIFIC POPULATIONS
 - 8.1 Pregnancy
 - 8.2 Labor and Delivery
 - 8.3 Nursing Mothers
 - 8.4 Pediatric Use
 - 8.5 Geriatric Use

9. OVERDOSAGE
10. DESCRIPTION
11. CLINICAL PHARMACOLOGY
 - 11.1 Mechanism of Action
 - 11.2 Pharmacodynamics
 - 11.3 Pharmacokinetics
 - 11.4 Pharmacokinetics: Uptake and Distribution
 - 11.5 Pharmacokinetics: Metabolism
 - 11.6 Pharmacokinetics: Elimination
12. NONCLINICAL TOXICOLOGY
 - 12.1 Carcinogenesis, Mutagenesis, Impairment of Fertility
13. CLINICAL STUDIES
 - 13.1 Treatment of Hypoxic Respiratory Failure (HRF)
 - 13.2 Ineffective in Adult Respiratory Distress Syndrome (ARDS)
14. HOW SUPPLIED/STORAGE AND HANDLING

*Sections or subsections omitted from the full prescribing information are not listed.

FULL PRESCRIBING INFORMATION

1 INDICATIONS AND USAGE

1.1 Treatment of Hypoxic Respiratory Failure

iNOmax[®] is a vasodilator, which, in conjunction with ventilatory support and other appropriate agents, is indicated for the treatment of term and near-term (>24 weeks) neonates with hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension, where it improves oxygenation and reduces the need for extracorporeal membrane oxygenation.

Utilize additional therapies to maximize oxygen delivery. In patients with collapsed alveoli, additional therapies might include surfactant and high-frequency oscillatory ventilation.

The safety and effectiveness of inhaled nitric oxide have been established in a population receiving other therapies for hypoxic respiratory failure, including vasodilators, intravenous fluids, bicarbonate therapy, and mechanical ventilation. Different dose regimens for nitric oxide were used in the clinical studies [see Clinical Studies (14)].

Monitor for PaO₂, methemoglobin, and inspired NO₂ during iNOmax administration.

2 DOSAGE AND ADMINISTRATION

2.1 Dosage

Term and near-term neonates with hypoxic respiratory failure

The recommended dose of iNOmax is 20 ppm. Treatment should be maintained up to 14 days or until the underlying oxygen desaturation has resolved and the neonate is ready to be weaned from iNOmax therapy.

An initial dose of 20 ppm was used in the NINOS and CIRRII trials. In CIRRII, patients whose oxygenation improved with 20 ppm were down-reduced to 5 ppm as tolerated at the end of 4 hours of treatment. In the NINOS trial, patients whose oxygenation failed to improve on 20 ppm could be increased to 60 ppm, but those patients did not then improve on the higher dose. As the risk of methemoglobinemia and elevated NO₂ levels increases significantly when iNOmax is administered at doses >20 ppm, doses above this level ordinarily should not be used.

2.2 Administration

The nitric oxide delivery systems used in the clinical trials provided operator-determined concentrations of nitric oxide in the breathing gas, and the concentration was constant throughout the respiratory cycle. iNOmax must be delivered through a system with these characteristics and which does not cause generation of excessive inhaled nitrogen dioxide. The iNOvent[®] system and other systems meeting these criteria were used in the clinical trials. In the ventilated neonate, precise monitoring of inspired nitric oxide and NO₂ should be instituted, using a properly calibrated analysis device with alarms. The system should be calibrated using a precisely defined calibration mixture of nitric oxide and nitrogen dioxide, such as iNOcal[®]. Sample gas for analysis should be drawn before the Y-piece, proximal to the patient. Oxygen levels should also be measured.

In the event of a system failure or a wall-outlet power failure, a backup battery power supply and reserve nitric oxide delivery system should be available.

Do not discontinue iNOmax abruptly, as it may result in an increase in pulmonary artery pressure (PAP) and/or worsening of blood oxygenation (PaO₂). Deterioration in oxygenation and elevation in PAP may also occur in children with no apparent response to iNOmax. Discontinue/wean cautiously.

3 DOSAGE FORMS AND STRENGTHS

Nitric oxide is a gas available in 100 ppm and 200 ppm concentrations.

4 CONTRAINDICATIONS

iNOmax is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood.

5 WARNINGS AND PRECAUTIONS

5.1 Rebound

Abrupt discontinuation of iNOmax may lead to worsening oxygenation and increasing pulmonary artery pressure.

5.2 Methemoglobinemia

Methemoglobinemia increases with the dose of nitric oxide. In clinical trials, maximum methemoglobin levels usually were reached

approximately 8 hours after initiation of inhalation, although methemoglobin levels have peaked as late as 40 hours following initiation of iNOmax therapy. In one study, 13 of 37 (35%) of neonates treated with iNOmax 60 ppm had methemoglobin levels exceeding 7%. Following discontinuation or reduction of nitric oxide, the methemoglobin levels returned to baseline over a period of hours.

5.3 Elevated NO₂ Levels

In one study, NO₂ levels were <0.5 ppm when neonates were treated with placebo, 5 ppm, and 20 ppm nitric oxide over the first 48 hours. The 60 ppm group had a mean peak NO₂ level of 2.6 ppm.

5.4 Heart Failure

Patients who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced serious adverse events (e.g., pulmonary edema).

6 ADVERSE REACTIONS

Because clinical trials are conducted under widely varying conditions, adverse reaction rates observed in the clinical trials of a drug cannot be directly compared to rates in the clinical trials of another drug and may not reflect the rates observed in practice. The adverse reaction information from the clinical studies does, however, provide a basis for identifying the adverse events that appear to be related to drug use and for approximating rates.

6.1 Clinical Trials Experience

Controlled studies have included 325 patients on iNOmax doses of 5 to 60 ppm and 251 patients on placebo. Total mortality in the pooled trials was 11% on placebo and 9% on iNOmax, a result adequate to exclude iNOmax mortality being more than 40% worse than placebo.

In both the NINOS and CIRRII studies, the duration of hospitalization was similar in iNOmax and placebo-treated groups.

From all controlled studies, at least 6 months of follow-up is available for 276 patients who received iNOmax and 212 patients who received placebo. Among these patients, there was no evidence of an adverse effect of treatment on the need for rehospitalization, special medical services, pulmonary disease, or neurological sequelae.

In the NINOS study, treatment groups were similar with respect to the incidence and severity of intracranial hemorrhage, Grade IV hemorrhage, periventricular leukomalacia, cerebral infarction, seizures requiring anticonvulsant therapy, pulmonary hemorrhage, or gastrointestinal hemorrhage.

The table below shows adverse reactions that occurred in at least 5% of patients receiving iNOmax in the CIRRII study with event rates >5% and greater than placebo event rates. None of the differences in these adverse reactions were statistically significant when inhaled nitric oxide patients were compared to patients receiving placebo.

Table 1:
Adverse Reactions in the CIRRII Study

Adverse Event	Placebo (n=85)	Inhaled NO (n=97)
Hypotension	9 (10%)	13 (13%)
Withdrawal	9 (10%)	12 (12%)
Arteriospasm	8 (9%)	9 (9%)
Hematuria	5 (6%)	6 (6%)
Hyperglycemia	5 (6%)	8 (8%)
Sepsis	2 (2%)	7 (7%)
Infection	3 (3%)	6 (6%)
Stridor	3 (3%)	5 (5%)
Celulitis	0 (0%)	5 (5%)

6.2 Post-Marketing Experience

The following adverse reactions have been identified during post-approval use of iNOmax. Because these reactions are reported voluntarily from a population of uncertain size, it is not always possible to estimate their frequency reliably or to establish a causal relationship to drug exposure. The listing is alphabetical: dose errors associated with the delivery system; headaches associated with environmental exposure of iNOmax in hospital staff; hypotension associated with acute withdrawal of the drug; hypoxemia associated with acute withdrawal of the drug; pulmonary edema in patients with CREST syndrome.

7 DRUG INTERACTIONS

No formal drug-interaction studies have been performed, and a clinically significant interaction with other medications used in the treatment of hypoxic respiratory failure cannot be excluded based on the available data. INOmax has been administered with telazolone, dopamine, dobutamine, steroids, surfactant, and high-frequency ventilation. Although there are no study data to evaluate the possibility, nitric oxide donor compounds, including sodium nitroprusside and nitroglycerin, may have an additive effect with INOmax on the risk of developing methemoglobinemia. An association between prilocaine and an increased risk of methemoglobinemia, particularly in infants, has specifically been described in a literature case report. This risk is present whether the drugs are administered as oral, parenteral, or topical formulations.

8 USE IN SPECIFIC POPULATIONS

8.1 Pregnancy

Pregnancy Category C

Animal reproduction studies have not been conducted with INOmax. It is not known if INOmax can cause fetal harm when administered to a pregnant woman or can affect reproductive capacity. INOmax is not intended for adults.

8.2 Labor and Delivery

The effect of INOmax on labor and delivery in humans is unknown.

8.3 Nursing Mothers

Nitric oxide is not indicated for use in the adult population, including nursing mothers. It is not known whether nitric oxide is excreted in human milk.

8.4 Pediatric Use

Nitric oxide for inhalation has been studied in a neonatal population (up to 14 days of age). No information about its effectiveness in other age populations is available.

8.5 Geriatric Use

Nitric oxide is not indicated for use in the adult population.

10 OVERDOSAGE

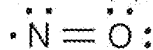
Overdosage with INOmax will be manifest by elevations in methemoglobin and pulmonary toxicities associated with inspired NO_2 . Elevated NO_2 may cause acute lung injury. Elevations in methemoglobinemia reduce the oxygen delivery capacity of the circulation. In clinical studies, NO_2 levels >3 ppm or methemoglobin levels >7% were treated by reducing the dose of, or discontinuing, INOmax.

Methemoglobinemia that does not resolve after reduction or discontinuation of therapy can be treated with intravenous vitamin C, intravenous methylene blue, or blood transfusion, based upon the clinical situation.

11 DESCRIPTION

INOmax (nitric oxide gas) is a drug administered by inhalation. Nitric oxide, the active substance in INOmax, is a pulmonary vasodilator. INOmax is a gaseous blend of nitric oxide and nitrogen (0.08% and 99.92%, respectively for 800 ppm; 0.01% and 99.99%, respectively for 100 ppm). INOmax is supplied in aluminum cylinders as a compressed gas under high pressure (2000 pounds per square inch gauge [psig]).

The structural formula of nitric oxide (NO) is shown below:



12 CLINICAL PHARMACOLOGY

12.1 Mechanism of Action

Nitric oxide is a compound produced by many cells of the body. It relaxes vascular smooth muscle by binding to the heme moiety of cytosolic guanylate cyclase, activating guanylate cyclase and increasing intracellular levels of cyclic guanosine 3',5'-monophosphate, which then leads to vasodilation. When inhaled, nitric oxide selectively dilates the pulmonary vasculature, and because of efficient scavenging by hemoglobin, has minimal effect on the systemic vasculature.

INOmax appears to increase the partial pressure of arterial oxygen (PaO_2) by dilating pulmonary vessels in better ventilated areas of the lung, redistributing pulmonary blood flow away from lung regions with low ventilation/perfusion (V/Q) ratios toward regions with normal ratios.

12.2 Pharmacodynamics

Effects on Pulmonary Vascular Tone in PPHN

Persistent pulmonary hypertension of the newborn (PPHN) occurs as a primary developmental defect or as a condition secondary to other diseases such as meconium aspiration syndrome (MAS), pneumonia, sepsis, hyaline membrane disease, congenital diaphragmatic hernia (CDH), and pulmonary hypoplasia. In these states, pulmonary vascular resistance (PVR) is high, which results in hypoxemia secondary to right-to-left shunting of blood through the patent ductus arteriosus and foramen ovale. In neonates with PPHN, INOmax improves oxygenation (as indicated by significant increases in PaO_2).

12.3 Pharmacokinetics

The pharmacokinetics of nitric oxide has been studied in adults.

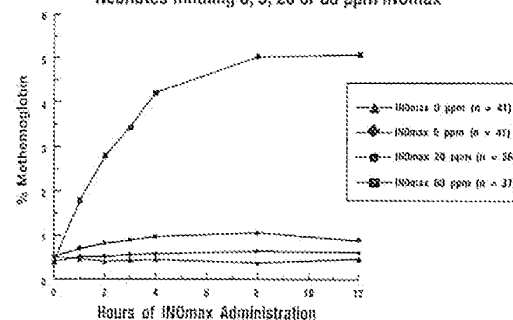
12.4 Pharmacokinetics: Uptake and Distribution

Nitric oxide is absorbed systemically after inhalation. Most of it traverses the pulmonary capillary bed where it combines with hemoglobin that is 60% to 100% oxygen-saturated. At this level of oxygen saturation, nitric oxide combines predominantly with oxyhemoglobin to produce methemoglobin and nitrate. At low oxygen saturation, nitric oxide can combine with deoxyhemoglobin to transiently form nitrosylhemoglobin, which is converted to nitrogen oxides and methemoglobin upon exposure to oxygen. Within the pulmonary system, nitric oxide can combine with oxygen and water to produce nitrogen dioxide and nitrite, respectively, which interact with oxyhemoglobin to produce methemoglobin and nitrate. Thus, the end products of nitric oxide that enter the systemic circulation are predominantly methemoglobin and nitrate.

12.5 Pharmacokinetics: Metabolism

Methemoglobin disposition has been investigated as a function of time and nitric oxide exposure concentration in neonates with respiratory failure. The methemoglobin (MetHb) concentration-time profiles during the first 12 hours of exposure to 0, 5, 20, and 80 ppm INOmax are shown in Figure 1.

Figure 1:
Methemoglobin Concentration – Time Profiles
Neonates Inhaling 0, 5, 20 or 80 ppm INOmax



Methemoglobin concentrations increased during the first 8 hours of nitric oxide exposure. The mean methemoglobin level remained below 1% in the placebo group and in the 5 ppm and 20 ppm INOmax groups, but reached approximately 5% in the 80 ppm INOmax group. Methemoglobin levels >7% were attained only in patients receiving 80 ppm, where they comprised 35% of the group. The average time to reach peak methemoglobin was 10 ± 9 (SD) hours (median, 8 hours) in these 13 patients, but one patient did not exceed 7% until 40 hours.

12.6 Pharmacokinetics: Elimination

Nitrate has been identified as the predominant nitric oxide metabolite excreted in the urine, accounting for >70% of the nitric oxide dose inhaled. Nitrate is cleared from the plasma by the kidney at rates approaching the rate of glomerular filtration.

13 NONCLINICAL TOXICOLOGY

13.1 Carcinogenesis, Mutagenesis, Impairment of Fertility

No evidence of a carcinogenic effect was apparent, at inhalation exposures up to the recommended dose (20 ppm), in rats for 20 hr/day for up to two years. Higher exposures have not been investigated.

Nitric oxide has demonstrated genotoxicity in Salmonella (Ames Test), human lymphocytes, and after *in vivo* exposure in rats. There are no animal or human studies to evaluate nitric oxide for effects on fertility.

14 CLINICAL STUDIES

14.1 Treatment of Hypoxic Respiratory Failure (HRF)

The efficacy of INOmax has been investigated in term and near-term newborns with hypoxic respiratory failure resulting from a variety of etiologies. Inhalation of INOmax reduces the oxygenation index (OI= mean airway pressure in cm H₂O × fraction of inspired oxygen concentration [FIO₂] × 100 divided by systemic arterial concentration in mm Hg [PaO₂]) and increases PaO₂ [see *Clinical Pharmacology* (12.1)].

NINOS Study

The Neonatal Inhaled Nitric Oxide Study (NINOS) group conducted a double-blind, randomized, placebo-controlled, multicenter trial in 235 neonates with hypoxic respiratory failure. The objective of the study was to determine whether inhaled nitric oxide would reduce the occurrence of death and/or initiation of extracorporeal membrane oxygenation (ECMO) in a prospectively defined cohort of term or near-term neonates with hypoxic respiratory failure unresponsive to conventional therapy. Hypoxic respiratory failure was caused by meconium aspiration syndrome (MAS; 49%), pneumonia/sepsis (21%), idiopathic primary pulmonary hypertension of the newborn (PPHN; 17%), or respiratory distress syndrome (RDS; 11%). Infants ≤14 days of age (mean, 1.7 days) with a mean PaO₂ of 46 mm Hg and a mean oxygenation index (OI) of 43 cm H₂O / mm Hg were initially randomized to receive 100% O₂ with (n=114) or without (n=121) 20 ppm nitric oxide for up to 14 days. Response to study drug was defined as a change from baseline in PaO₂ 30 minutes after starting treatment (full response = >20 mm Hg, partial = 10–20 mm Hg, no response = <10 mm Hg). Neonates with a less than full response were evaluated for a response to 80 ppm nitric oxide or control gas. The primary results from the NINOS study are presented in Table 2.

Table 2:
Summary of Clinical Results from NINOS Study

	Control (n=121)	NO (n=114)	P value
Death or ECMO*†	77 (64%)	52 (46%)	0.006
Death	20 (17%)	16 (14%)	0.60
ECMO	66 (55%)	44 (39%)	0.014

* Extracorporeal membrane oxygenation

† Death or need for ECMO was the study's primary end point

Although the incidence of death by 120 days of age was similar in both groups (NO, 14%; control, 17%), significantly fewer infants in the nitric oxide group required ECMO compared with controls (39% vs. 55%, p = 0.014). The combined incidence of death and/or initiation of ECMO showed a significant advantage for the nitric oxide treated group (46% vs. 64%, p = 0.006). The nitric oxide group also had significantly greater increases in PaO₂ and greater decreases in the OI and the alveolar-arterial oxygen gradient than the control group (p<0.001 for all parameters). Significantly more patients had at least a partial response to the initial administration of study drug in the nitric oxide group (66%) than the control group (26%, p<0.001). Of the 125 infants who did not respond to 20 ppm nitric oxide or control, similar percentages of NO-treated (18%) and control (20%) patients had at least a partial response to 80 ppm nitric oxide for inhalation or control drug, suggesting a lack of additional benefit for the higher dose of nitric oxide. No infant had study drug discontinued for toxicity. Inhaled nitric oxide had no detectable effect on mortality. The adverse events collected in the NINOS trial occurred at similar incidence rates in both treatment groups [see *Adverse Reactions* (6.1)]. Follow-up exams were performed at 18–24 months for the infants enrolled in this trial. In the infants with available follow-up, the two treatment groups were similar with respect to their mental, motor, audiological, or neurologic evaluations.

CINRGI Study

This study was a double-blind, randomized, placebo-controlled, multicenter trial of 186 term and near-term neonates with pulmonary hypertension and hypoxic respiratory failure. The primary objective of the study was to determine whether INOmax would reduce the receipt

of ECMO in these patients. Hypoxic respiratory failure was caused by MAS (35%), idiopathic PPHN (30%), pneumonia/sepsis (24%), or RDS (8%). Patients with a mean PaO₂ of 54 mm Hg and a mean OI of 44 cm H₂O / mm Hg were randomly assigned to receive either 20 ppm INOmax (n=97) or nitrogen gas (placebo; n=89) in addition to their ventilatory support. Patients who exhibited a PaO₂ >60 mm Hg and a pH < 7.55 were weaned to 5 ppm INOmax or placebo. The primary results from the CINRGI study are presented in Table 3.

Table 3:
Summary of Clinical Results from CINRGI Study

	Placebo	INOmax	P value
ECMO*†	51/89 (57%)	30/97 (31%)	<0.001
Death	5/89 (6%)	3/97 (3%)	0.48

* Extracorporeal membrane oxygenation

† ECMO was the primary end point of this study

Significantly fewer neonates in the INOmax group required ECMO compared to the control group (31% vs. 57%, p<0.001). While the number of deaths were similar in both groups (INOmax, 3%; placebo, 6%), the combined incidence of death and/or receipt of ECMO was decreased in the INOmax group (33% vs. 58%, p<0.001).

In addition, the INOmax group had significantly improved oxygenation as measured by PaO₂, OI, and alveolar-arterial gradient (p<0.001 for all parameters). Of the 97 patients treated with INOmax, 2 (2%) were withdrawn from study drug due to methemoglobin levels >4%. The frequency and number of adverse events reported were similar in the two study groups [see *Adverse Reactions* (6.1)].

14.2 Ineffective in Adult Respiratory Distress Syndrome (ARDS) ARDS Study

In a randomized, double-blind, parallel, multicenter study, 385 patients with adult respiratory distress syndrome (ARDS) associated with pneumonia (46%), surgery (33%), multiple trauma (26%), aspiration (23%), pulmonary contusion (18%), and other causes, with PaO₂/FIO₂ <250 mm Hg despite optimal oxygenation and ventilation, received placebo (n=193) or INOmax (n=192), 5 ppm, for 4 hours to 28 days or until weaned because of improvements in oxygenation. Despite acute improvements in oxygenation, there was no effect of INOmax on the primary endpoint of days alive and off ventilator support. These results were consistent with outcome data from a smaller dose ranging study of nitric oxide (1.25 to 80 ppm). INOmax is not indicated for use in ARDS.

16 HOW SUPPLIED/STORAGE AND HANDLING

INOmax (nitric oxide) is available in the following sizes:

Size D	Portable aluminum cylinders containing 353 liters at STP of nitric oxide gas in 800 ppm concentration in nitrogen (delivered volume 344 liters) (NDC 64693-002-01)
Size D	Portable aluminum cylinders containing 353 liters at STP of nitric oxide gas in 100 ppm concentration in nitrogen (delivered volume 344 liters) (NDC 64693-001-01)
Size 88	Aluminum cylinders containing 1963 liters at STP of nitric oxide gas in 800 ppm concentration in nitrogen (delivered volume 1918 liters) (NDC 64693-002-02)
Size 88	Aluminum cylinders containing 1963 liters at STP of nitric oxide gas in 100 ppm concentration in nitrogen (delivered volume 1918 liters) (NDC 64693-001-02)

Store at 25°C (77°F) with excursions permitted between 15–30°C (59–86°F) [see USP Controlled Room Temperature].

Occupational Exposure

The exposure limit set by the Occupational Safety and Health Administration (OSHA) for nitric oxide is 25 ppm, and for NO₂ the limit is 5 ppm.

INO Therapeutics
6 Route 173 West
Clinton, NJ 08809
USA

© 2009 INO Therapeutics

SPC-0303 V.4.0

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO)	
Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1613
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Updated Pre-Examination Search Document

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Updated Pre-Examination Search Document is provided in support of the Petition for Accelerated Examination filed herewith. This Document is provided as an update of the Search Document filed on June 22, 2010.

An updated pre-examination search was conducted involving U.S. patents and patent application publications, foreign patent documents and non-patent literature as indicated below. The results of the search are provided on an Information Disclosure Statement filed concurrently herewith.

The search primarily includes the following aspects:

- The method of reducing the risk of the occurrence in neonates or near-term neonates of adverse events or serious adverse events associated with inhalation of nitric oxide (iNO) by identifying such patient in need of iNO, administering iNO to the patient unless the patient is identified as having left ventricular dysfunction (LVD) or right-to-left shunting of blood. (See new claim 20).

- The method of reducing the risk of adverse events or serious adverse events in a neonate or near-term neonate associated with iNO by providing NO gas to a medical provider, informing the provider that right-to-left shunting of blood is contraindicated, and that elevated capillary wedge pressure (PCWP) is a risk factor leading to pulmonary edema. (See new claim 21).
- Specifically, that PCWP \geq 20 mm Hg is a risk factor. (See new claim 22).
- Specifically, that neonate patients are receiving iNO for treatment of respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension. (See new claim 23).
- Specifically, that the iNO is sourced from a pressurized cylinder containing NO and inert gases. (See new claim 24).
- The method of reducing the risk of adverse events or serious adverse events using iNO in term or near-term neonates by providing iNO to a medical provider, and informing the provider of two risk factors being a contraindication for right-to-left shunting of blood and the risk of increasing PCWP if there is pre-existing LVD. (See new claim 25).
- Specifically, that the LVD is characterized by elevated pulmonary capillary wedge pressure, diastolic dysfunction, hypertensive cardiomyopathy, systolic dysfunction, ischemic cardiomyopathy, viral cardiomyopathy, idiopathic cardiomyopathy, autoimmune disease related cardiomyopathy, drug-related cardiomyopathy, toxin-related cardiomyopathy, structural heart disease, valvular heart disease or congenital heart disease. (See new claim 26).
- Specifically, that the LVD is characterized by PCWP \geq 20 mm Hg. (See new claim 27).

A pre-examination search was conducted involving U.S. patents and patent application publications, foreign patent documents and non-patent literature as indicated below. The results of the search are provided on an Information Disclosure Statement filed concurrently herewith.

8 (A) Pre-examination Search

US patent classification Field of Search:

Class(es)/Subclass(es) Searched:

128/200.14, 128/200.24, 128/203.15, 128/20312, 558 /486, 600/481, 600/513

International patent classification field of Search

Section(s)/Class(es)/Subclass(es)/Main Group(s)/Sub group(s) searched

A61K 33/00, A61K 33/08, A61P 9/00, A61P 9/04, A61P 9/08, A61P 43/00, C01B
21/24

Date Conducted: April 15, 2011

Database Searches:

1) Database Service: MicroPatent, Thomson Innovation

Data Searched:

US Patent Document Databases: US-A, US-G

Foreign Patent Document Databases: EP-A, EP-B, JP, WO, GB-A, INPADOC

Search Logic:

1. (inhal*6 OR breath*3 OR gasp*3) NEAR5 (Nitrogen ADJ1 oxide OR Nitric ADJ1 oxide OR nitrogen ADJ1 monoxide OR NO OR iNO) WITH ((adverse OR undesirable OR unfavourable OR unfavorable) ADJ1 (event*1 OR consequence*1 OR indication*1 OR effect*1) OR trouble*1 OR risk* OR contraindication*1 OR danger* OR threat* OR side ADJ1 effect*1 OR toxin* OR toxic* OR safety OR caution* OR precaution OR warning*)
2. (Nitrogen ADJ1 oxide OR Nitric ADJ1 oxide OR nitrogen ADJ1 monoxide OR iNO) WITH ((adverse OR undesirable OR unfavourable OR unfavorable) ADJ1

- (event*1 OR consequence*1 OR indication*1 OR effect*1) OR trouble*1 OR risk*
 OR contraindication*1 OR danger* OR threat* OR side ADJ1 effect*1 OR toxin*
 OR toxic* OR safety OR caution* OR precaution OR warning*)
3. (avoid* OR exclud*6 OR except*4 OR omit*4 OR leav*3 ADJ1 out OR tak*3
 ADJ1 out) AND (infant*1 OR child*3 OR neonate*1 OR neonatal OR neo-natal
 OR baby OR babies OR newborn*1 OR term OR pre-term OR near-term)
 4. 2 AND 3
 5. (identif*8 OR select*3 OR choos*3 OR choice OR opt*4 OR pick*3 OR screen*3
 OR find*3 OR segregat*4 OR separat*3 OR distinguish*3 OR detect* OR
 diagnos* OR test*3 OR recogni* OR spot*4 OR determin* OR assess*) NEAR5
 (infant*1 OR child*3 OR neonate*1 OR neonatal OR neo-natal OR baby OR
 babies OR newborn*1 OR pre-term OR near-term) WITH (Nitric ADJ1 oxide OR
 nitrogen ADJ1 (monoxide OR oxide) OR NO OR iNO)
 6. (inhal*6 OR breath*3 OR gasp*3) NEAR5 (Nitrogen ADJ1 oxide OR Nitric ADJ1
 oxide OR nitrogen ADJ1 monoxide OR NO OR iNO)
 7. 5 AND 6
 8. 3 AND 6
 9. ((RL OR R-L OR RIGHT ADJ5 LEFT OR pulmonary) ADJ5 SHUNT* OR Patent
 ADJ1 ductus ADJ1 arteriosus OR septal ADJ1 defect OR foramen ADJ1 ovale
 OR Pulmonary ADJ1 stenosis OR Overriding ADJ1 aorta OR Ventricular ADJ1
 hypertrophy)
 10. (left ADJ1 ventric* ADJ2 dysfunction*3 OR LVD OR left ADJ1 ventricle OR
 ((diastolic OR systolic) NEAR2 Dysfunction*3) OR Pulmonary ADJ1 Capillary
 ADJ1 wedge ADJ1 pressure OR PCWP OR Pulmonary ADJ1 edema)
 11. 6 AND 9
 12. (3 OR 5) AND 6 AND 9
 13. 6 AND 10
 14. (3 OR 5) AND 6 AND 10
 15. 1 AND 9
 16. 2 AND 9
 17. 1 AND 10

18.2 AND 10

19. (Treat* OR cure OR curing) NEAR5 (Hypoxic ADJ1 respiratory ADJ1 failure OR Pulmonary ADJ1 hypertension OR hypoxia OR hypoxemia)

20.19 AND 1

21.19 AND 6 AND 9

22.19 AND 6 AND 10

Date Conducted: April 16, 2011

2) Database: Google, Google Scholar, The Journal of Pediatrics, American Academy of Pediatrics, MEDLINE, Journal of Medicinal Chemistry, PubMed

Search Strategy:

1. (right-to-left OR RL OR R-L) AND (shunt OR shunting OR flow OR pump) AND (Nitrogen oxide OR Nitric oxide OR nitrogen monoxide OR NO OR iNO) AND (inhalation OR inhaling OR inhale OR breath OR breathing)
2. (right-to-left OR RL OR R-L) AND (shunt OR shunting OR flow OR pump) AND (Nitrogen oxide OR Nitric oxide OR nitrogen monoxide OR NO OR iNO) AND (risk OR safety OR caution OR precaution OR warning OR contraindication OR contra-indication OR danger OR threat)
3. (right-to-left OR RL OR R-L) AND (shunt OR shunting OR flow OR pump) AND (Nitrogen oxide OR Nitric oxide OR nitrogen monoxide OR NO OR iNO) AND (side effect OR adverse OR undesirable OR unfavourable OR unfavorable)
4. (Pulmonary shunting OR Pulmonary stenosis OR Overriding aorta OR Ventricular hypertrophy OR Patent ductus arteriosus OR atrial septal defect OR Ventricular septal defect OR foramen ovale) AND (risk OR safety OR caution OR precaution OR warning OR contraindication OR contra-indication OR danger OR threat) AND (Nitrogen oxide OR Nitric oxide OR nitrogen monoxide OR NO OR iNO)
5. Inhalation AND Nitric oxide AND right-to-left shunting
6. Inhalation AND Nitric oxide AND Pulmonary shunting

7. Inhalation AND Nitric oxide AND risk AND right-to-left shunting
8. Inhalation AND Nitric oxide AND risk AND Pulmonary Capillary wedge pressure
9. Inhalation AND Nitric oxide AND risk AND left ventric dysfunction
10. Inhalation AND Nitric oxide AND risk AND left ventricular dysfunction
11. Inhalation AND Nitric oxide AND risk AND shunt

Date Conducted: April 17, 2011

8(B) Search Directed to the Invention

The pre-examination search was directed to the claimed invention, encompassing all the features of the claims and giving the claims their broadest reasonable interpretation.

8(C) Search Directed to the Disclosure

No disclosed features that are unclaimed at this time are currently seen as features that may be claimed later.

8(D) Search Report from a Foreign Patent Office

No search report from a foreign patent office is provided here as the pre-examination search.

8(E) Statement of Good Faith

All statements above in support of the petition to make special are based on a good faith belief that the search was conducted in compliance with the requirements of this rule.

Respectfully Submitted,

Lee & Hayes, PLLC
Representatives for Applicant

By: /Christopher P. Rogers, Reg No. 36334/

Dated: May 2, 2011

Christopher P. Rogers
(chriss@leehayes.com; 509-944-4785)
Registration No. 36334

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866	
	Filing Date		2010-06-22	
	First Named Inventor	James S. Baldassarre		
	Art Unit	1613		
	Examiner Name	Arnold, Ernst V.		
	Attorney Docket Number	I001-0002USC1		

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² i	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866
	Filing Date		2010-06-22
	First Named Inventor	James S. Baldassarre	
	Art Unit		1613
	Examiner Name	Arnold, Ernst V.	
	Attorney Docket Number		I001-0002USC1

1	Delivery of Inhaled Nitric Oxide Therapy through an Adult or Pediatric Nasal Cannula, Reference: UTMB RESPIRATORY CARE SERVICES Reviewed: 05/31/05	<input type="checkbox"/>
2	Ichinose, et al., Inhaled Nitric Oxide - A Selective Pulmonary Vasodilator: Current Uses and Therapeutic Potential, Circulation. 2004;109:3106-3111.	<input type="checkbox"/>
3	Konduri, et al., A Randomized Trial of Early Versus Standard Inhaled Nitric Oxide Therapy in Term and Near-Term Newborn Infants with Hypoxic Respiratory Failure, PEDIATRICS Vol. 113 No. 3 March 2004, pp. 559-564	<input type="checkbox"/>
4	Fraisse, et al., Doppler echocardiographic predictors of outcome in newborns with persistent pulmonary hypertension, Cardiol Young. 2004 Jun;14(3):277-83.	<input type="checkbox"/>
5	Malloy, Nitric Oxide Weaning, RT: For Decision Makers in Respiratory Care, December 2000, 2 pages.	<input type="checkbox"/>
6	Rosenberg, Inhaled nitric oxide in the premature infant with severe hypoxemic respiratory failure: A time for caution, The Journal of Pediatrics, Volume 133, Issue 6 , Pages 720-722, December 1998	<input type="checkbox"/>
7	Soto, et al., Cardiopulmonary Hemodynamics in Pulmonary Hypertension: Pressure Tracings, Waveforms, and More, Advances in Pulmonary Hypertension Winter 2008;7(4):386-393.	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	Date Considered
--------------------	-----------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Arnold, Ernst V.
	Attorney Docket Number	I001-0002USC1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

- See attached certification statement.
- The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.
- A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Christopher P. Rogers/	Date (YYYY-MM-DD)	2011-05-02
Name/Print	Christopher P. Rogers	Registration Number	36334

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Patent Application Fee Transmittal

Application Number:	12820866
Filing Date:	22-Jun-2010
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Filer:	Lewis Carl Lee/Anna Goforth
Attorney Docket Number:	I001-0002USC1

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 3 months with \$0 paid	2253	1	555	555

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Request for continued examination	2801	1	405	405
Total in USD (\$)				960

Electronic Acknowledgement Receipt

EFS ID:	10000852
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Lewis Carl Lee/Anna Goforth
Filer Authorized By:	Lewis Carl Lee
Attorney Docket Number:	I001-0002USC1
Receipt Date:	02-MAY-2011
Filing Date:	22-JUN-2010
Time Stamp:	16:42:13
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$960
RAM confirmation Number	3571
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
-----------------	----------------------	-----------	----------------------------------	------------------	------------------

1		QD9029.PDF	3042148	yes	49
			91969dc4104c5434dbce6a595f3c24898b1dcd		
Multipart Description/PDF files in .zip description					
		Document Description	Start	End	
		Accelerated Exam - Transmittal amendment/reply	1	1	
		Specification	2	2	
		Claims	3	5	
		Applicant Arguments/Remarks Made in an Amendment	6	49	
Warnings:					
Information:					
2	Statement of preexamination search	QD9036.PDF	105452	no	7
			9634a0593a04fb0f3f8c283cd884164a522fa007		
Warnings:					
Information:					
3	Request for Continued Examination (RCE)	QE1032.PDF	56653	no	1
			381c14b25184d4130fb8413ff456ac58db6649f7		
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
4	Examination support document	QE1140.PDF	89162	no	7
			4e28532ab447aa95cc5bf2664035ad9dad81f488		
Warnings:					
Information:					
5	Information Disclosure Statement (IDS) Filed (SB/08)	QD8994.PDF	35371	no	3
			b48729b0e3203f20564d24f8789e05e85bd65b52		
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
6	NPL Documents	Q90633.PDF	226764	no	4
			5440c51eb1fc032fb36dfb1e04b87d2bd700d7b2		
Warnings:					
Information:					

7	NPL Documents	Q90637.PDF	170070 6dff4d261e8b917be34c85499d1ea96fe7e6b5b	no	7
Warnings:					
Information:					
8	NPL Documents	Q90639.PDF	184722 31f3324586eeb90818c89b67666585a99e2b0c1b	no	8
Warnings:					
Information:					
9	NPL Documents	Q90641.PDF	25419181 5c3b928db7c3e63865ec2f3b5937e1b4135ab28	no	60
Warnings:					
Information:					
10	NPL Documents	Q90643.PDF	387048 cbbfe416f5f159e8800829bd9dd96ce306f91f3	no	4
Warnings:					
Information:					
11	NPL Documents	Q90645.PDF	87165 0842328452cc636ae2b5c7e0c553f1bc64458f0a	no	4
Warnings:					
Information:					
12	NPL Documents	Q90647.PDF	1143774 e2c1600fa5d9258642d67c7e133d665bd8d44e86	no	8
Warnings:					
Information:					
13	Fee Worksheet (PTO-875)	fee-info.pdf	32658 b56c68f0339b6fc21949858f4184a89bb419a08a	no	2
Warnings:					
Information:					
Total Files Size (in bytes):				30980168	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 12/820,866		Filing Date 06/22/2010		<input type="checkbox"/> To be Mailed			
APPLICATION AS FILED – PART I					SMALL ENTITY <input checked="" type="checkbox"/> OR OTHER THAN SMALL ENTITY						
(Column 1)		(Column 2)			(Column 3)		(Column 4)				
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)			
<input type="checkbox"/> BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A		N/A			
<input type="checkbox"/> SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A		N/A			
<input type="checkbox"/> EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =		OR X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		X \$ =		OR X \$ =			
<input type="checkbox"/> APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))											
* If the difference in column 1 is less than zero, enter "0" in column 2.											
APPLICATION AS AMENDED – PART II					SMALL ENTITY <input type="checkbox"/> OR OTHER THAN SMALL ENTITY						
(Column 1)		(Column 2)		(Column 3)		(Column 4)		(Column 5)			
AMENDMENT	05/02/2011	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 8	Minus	** 20	= 0	X \$26 =	0	OR	X \$ =		
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X \$110 =	0	OR	X \$ =		
	<input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))										
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE		0	OR	TOTAL ADD'L FEE	
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =		
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =		
	<input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))										
	<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE			OR	TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.											
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".											
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".											
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.											
						Legal Instrument Examiner: /FLORENCE PATTERSON/					

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
 If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

1	Ameduri, et al., Heart Failure in Children, MED-Continuing Medical Education, University of Minnesota. 2009 July 29 (cited 2010 Nov 12); available from URL: http://www.cme.umn.edu/prod/groups/med/@pub/@med/@cme/documents/content/med_content_124593.pdf	<input type="checkbox"/>
2	AU 2009202685 Office Action dated 06/17/10 (3 pages)	<input type="checkbox"/>
3	AU 2009202685 Office Action Response dated 07/29/2010, 19 pages	<input type="checkbox"/>
4	Bates, Inhaled Nitric Oxide: A Selective Pulmonary Vasodilator,	<input type="checkbox"/>
5	Behera, et al., Nesiritide Improves Hemodynamics in Children with Dilated Cardiomyopathy: A Pilot Study, <i>Pediatr Cardiol</i> (2009) 30:26-34	<input type="checkbox"/>
6	Bhagavan, et al., Potential role of ubiquinone (coenzyme Q10) in pediatric cardiomyopathy, <i>Clinical Nutrition</i> (2005) 24, 331-338, pp. 331-338	<input type="checkbox"/>
7	Branson, Inhaled Nitric Oxide in Adults, <i>The Science Journal of the American Association for Respiratory Care</i> 1997 Open Forum Abstracts, December 7, 1997, 2 pages, retrieved at << http://www.rcjournal.com/abstracts/1997/?id=A00000929 >> on 12/22/2010	<input type="checkbox"/>
8	Braunwald, Heart Failure, chapter 233 of <i>Harrison's Principles of Internal Medicine</i> , 14th Edition, 1998, pp. 1287-1291 & 1360	<input type="checkbox"/>
9	Bublik, et al., Pediatric cardiomyopathy as a chronic disease: A perspective on comprehensive care programs, <i>Progress in Pediatric Cardiology</i> 25 (2008) 103-111	<input type="checkbox"/>
10	Clark, et al., Low-Dose Nitric Oxide Therapy for Persistent Pulmonary Hypertension of the Newborn, <i>New England Journal of Medicine</i> , Vol 342, No 7, pp. 469-474	<input type="checkbox"/>
11	Comparison of Supplemental Oxygen and Nitric Oxide for Inhalation in the Evaluation of the Reactivity of the Pulmonary Vasculature During Acute Pulmonary Vasodilator Testing, http://clinicaltrials.gov/archive/NCT00626028/2009_01_12 January 12, 2009	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

12	Cox, et al., Factors Associated With Establishing a Causal Diagnosis for Children With Cardiology, Pediatrics, Vol 118, No 4, October 4, 2006, pp 1519-1531, published online October 2, 2006	<input type="checkbox"/>
13	Cox, et al., Factors Associated with Establishing a Causal Diagnosis for Children with Cardiomyopathy, Pediatrics Vol 118, No 4, October 2006, pp 1519-1531	<input type="checkbox"/>
14	Cuthbertson et al., "UK guidelines for the use of inhaled nitric oxide therapy in adults ICUs", Intensive Care Med (1997), 23, Springer-Verlag, 1997, pp#1212-pp#1218	<input type="checkbox"/>
15	Dermatological Cryosurgery in Primary Care with Dimethyl Ether Propane Spray in Comparison with Liquid Nitrogen, Martinez, et al., Atencion Primaria, Vol. 18, No. 5, (211, 216), September 30, 1996	<input type="checkbox"/>
16	Ivy, et al., "Dipyridamole attenuates rebound pulmonary hypertension after inhaled nitric oxide withdrawal in postoperative congenital heart disease", J Thorac Cardiovasc Surg 1998; 115:875-882.	<input type="checkbox"/>
17	Dronedarone is Less Effective, But Safer Than Amiodarone in Atrial Fibrillation, October 27, 2009, p. 3, << http://www.npci.org.uk/blog/?p=778 >>	<input type="checkbox"/>
18	Early Inhaled Nitric Oxide Therapy in Term and Near Term Infants with Respiratory Failure, from ClinicalTrials.gov archive, NCT00005773, 06/23/2005	<input type="checkbox"/>
19	Ehrenkranz RA, "Inhaled Nitric Oxide in Full-Term and Nearly Full-Term Infants with Hypoxic Respiratory Failure", The Neonatal Inhaled Nitric Oxide Study Group, N Engl J Med, 1997, Vol. 336, No. 9, pp. 597-605.	<input type="checkbox"/>
20	Elbl, et al., Long-term serial echocardiographic examination of late anthracycline cardiotoxicity and its prevention by dexrazoxane in paediatric patients, Eur J Pediatr (2005) 164: 678-684	<input type="checkbox"/>
21	The Encarta Webster's Dictionary of the English Language (2004) is the second edition of the Encarta World Dictionary, published 1999, << http://encarta.msn.com/encnet/features/dictionary/dictionaryhome.aspx >>; used to look up the definitions of "precaution" and "exclusion"	<input type="checkbox"/>
22	EP 09251949 Office Action dated 10/11/2010, 5 pages	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

23	Guideline for Industry; Clinical Safety Data Management: Definitions and Standards for Expedited Reporting, March 1995, 17 pages	<input type="checkbox"/>
24	Harrison's Principles of Internal Medicine, Fauci, et al., p. 1287-1291 and 1360, 12th edition, McGraw Hill, 1998.	<input type="checkbox"/>
25	Headrick, Hemodynamic monitoring of the critically ill neonate, J Perinat Neonatal Nurs 1992; 5(4): 58-67	<input type="checkbox"/>
26	Huddleston, Indications for heart transplantation in children, Progress in Pediatric Cardiology 26 (2009) 3-9	<input type="checkbox"/>
27	Inhaled Nitric Oxide by Oxygen Hood in Neonates, from ClinicalTrials.gov, NCT00732537, 08/08/2008	<input type="checkbox"/>
28	Inhaled Nitric Oxide in Neonates with Elevated A-a DO2 Gradients Not Requiring Mechanical Ventilation, from ClinicalTrials.gov archive, NCT00041548, 06/23/2005, 2 pages	<input type="checkbox"/>
29	INO Therapeutics, LLC, "INOflo for Inhalation 800ppm", package leaflet, 2010, 2	<input type="checkbox"/>
30	James, et al., Treatment of heart failure in children, Current Paediatrics (2005) 15, 539-548	<input type="checkbox"/>
31	JP 2009157623 Office Action dated 02/23/2010, 3 pages	<input type="checkbox"/>
32	JP 2009157623 Office Action dated 07/30/2010, 6 pages	<input type="checkbox"/>
33	JP 2009157623 Office Action response filed 06/18/2010, 37 pages (no translation)	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

34	JP 2009157623 request for accelerated exam filed 01/15/2010 (60 pages)	<input type="checkbox"/>
35	JP 2009157623 response filed 11/30/2010, 58 pages	<input type="checkbox"/>
36	JP 2009-157623 Office Action dated 02/15/2011, 3 pages	<input type="checkbox"/>
37	Lavigne, et al., Cardiovascular Outcomes of Pediatric Seroreverters Perinatally Exposed to HAART, Cardiovascular Toxicology (2004) 04 187-197	<input type="checkbox"/>
38	Letter of Acceptance for AU 2010202422, dated 10/7/2010	<input type="checkbox"/>
39	Letter of acceptance of AU application 2009202685, dated 08/10/2010, 3 pages	<input type="checkbox"/>
40	Lipschultz, The effect of dexrazoxane on myocardial injury in doxorubicin-treated children with acute lymphoblastic leukemia, New England Journal of Medicine 2004; 351:145-153.	<input type="checkbox"/>
41	Lipschultz, The incidence of pediatric cardiomyopathy in two regions of the United States, New England Journal of Medicine, April 24, 2003. << http://www.nejm.org/doi/full/10.1056/NEJMoa021715 >>	<input type="checkbox"/>
42	Lipshultz, et al., Cardiovascular status of infants and children of women infected with HIV-1 (P2C2 HIV): a cohort study, The Lancet, Vol 360, August 3, 2002, pp. 368-373.	<input type="checkbox"/>
43	Lipshultz, et al., Cardiovascular Trials in Long-Term Survivors of Childhood Cancer, Journal of Clinical Oncology, Vol 22, Number 5, March 1, 2004, pp. 769-773.	<input type="checkbox"/>
44	Lipshultz, Chronic Progressive Cardiac Dysfunction Years After Doxorubicin Therapy for Childhood Acute Lymphoblastic Leukemia, Journal of Clinical Oncology, Vol 23, No 12, April 20, 2005. 8 pages.	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

45	Lipshultz, Clinical research directions in pediatric cardiology, Current Opinion in Pediatrics 2009, 21:585-593	<input type="checkbox"/>
46	Lipshultz, Establishing norms for echocardiographic measurement of cardiovascular structures and function in children, J Appl Physiol 99: 386-388, 2005	<input type="checkbox"/>
47	Lipshultz, Frequency of clinically unsuspected myocardial injury at a children's hospital, American Heart Journal, Vol 151, No 4, pp 916-922	<input type="checkbox"/>
48	Lipshultz, et al., Long-Term Enalapril Therapy for Left Ventricular Dysfunction in Doxorubicin-Treated Survivors of Childhood Cancer, Journal of Clinical Oncology, Vol 20, No 23 (December 1), 2002; pp 4517-4522	<input type="checkbox"/>
49	Madriago, Heart Failure in Infants and Children, Pediatrics in Review, 2010; 31:4-12	<input type="checkbox"/>
50	http://www.medterms.com/script/main/art.asp?articlekey=17824	<input type="checkbox"/>
51	Miller, et al., Nutrition in Pediatric Cardiomyopathy, Prog Pediatr Cardiol, 2007 November; 24(1): 59-71	<input type="checkbox"/>
52	Mone, Effects of Environmental Exposures on the Cardiovascular System: Prenatal Period Through Adolescence, Pediatrics Vol 113, No 4, April 2004, pp 1058-1069	<input type="checkbox"/>
53	Murray, Angiotensin Converting Enzyme Inhibitory Peptides Derived from Food Proteins: Biochemistry, Bioactivity and Production,	<input type="checkbox"/>
54	NIH Clinical Center Services, retrieved at < http://www.cc.nih.gov/ccmd/clinical_services.html >> on 08/18/2010	<input type="checkbox"/>
55	NIH Clinical Center, Department Policy and Procedure Manual for the Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, 2000, sections 3.1-3.1.2 & 5.2.3	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

56	Notification of Reason for Rejection, mailed 7/30/2010, from Japanese Patent Application No. 2009-157623 (cites foreign references).	<input type="checkbox"/>
57	Office Action for AU 2010202422 dated 07/09/2010, 3 pages	<input type="checkbox"/>
58	Office Action from AU 2009202685 dtd 03/15/2010	<input type="checkbox"/>
59	Office Action from AU 2010206032 dated 08/16/2010 (3 pages)	<input type="checkbox"/>
60	Office Action Response for AU 2009202685 to 03/15/2010 OA, filed 06/08/2010 (16 pages)	<input type="checkbox"/>
61	Office Action Response for JP2007157623 filed on 11/12/2009 (no English translation)	<input type="checkbox"/>
62	Office Action Response to AU 2010202422 OA dated 07/09/2010, response filed 09/01/2010	<input type="checkbox"/>
63	Translated copy of the Japanese Office Action mailed February 15, 2011 for Japanese Patent Application No. 2009-157623, a counterpart foreign application for US Patent Application No. 12/494,598	<input type="checkbox"/>
64	Pazopanib Plus Lapatinib Compared to Lapatinib Alone in Subjects With Inflammatory Breast Cancer, April 22, 2010, p. 4, ClinicalTrials.gov, << http://clinicaltrials.gov/ct2/show/NCT00558103 >>	<input type="checkbox"/>
65	PCT/US2010/038652 Search Report dated 07/29/2010, 16 pages	<input type="checkbox"/>
66	Ratnasamy, et al., Associations between neurohormonal and inflammatory activation and heart failure in children, American Heart Journal, March 2008, pp. 527-533	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

67	Response filed 08/18/2010 to EP Search Report dated 05/10/10 for EP09251949	<input type="checkbox"/>
68	NIH Clinical Center 2 Critical Care Medicine Department Sample Rotations, Updated January 2007<< http://www.cc.nih.gov/ccmd/prof_opps/rotation.html >>	<input type="checkbox"/>
69	Search Report from EP 09251949 dated 05/10/10	<input type="checkbox"/>
70	Sibutramine-metformin Combination vs. Sibutramine and Metformin Monotherapy in Obese Patients, July 15, 2009, p. 3, ClinicalTrials.gov, << http://clinicaltrials.gov/ct2/showNCT00941382 >>	<input type="checkbox"/>
71	Somarriba, et al., Exercise rehabilitation in pediatric cardiomyopathy, Progress in Pediatric Cardiology 25 (2008) 91-102	<input type="checkbox"/>
72	Strauss, et al., Pediatric Cardiomyopathy - A Long Way to Go, The New England Journal of Medicine, 348; 17, April 24, 2003, pp. 1703-1705	<input type="checkbox"/>
73	Study of Comparative Effects of Oral Clonidine vs. Oral Diazepam Pre-Medication on the Extent and Duration of Sensory Blockade in Patients Undergoing Vaginal Hysterectomy Under Spinal Anaesthesia, Toshniwal, et al., Interenet Journal of Anesthesiology, 2009, << http://www.britannica.com/bps/additionalcontent/18/41575551/Study-of-Comparative-Effects-Oral-Clonidine-vs-Oral-Diazepam-Pre-Medication-on-the-Extent-and-Duration-of-Sensory-Blockade-in-Patients-Undergoing-Vaginal-Hysterectomy-Under-Spinal-Anaesthesia >>	<input type="checkbox"/>
74	The Effects of Nitric Oxide for Inhalation on the Development of Chronic Lung Disease in Pre-Term Infants, from ClinicalTrials.gov archive, NCT00551642, 10/30/2007, 3 pages	<input type="checkbox"/>
75	Towbin, et al., Incidence, Causes, and Outcomes of Dilated Cardiomyopathy in Children, JAMA, October 18, 2006 - Vol 296, No. 15, pp. 1867-1876	<input type="checkbox"/>
76	van Dalen, Treatment for Asymptomatic Anthracycline-Induced Cardiac Dysfunction in Childhood Cancer Survivors: The Need for Evidence, Journal of Clinical Oncology, Vol 21, No 17, (September 11) 2003, pp. 3375-3379	<input type="checkbox"/>
77	Wilkinson, et al., Epidemiological and outcomes research in children with pediatric cardiomyopathy; discussions from the international workshop on primary and idiopathic cardiomyopathies in children, Progress in Pediatric Cardiology 25 (2008) 23-25	<input type="checkbox"/>

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866
	Filing Date		2010-06-22
	First Named Inventor	James S. Baldassarre	
	Art Unit		1613
	Examiner Name	Ernst V. Arnold	
	Attorney Docket Number		I001-0002USC1

78	http://www.cc.nih.gov/ccmd/clinical_services.html	<input type="checkbox"/>
79	www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidance/ucm073087.pdf >>	<input type="checkbox"/>
80	Federal Regulations 21 CFR Part 312, << http://www.gcrc.uci.edu/rsa/aer.cfm >>	<input type="checkbox"/>
81	Yoshida, Kiyoshi, " Well-illustrated Diagnostics and Treatment of Heart Failure" Professor of Kawasaki Medical University, cardiovascular internal medicine CIRCULATION Up-to-Date Vol. 2, No. 4, 2007(343), pp. 23-28	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature		Date Considered	
--------------------	--	-----------------	--

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

OR

That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement.

See attached certification statement.

Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Christopher P. Rogers, RegNo 36334/	Date (YYYY-MM-DD)	2011-05-03
Name/Print	Christopher P. Rogers	Registration Number	36,334

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

PATENT COOPERATION TREATY

PCT

From the INTERNATIONAL SEARCHING AUTHORITY

To:
 Rogers, Christopher...
 LEE & HAYES, PLLC
 601 West Riverside Avenue Suite 1400
 Spokane WA 99201
 ETATS-UNIS D'AMERIQUE

NOTIFICATION OF TRANSMITTAL OF
 THE INTERNATIONAL SEARCH REPORT AND
 THE WRITTEN OPINION OF THE INTERNATIONAL
 SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing <i>(day/month/year)</i> <p style="text-align: right;">29 July 2010 (29-07-2010)</p>
Applicant's or agent's file reference I001 - 0002PCT	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US2010/038652	International filing date <i>(day/month/year)</i> <p style="text-align: right;">15 June 2010 (15-06-2010)</p>
Applicant <p style="text-align: center;">Ikaria Holdings, Inc.</p>	

1. The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.
Filing of amendments and statement under Article 19:
 The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):
When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.
Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70
For more detailed instructions, see the notes on the accompanying sheet.
2. The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.
3. **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
 - the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
 - no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.
4. **Reminders**
 Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.
 The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.
 Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.
 In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.
 See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, National Chapters.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040 Fax: (+31-70) 340-3016	Authorized officer HODZIC, Iris Tel: +49 (0)89 2399-2084
--	--

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Annex B).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, International Phase, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet or sheets containing a complete set of claims in replacement of all the claims previously filed must be submitted.

Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively in Arabic numerals (Section 205(a)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1bis(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion together, where appropriate, with amendments before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later (Rule 43bis.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, National Chapters.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference I001 - 0002PCT	FOR FURTHER ACTION		see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2010/038652	International filing date (day/month/year) 15/06/2010	(Earliest) Priority Date (day/month/year) 30/06/2009	
Applicant Ikaria Holdings, Inc.			

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of:

- the international application in the language in which it was filed
 a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. **Certain claims were found unsearchable** (See Box No. II)

3. **Unity of invention is lacking** (see Box No III)

4. With regard to the **title**,

- the text is approved as submitted by the applicant
 the text has been established by this Authority to read as follows:

METHODS OF IDENTIFYING A PATIENT POPULATION ELIGIBLE FOR TREATMENT WITH NITRIC OXIDE VIA INHALATION

5. With regard to the **abstract**,

- the text is approved as submitted by the applicant
 the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,

- a. the figure of the **drawings** to be published with the abstract is Figure No. _____
 as suggested by the applicant
 as selected by this Authority, because the applicant failed to suggest a figure
 as selected by this Authority, because this figure better characterizes the invention
- b. none of the figures is to be published with the abstract

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/038652

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

The invention relates to methods of reducing the risk or preventing the occurrence of an adverse event (AE) or a serious adverse event (SAE) associated with a medical treatment comprising inhalation of nitric oxide.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/038652

A. CLASSIFICATION OF SUBJECT MATTER
 INV. A61K31/21 A61K33/00 A61K45/06 A61P9/08 A61P9/12
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, BIOSIS, CHEM ABS Data, EMBASE, PASCAL, SCISEARCH, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LOH EVAN ET AL: "Cardiovascular Effects of Inhaled Nitric Oxide in patients With Left Ventricular Dysfunction" CIRCULATION, vol. 90, no. 6, 1994, pages 2780-2785, XPO02577161 ISSN: 0009-7322 the whole document ----- -/--	1-30

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance	*I* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
E earlier document but published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
O document referring to an oral disclosure, use, exhibition or other means	*&* document member of the same patent family
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 23 July 2010	Date of mailing of the international search report 29/07/2010
---	--

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Albrecht, Silke
--	---

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/038652

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SEMIGRAN MARC J ET AL: "Hemodynamic effects of inhaled nitric oxide in heart failure" JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY, vol. 24, no. 4, 1994, pages 982-988, XP009131903 ISSN: 0735-1097 cited in the application the whole document	1-30
X	HAYWARD C S ET AL: "Inhaled nitric oxide in cardiac failure: Vascular versus ventricular effects" JOURNAL OF CARDIOVASCULAR PHARMACOLOGY, vol. 27, no. 1, 1996, pages 80-85, XP009131904 ISSN: 0160-2446 cited in the application the whole document	1-30
X	OVODOV ET AL: "Nitric oxide: Clinical applications" SEMINARS IN ANESTHESIA, SAUNDERS, CO, NEW YORK, NY, US LNKD- DOI:10.1053/SA.2000.6785, vol. 19, no. 2, 1 June 2000 (2000-06-01), pages 88-97, XP005426335 ISSN: 0277-0326 page 90, column 1 page 93, column 2 - page 94	1-30
X	HENRICHSEN ET AL: "Inhaled nitric oxide can cause severe systemic hypotension" JOURNAL OF PEDIATRICS, MOSBY-YEAR BOOK, ST. LOUIS, MO, US LNKD- DOI:10.1016/S0022-3476(96)70230-5, vol. 129, no. 1, 1 July 1996 (1996-07-01), page 183, XP022199226 ISSN: 0022-3476 the whole document	1-30
X	ADATIA ET AL: "Inhaled nitric oxide and hemodynamic evaluation of patients with pulmonary hypertension before transplantation" JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY, ELSEVIER, NEW YORK, NY, US LNKD- DOI:10.1016/0735-1097(95)00048-9, vol. 25, no. 7, 1 June 1995 (1995-06-01), pages 1656-1664, XP005857183 ISSN: 0735-1097 page 1663, column 1	1-30

-/--

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/038652

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>CUJEC BIBIANA ET AL: "Inhaled nitric oxide reduction in systolic pulmonary artery pressure is less in patients with decreased left ventricular ejection fraction" CANADIAN JOURNAL OF CARDIOLOGY, vol. 13, no. 9, 1997, pages 816-824, XP002577162 ISSN: 0828-282X the whole document</p>	1-30
X	<p>-----</p> <p>FINDLAY G P: "Paradoxical haemodynamic response to inhaled nitric oxide" INTERNATIONAL JOURNAL OF INTENSIVE CARE 1998 GB, vol. 5, no. 4, 1998, pages 134-139, XP001536771 ISSN: 1350-2794 the whole document</p>	1-30
X	<p>-----</p> <p>BOCCHI E A ET AL: "Inhaled nitric oxide leading to pulmonary edema in stable severe heart failure" AMERICAN JOURNAL OF CARDIOLOGY, CAHNER'S PUBLISHING CO., NEWTON, MA, US LNKD- DOI:10.1016/0002-9149(94)90496-0, vol. 74, no. 1, 1 July 1994 (1994-07-01), pages 70-72, XP023278686 ISSN: 0002-9149 [retrieved on 1994-07-01] cited in the application the whole document</p> <p>-----</p>	1-30

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43bis.1)

To:

see form PCT/ISA/220

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.
PCT/US2010/038652

International filing date (day/month/year)
15.06.2010

Priority date (day/month/year)
30.06.2009

International Patent Classification (IPC) or both national classification and IPC
INV. A61K31/21 A61K33/00 A61K45/06 A61P9/08 A61P9/12

Applicant
Ikaria Holdings, Inc.

1. This opinion contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the international application
- Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:



European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0
Fax: +49 89 2399 - 4465


Date of completion of this opinion

see form
PCT/ISA/210

Authorized Officer

Albrecht, Silke

Telephone No. +49 89 2399-7864



**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US2010/038652

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 - the international application in the language in which it was filed
 - a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).
2. This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:
 - a. (means)
 - on paper
 - in electronic form
 - b. (time)
 - in the international application as filed
 - together with the international application in electronic form
 - subsequently to this Authority for the purposes of search
4. In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of

the entire international application

claims Nos. 16-23

because:

the said international application, or the said claims Nos. 16-23 relate to the following subject matter which does not require an international search (*specify*):

see separate sheet

the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):

the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed (*specify*):

no international search report has been established for the whole application or for said claims Nos.

a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.

furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.

pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rules 13*ter*.1(a) or (b).

See Supplemental Box for further details

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US2010/038652

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>1-30</u>
	No: Claims	
Inventive step (IS)	Yes: Claims	
	No: Claims	<u>1-30</u>
Industrial applicability (IA)	Yes: Claims	<u>1-30</u>
	No: Claims	

2. Citations and explanations

see separate sheet

Re Item III

Non- establishment of opinion with regard to novelty, inventive step and industrial applicability

Independent claims 16, 20 will not be examined in accordance with Rule 67.1(v) PCT, as their subject-matter is limited to mere presentations of information (i.e. informing the medical provider in accordance with feature b of claims 16, 20). Mutatis mutandis dependent claims 17-19, 21-23.

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

The following documents (D1-D9) are referred to in this report; the numbering results from the order of citations found in the Search Report (SR) and will be adhered to in the rest of the procedure. The cited passage (s) for each citation will be considered unless otherwise specified.

Claims 1-15, 24-30 relate to subject-matter considered by this Authority to be covered by the provision of Rule 39.1 (iv)/67.1 (iv) PCT. The patentability can be dependent upon the formulation of the claims. The EPO, for example, does not recognise as patentable claims the use of a compound in medical treatment, but may allow claims to a product, in particular substances or compositions for use in a first or further medical treatment.

Claims 1-15, 24-30 do not comply with the requirements of Article 5 PCT, the reasons being as follows:

These claims comprise i.a. the step of identifying near-term neonate, neonate or child patients eligible for/ in need of treatment with NO by inhalation. However, in the present case, the disclosure in the patent application does not give the skilled person any guidance on how to identify these patients (eg method of screening, criteria of inclusion/exclusion etc). Independent of the foregoing claims 1-15, 24-30 also lack clarity in the sense of Article 6 PCT, as the wording of feature (a) of claims 9, 24, 25 and claim 1 is vague and leaves the skilled reader in doubt about the exact scope of these claims. Mutatis mutandis dependent claims 2-8, 10-15, 26-30.

Furthermore, claims 1-15, 24-30 are also considered to be unclear in that they comprise a diagnostic step (eg feature (b) of claims 9, 24, 25), but the said diagnostic procedure is not further defined (e.g. omission of the method steps of data collection, of comparison of data with standard values, of finding of any significant deviation during the comparison). As these features are essential to the definition of the invention, but are nevertheless not mentioned in independent claims 1, 9, 24, 25,

these claims do not meet the requirement following from Article 6 PCT that any independent claim must contain all the technical features essential to the definition of the invention.

In addition, claims 28-30 as dependent claims of claims 16, 20 do not meet the requirements of Article 6 PCT in that the matter for which protection is sought is not clearly defined. The reasons are as follows:

Claims 28-30 refer to a medical treatment of a patient (i.e. reducing left ventricular afterload), whereas claims 16, 20 do not relate to any medical treatment of a patient. The method described in claims 16, 20 is merely limited to providing a medical provider with nitric oxide gas and informing him in accordance with feature b of these claims. This contradiction between the subject-matter of claims 16, 20 on one hand and claims 28-30 on the other hand produces a lack of clarity as to the scope of protection afforded by claims 28-30.

In view of the foregoing objections, novelty and inventive step cannot be discussed in detail at present. However, the following should be noted:

The core of the invention appears to reside in the discovery that patients with pre-existing LVD often experience an increased risk of (serious) adverse events when treated with NO by inhalation (cf par.5, 50, 52, 61, 68, 69 of the present application). However, this finding has already been reported in prior art. In particular, D3- D8 explicitly recommend to use inhaled NO with caution in patients with LVD. Furthermore, the authors of D1 state that inhaled NO may have adverse effects in patients with LVD and hence may not be desirable in patients with severe left ventricular failure. D2 reports on the haemodynamic effects of inhaled NO in patients with LVD and concludes that the increase in left ventricular filling pressure seen during NO administration may limit its role to that of a diagnostic agent rather than a therapeutic agent in these patients. As for the specific patient group claimed in the present claims, this cannot contribute to inventive step either, since D5 and D6 refer to neonates and children respectively.

In light of these teachings, it would be obvious for the skilled person to screen patients including neonates and children about to undergo treatment with NO by inhalation and to exclude those with LVD therefrom.

Possible steps after receipt of the international search report (ISR) and written opinion of the International Searching Authority (WO-ISA)

General information For all international applications filed on or after 01/01/2004 the competent ISA will establish an ISR. It is accompanied by the WO-ISA. Unlike the former written opinion of the IPEA (Rule 66.2 PCT), the WO-ISA is not meant to be responded to, but to be taken into consideration for further procedural steps. This document explains about the possibilities.

Amending claims under Art. 19 PCT Within 2 months after the date of mailing of the ISR and the WO-ISA the applicant may file amended claims under Art. 19 PCT directly with the International Bureau of WIPO. The PCT reform of 2004 did not change this procedure. For further information please see Rule 46 PCT as well as form PCT/ISA/220 and the corresponding Notes to form PCT/ISA/220.

Filing a demand for international preliminary examination In principle, the WO-ISA will be considered as the written opinion of the IPEA. This should, in many cases, make it unnecessary to file a demand for international preliminary examination. If the applicant nevertheless wishes to file a demand this must be done before expiry of 3 months after the date of mailing of the ISR/WO-ISA or 22 months after priority date, whichever expires later (Rule 54bis PCT). Amendments under Art. 34 PCT can be filed with the IPEA as before, normally at the same time as filing the demand (Rule 66.1 (b) PCT).

If a demand for international preliminary examination is filed and no comments/amendments have been received the WO-ISA will be transformed by the IPEA into an IPRP (International Preliminary Report on Patentability) which would merely reflect the content of the WO-ISA. The demand can still be withdrawn (Art. 37 PCT).

Filing informal comments After receipt of the ISR/WO-ISA the applicant may file informal comments on the WO-ISA directly with the International Bureau of WIPO. These will be communicated to the designated Offices together with the IPRP (International Preliminary Report on Patentability) at 30 months from the priority date. Please also refer to the next box.

End of the international phase At the end of the international phase the International Bureau of WIPO will transform the WO-ISA or, if a demand was filed, the written opinion of the IPEA into the IPRP, which will then be transmitted together with possible informal comments to the designated Offices. The IPRP replaces the former IPER (international preliminary examination report).

Relevant PCT Rules and more information Rule 43 PCT, Rule 43bis PCT, Rule 44 PCT, Rule 44bis PCT, PCT Newsletter 12/2003, OJ 11/2003, OJ 12/2003

Bitte beachten Sie, dass angeführte Nichtpatentliteratur (wie z. B. wissenschaftliche oder technische Dokumente) je nach geltendem Recht dem Urheberrechtsschutz und/oder anderen Schutzarten für schriftliche Werke unterliegen könnte. Die Vervielfältigung urheberrechtlich geschützter Texte, ihre Verwendung in anderen elektronischen oder gedruckten Publikationen und ihre Weitergabe an Dritte ist ohne ausdrückliche Zustimmung des Rechtsinhabers nicht gestattet.

Veillez noter que les ouvrages de la littérature non-brevets qui sont cités, par exemple les documents scientifiques ou techniques, etc., peuvent être protégés par des droits d'auteur et/ou toute autre protection des écrits prévue par les législations applicables. Les textes ainsi protégés ne peuvent être reproduits ni utilisés dans d'autres publications électroniques ou imprimées, ni rediffusés sans l'autorisation expresse du titulaire du droit d'auteur.

Please be aware that cited works of non-patent literature such as scientific or technical documents or the like may be subject to copyright protection and/or any other protection of written works as appropriate based on applicable laws. Copyrighted texts may not be copied or used in other electronic or printed publications or re-distributed without the express permission of the copyright holder.

XS CPRTENFRDE

Electronic Acknowledgement Receipt

EFS ID:	10012403
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Lewis Carl Lee/Anna Goforth
Filer Authorized By:	Lewis Carl Lee
Attorney Docket Number:	I001-0002USC1
Receipt Date:	03-MAY-2011
Filing Date:	22-JUN-2010
Time Stamp:	17:09:15
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	QE8257.PDF	75151 <small>0b4dd165fcc09b0d881e63f71a2ca544cf63f2db</small>	no	10

Warnings:

Information:

This is not an USPTO supplied IDS fillable form					
2	NPL Documents	O86044.pdf	153932	no	4
			96945d60944cf4e06475c57b2ccf5d35497f2fcf		
Warnings:					
Information:					
3	NPL Documents	O86037.pdf	369742	no	5
			4a332bd82d6f9a661ba2a15ce0e7b15d484387f		
Warnings:					
Information:					
4	NPL Documents	O86041.pdf	727722	no	7
			40545b06db1277e5c6aa458c60f1a65408c4503a		
Warnings:					
Information:					
5	NPL Documents	OH8890.PDF	164479	no	9
			23fc7d9efd65e6829e03ef05a783c3a252d6e90a		
Warnings:					
Information:					
6	NPL Documents	OE2720.PDF	97276	no	1
			cd6397f7339534fd58c4472dd3fd57a0c4e31301		
Warnings:					
Information:					
7	NPL Documents	OE2722.PDF	591614	no	8
			261961ecc1d071d132c31aabee6d7ba4d88e7717		
Warnings:					
Information:					
8	NPL Documents	OE2725.PDF	206048	no	10
			08852912c18d788810fcf11b8b7828b29cea8686		
Warnings:					
Information:					
9	NPL Documents	NQ3600.PDF	200468	no	8
			a68c776d620b936d03dc2d345e1aff0fa8daa817		
Warnings:					
Information:					
10	NPL Documents	OF5769.PDF	106768	no	6
			374166576eb9c153c27804ac893837e47c47d4bf		

Warnings:					
Information:					
11	NPL Documents	OI1167.PDF	494491 6b20451613ebb78c92357d959fe442310d3532eb	no	19
Warnings:					
Information:					
12	NPL Documents	OF5771.PDF	87066 43dafefded451c630d25ed61aeb7c0e11b5ac45c	no	6
Warnings:					
Information:					
13	NPL Documents	OF5773.PDF	73308 cd4f1b0b2be51cba3defd025ae138102b3f71165	no	5
Warnings:					
Information:					
14	NPL Documents	OF5781.PDF	174148 d7aeced490f81be9dea2cb0ad21055bc288536c2c	no	14
Warnings:					
Information:					
15	NPL Documents	OF5784.PDF	172645 8e294d7d2aaf3d22d477035dec610c520c6af08b	no	15
Warnings:					
Information:					
16	NPL Documents	OF5786.PDF	78152 7d8dc68bf9928668a617e2338627d14bc1460fe	no	3
Warnings:					
Information:					
17	NPL Documents	OF5777.PDF	178631 335fc27a652b3704625f90d2195d132d1ff20f30	no	8
Warnings:					
Information:					
18	NPL Documents	OI4894.PDF	121034 6e8df1d099c67b772be812352310339c9e79f79f	no	7
Warnings:					
Information:					
19	NPL Documents	OI5260.PDF	654479 76be47b08c2c75336f54e3b1d7178db8debde23c	no	6

Warnings:					
Information:					
20	NPL Documents	OI5331.PDF	232089 85a31092586f5bbbcdb7ef3507570262ccb97	no	6
Warnings:					
Information:					
21	NPL Documents	OI5476.PDF	105410 e697ae28e060f0891205e3d71d85a7b8d07678b	no	7
Warnings:					
Information:					
22	NPL Documents	OI5506.PDF	139810 2e409a17af5911b7f3b793056c79354ee2bd5674	no	9
Warnings:					
Information:					
23	NPL Documents	OI5739.PDF	164467 4ee2a33b03ca415db6260a5f5b8f68f6ccb91a6	no	10
Warnings:					
Information:					
24	NPL Documents	OF5779.PDF	73133 5631483bb1a40f16b5bb559cbb3da4c81af6cd44	no	4
Warnings:					
Information:					
25	NPL Documents	OF5846.PDF	576791 006e6f18a8704b71d3d2f961383241cc100f4b3	no	12
Warnings:					
Information:					
26	NPL Documents	OI5989.PDF	245833 5ad6375d99e4d3beb6771f065965fb22a4a124d	no	7
Warnings:					
Information:					
27	NPL Documents	OI6261.PDF	227013 97120fab9318ed58086ae78bd67d049ada3c925	no	11
Warnings:					
Information:					
28	NPL Documents	OI6342.PDF	126443 e184f32669042cfabf820ffebbdfa9ccecb99bda0	no	7

Warnings:					
Information:					
29	NPL Documents	OI6517.PDF	139951 81c864c2202ca87243a5a5facd4371552da9f6c7	no	9
Warnings:					
Information:					
30	NPL Documents	OI6602.PDF	289637 144304143d42035e47259969d1e42c5632afac0c	no	9
Warnings:					
Information:					
31	NPL Documents	OI7415.PDF	310458 bf072a2265fdbac35890ba46c829899470740fba	no	21
Warnings:					
Information:					
32	NPL Documents	OI7522.PDF	78601 b4811f502f03c08bef0710f8e11ae29400142ba1	no	3
Warnings:					
Information:					
33	NPL Documents	PJ7125.PDF	198204 cc79b3958ad6cf54b1eb1609875cc1a736b64f75	no	3
Warnings:					
Information:					
34	NPL Documents	PJ7358.PDF	133108 88d96a471b04ede34b7c6142e2bc6197b7e5ab69	no	16
Warnings:					
Information:					
35	NPL Documents	PJ7362.PDF	243310 566983fb5e1f4c09e29d5939f2791e21dd935f02	no	3
Warnings:					
Information:					
36	NPL Documents	PJ7381.PDF	569514 1b0ab55e87d4370c653190ec39e017684764e75a	no	19
Warnings:					
Information:					
37	NPL Documents	PJ7395.PDF	122274 748d3dc116ffc86804fa5766565ab7fcfb91687e	no	3

Warnings:					
Information:					
38	NPL Documents	PJ7450.PDF	213730 0b4b720456e3462fcb3e995cd58809bcb76aa1d7	no	3
Warnings:					
Information:					
39	NPL Documents	PJ7588.PDF	122805 27447a99e0c09ca08d4a868df0cbb3ee0b7287f4	no	3
Warnings:					
Information:					
40	NPL Documents	PJ7582.pdf	75637 8c587754395f1147728425f642ac5d66b69e4e71	no	8
Warnings:					
Information:					
41	NPL Documents	PJ7592.PDF	183271 e0fa89cc64e1c4282086d7814153aa8e16cd9935	no	3
Warnings:					
Information:					
42	NPL Documents	PJ7633.PDF	129016 49af91f882b60527f76be352a7c0cccb7882eba8	no	6
Warnings:					
Information:					
43	NPL Documents	PJ7681.PDF	260513 8f5ac539406d9ff9c966ba83bc654675c3a0ffcf4	no	5
Warnings:					
Information:					
44	NPL Documents	PJ7747.PDF	156607 8ca79138b956c52a91deaaf374c9d99bc412dd7b1	no	3
Warnings:					
Information:					
45	NPL Documents	PJ7765.PDF	4602602 5c0c0d0a981b28a505f4a88ad8fc677d35fb9b61	no	61
Warnings:					
Information:					
46	NPL Documents	PJ7781.PDF	230254 2ccd1f890ad563893edd16e735954b4b73b9192b	no	6

Warnings:					
Information:					
47	NPL Documents	PJ7794.PDF	3223885 5583514f8e150572f21e4b86908b4791b31887f5	no	37
Warnings:					
Information:					
48	NPL Documents	PJ7816.PDF	150561 8dc51a20dbe0ef0dab6dec7f00e3fee72f8c6948	no	6
Warnings:					
Information:					
49	NPL Documents	PJ7828.PDF	4959469 4f4c0c51d4bfada18c7b380f92cba204685ce7b6	no	58
Warnings:					
Information:					
50	NPL Documents	PJ7842.PDF	925157 4e88171a2b6766e6dd7296964e93b2e37c3269df	no	16
Warnings:					
Information:					
51	NPL Documents	PJ9211.PDF	1554798 945ac20e6d6b3610cb1aafd9123a2e32803b8e25	no	14
Warnings:					
Information:					
52	NPL Documents	PJ9210.PDF	841048 7654f9be9b81105f7d568aa25c6b9d91a91e8a	no	10
Warnings:					
Information:					
53	NPL Documents	PJ9202.PDF	163255 5bc63ac809124d17e3414ac7c5902aab97aa899b	no	2
Warnings:					
Information:					
54	NPL Documents	PJ9205.PDF	239152 6cf674b3ce93b00ed2c512d71a9e73edf0b0a1de	no	2
Warnings:					
Information:					
55	NPL Documents	PJ9203.PDF	807230 a17d66a41ae3f3b553d9d4d593a30c84674dc44a	no	17

Warnings:					
Information:					
56	NPL Documents	PJ9198.PDF	2243467 a1d96ce1a1cd2a590601c2e902c06ab00027192	no	8
Warnings:					
Information:					
57	NPL Documents	PJ9209.PDF	699187 510d5ec8081033997a1ea0fccb1d419179f1879	no	6
Warnings:					
Information:					
58	NPL Documents	MJ2488.PDF	271187 9254509a5c442d2cd7d3a92a0af52dec4b8d67c6	no	10
Warnings:					
Information:					
59	NPL Documents	NI3971.PDF	607899 5aa52842927c2ee7ca57b867c54ea1be73db0fe7	no	7
Warnings:					
Information:					
60	NPL Documents	PQ9291.PDF	76697 37bc803917775e04db414e5d2eb53b28c7610ef	no	3
Warnings:					
Information:					
Total Files Size (in bytes):			31440627		
<p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p>					

Electronic Acknowledgement Receipt

EFS ID:	10012605
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Lewis Carl Lee/Anna Goforth
Filer Authorized By:	Lewis Carl Lee
Attorney Docket Number:	I001-0002USC1
Receipt Date:	03-MAY-2011
Filing Date:	22-JUN-2010
Time Stamp:	17:20:53
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	NPL Documents	PR0059.PDF	142639 <small>801530f285133d7f56eb718be9db231b46569509</small>	no	3

Warnings:

Information:

2	NPL Documents	NU9245.PDF	818488	no	6
			5220ea4e3e43dc1dde06e4a6b7133079e8b8ba59		
Warnings:					
Information:					
3	NPL Documents	NU9274.PDF	409460	no	7
			496e0bcd53a949a38d54c751d6ef2c9f3505181		
Warnings:					
Information:					
4	NPL Documents	NU9554.PDF	1846013	no	5
			0dc0893c0b381676dafa84b4be12bdfcc70c8d59		
Warnings:					
Information:					
5	NPL Documents	OV9562.PDF	557227	no	13
			8a2fec9ea31e5ae786962a420838f9bc1c9dbd9d		
Warnings:					
Information:					
6	NPL Documents	NU9269.PDF	426499	no	6
			65140e05b03a2b896bee3183cd814aae53957e0a		
Warnings:					
Information:					
7	NPL Documents	NU9260.PDF	255375	no	5
			e8a9ce2cde24cd2fa77c7a9249632e61042422e7		
Warnings:					
Information:					
8	NPL Documents	NU9208.PDF	191198	no	2
			57382c738bc2bf10296787137a9a0fca3e82ef3a		
Warnings:					
Information:					
9	NPL Documents	PS5781.PDF	147920	no	3
			9cc705762e2457f76cc76c8c2932e26c82f33738		
Warnings:					
Information:					
10	NPL Documents	PS4787.PDF	384261	no	3
			d2f2bbad8d658c75d7bc7f782d256876a291fc0		
Warnings:					
Information:					

11	NPL Documents	KD6589.PDF	188129	no	9
			5dfbddab4bd904d4137c2e20bbe4c82bac a028a		
Warnings:					
Information:					
12	NPL Documents	OI8417.PDF	342110	no	11
			8d1fe14d22147f6308bf4afad2d77a6ca37df 8cd		
Warnings:					
Information:					
13	NPL Documents	PT3285.PDF	110728	no	3
			4231a6373f636407e4baf7ff540415b1755 eaaa		
Warnings:					
Information:					
14	NPL Documents	EPAugust18.pdf	106579	no	6
			75056a1b6125e7a8dfd3f48eca9ed624317 240b3		
Warnings:					
Information:					
Total Files Size (in bytes):			5926626		
<p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p>					

Electronic Acknowledgement Receipt

EFS ID:	10013036
Application Number:	12820866
International Application Number:	
Confirmation Number:	2913
Title of Invention:	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor/Applicant Name:	James S. Baldassarre
Customer Number:	49584
Filer:	Lewis Carl Lee/Anna Goforth
Filer Authorized By:	Lewis Carl Lee
Attorney Docket Number:	I001-0002USC1
Receipt Date:	03-MAY-2011
Filing Date:	22-JUN-2010
Time Stamp:	17:48:09
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	NPL Documents	clinical1.pdf	92093 <small>8a83b87a169ba76fb1546d04ed5d1915c8f b2382</small>	no	2

Warnings:

Information:

2	NPL Documents	clinical2.pdf	157560	no	3
			83db810270c7e4447f041e2adac6e974fca8fde		
Warnings:					
Information:					
3	NPL Documents	clinical3.pdf	188994	no	4
			25f8281700c23104a584e8d706e81f30495c835		
Warnings:					
Information:					
4	NPL Documents	clinical4.pdf	234663	no	4
			3eceb8080e7896f877f367903bb2e62010d85e4e		
Warnings:					
Information:					
5	NPL Documents	medinecinenet.pdf	223157	no	2
			3246d0f55b5631620b5d8634c540ecc9f3cd8fe6		
Warnings:					
Information:					
6	NPL Documents	fda.pdf	122803	no	17
			1a6f1ec5626919d1edf9c73e28bea3875931c9c		
Warnings:					
Information:					
7	NPL Documents	StudyofComparative.pdf	318637	no	5
			27dc3555af044a241d24e2e349f5ab33548243f8		
Warnings:					
Information:					
Total Files Size (in bytes):			1337907		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/820,866	06/22/2010	James S. Baldassarre	I001-0002USC1	2913
49584	7590	06/08/2011	EXAMINER	
LEE & HAYES, PLLC 601 W. RIVERSIDE AVENUE SUITE 1400 SPOKANE, WA 99201			ARNOLD, ERNST V	
			ART UNIT	PAPER NUMBER
			1613	
			NOTIFICATION DATE	DELIVERY MODE
			06/08/2011	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

lhpto@leehayes.com

Office Action Summary for Applications Under Accelerated Examination	Application No. 12/820,866	Applicant(s) BALDASSARRE ET AL.
	Examiner ERNST ARNOLD	Art Unit 1613
<p>-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address -- Since this application has been granted special status under the accelerated examination program, NO extensions of time under 37 CFR 1.136(a) will be permitted and a SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE:</p> <p>ONE MONTH OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION – if this is a non-final action or a <i>Quayle</i> action. (Examiner: For FINAL actions, please use PTOL-326.)</p> <p>The objective of the accelerated examination program is to complete the examination of an application within twelve months from the filing date of the application. Any reply must be filed electronically via EFS-Web so that the papers will be expeditiously processed and considered. If the reply is not filed electronically via EFS-Web, the final disposition of the application may occur later than twelve months from the filing of the application.</p> <p>Status</p> <p>1) <input checked="" type="checkbox"/> Responsive to communication(s) filed on <u>02 May 2011</u>.</p> <p>2) <input type="checkbox"/> Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under <i>Ex parte Quayle</i>, 1935 C.D. 11, 453 O.G. 213.</p> <p>Disposition of Claims</p> <p>3) <input checked="" type="checkbox"/> Claim(s) <u>20-27</u> is/are pending in the application. 3a) Of the above claim(s) _____ is/are withdrawn from consideration.</p> <p>4) <input type="checkbox"/> Claim(s) _____ is/are allowed.</p> <p>5) <input checked="" type="checkbox"/> Claim(s) <u>20-27</u> is/are rejected.</p> <p>6) <input type="checkbox"/> Claim(s) _____ is/are objected to.</p> <p>7) <input type="checkbox"/> Claim(s) _____ are subject to restriction and/or election requirement.</p> <p>Application Papers</p> <p>8) <input checked="" type="checkbox"/> The specification is objected to by the Examiner.</p> <p>9) <input type="checkbox"/> The drawing(s) filed on _____ is/are: a) <input type="checkbox"/> accepted or b) <input type="checkbox"/> objected to by the Examiner. Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a). Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).</p> <p>10) <input type="checkbox"/> The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.</p> <p>Priority under 35 U.S.C. § 119</p> <p>11) <input type="checkbox"/> Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f). a) <input type="checkbox"/> All b) <input type="checkbox"/> Some * c) <input type="checkbox"/> None of: 1. <input type="checkbox"/> Certified copies of the priority documents have been received. 2. <input type="checkbox"/> Certified copies of the priority documents have been received in Application No. _____. 3. <input type="checkbox"/> Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).</p> <ul style="list-style-type: none"> • See the attached detailed Office action for a list of the certified copies not received. 		
Attachment(s)		
1) <input type="checkbox"/> Notice of References Cited (PTO-892)	4) <input type="checkbox"/> Interview Summary (PTO-413) Paper No(s)/Mail Date. _____	
2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)	5) <input type="checkbox"/> Notice of Informal Patent Application	
3) <input checked="" type="checkbox"/> Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date <u>5/2/11; 5/3/11</u> .	6) <input type="checkbox"/> Other: _____	

DETAILED ACTION

A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after final rejection. Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, the finality of the previous Office action has been withdrawn pursuant to 37 CFR 1.114. Applicant's submission filed on 5/2/11 has been entered.

Claims 1-19 have been cancelled and claims 20-27 are new. Claims 20-27 are pending and under examination.

Information Disclosure Statement

The information disclosure statements (IDS) submitted on 5/2/11 and 5/3/11 were filed after the mailing date of the Office Action on 11/02/10. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner to the extent that English language translations, abstracts or relevance has been provided for foreign references. References without a date have not been considered and a line has been drawn through the reference.

Withdrawn rejections:

Applicant's amendments and arguments filed 5/2/11 are acknowledged and have been fully considered. Any rejection and/or objection not specifically addressed below is herein withdrawn. Since Applicant has cancelled all previously rejected claims, then all previous claim rejections have been rendered moot and are withdrawn.

The following rejections and/or objections are either reiterated or newly applied. They constitute the complete set of rejections and/or objections presently being applied to the instant application.

Specification

The disclosure is objected to because of the following informalities: The attempt to incorporate subject matter into the specification by reference to INOmax® is defective because the subject matter being incorporated into the claims must also be present in the specification. The same exact language is not present in the specification as used in the claims. See MPEP 608.01(p).

The incorporation by reference will not be effective until correction is made to comply with 37 CFR 1.57(b), (c), or (d). If the incorporated material is relied upon to meet any outstanding objection, rejection, or other requirement imposed by the Office, the correction must be made within any time period set by the Office for responding to the objection, rejection, or other requirement for the incorporation to be effective. Compliance will not be held in abeyance with respect to responding to the objection, rejection, or other requirement for the incorporation

to be effective. In no case may the correction be made later than the close of prosecution as defined in 37 CFR 1.114(b), or abandonment of the application, whichever occurs earlier.

Any correction inserting material by amendment that was previously incorporated by reference must be accompanied by a statement that the material being inserted is the material incorporated by reference and the amendment contains no new matter. 37 CFR 1.57(f).

Appropriate correction is required.

Claim Rejections - 35 USC § 112

The following is a quotation of the first paragraph of 35 U.S.C. 112:

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

Claim 24 is rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention. Claim 24 introduces new matter as the claim recites the limitation: "a pressurized cylinder containing nitric oxide and one or more inert gases" There is no support in the specification for this limitation. The limitation of: " a pressurized cylinder containing nitric oxide and one or more inert gases" was not described in the specification as filed, and person skilled in the art would not recognize in the applicant's disclosure a description of the invention as presently claimed. The specification discloses "a gaseous blend of NO and nitrogen...cylinders as a compressed gas

under high pressure” [0021] but does not describe the instantly claimed limitation. There is no guidance in the specification to select “a pressurized cylinder containing nitric oxide and one or more inert gases” which is broader in scope and represents a new concept. From MPEP 2163.06: “Applicant should therefore specifically point out the support for any amendments made to the disclosure.” Applicant has not directed the Examiner to the support in the specification for the amendments. Therefore, it is the Examiner’s position that the disclosure does not reasonably convey that the inventor had possession of the subject matter of the amendment at the time of filing of the instant application.

Claim Rejections - 35 USC § 112

The following is a quotation of the second paragraph of 35 U.S.C. 112:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claims 25-27 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Claims 25 and 27 recite “children” but the method is drawn to "term or near-term neonates" which is a different patient population. While Applicant defines "children" to include those being around 4 weeks to 18 years of age [0023], the claim is internally inconsistent as a 'term or near-term neonate' does not embrace up to 18 years of age. This is especially problematic when the second risk factor is based on children, which can include 18 year olds, and not term or near-term neonates. Claim 26 is rejected as indefinite because it is based on an indefinite base claim. The claims will be examined as they read on term or near term neonates.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

Claims 20-27 are rejected under 35 U.S.C. 103(a) as being unpatentable over Atz et al. (Seminars in Perinatology 1997, 21(5), pp 441-455) and Kinsella et al. (The Lancet 1999, 354, 1061-1065) and Loh et al. (Circulation 1994, 90, 2780-2785).

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Applicants claims, for example:

20. (New) A method of reducing the risk of the occurrence, in a neonate or near-term neonate patient, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide, said method comprising:

- (a) identifying a patient in need of inhaled nitric oxide treatment;
- (b) identifying if said patient has a first condition, said first condition being where the patient is known to be dependent on right-to-left shunting of blood;
- (c) further identifying if said patient has a second condition, said second condition being pre-existing left ventricular dysfunction, independent and separate from whether said patient is dependent on right-to-left shunting of blood; and
- (d) administering said inhaled nitric oxide treatment to said patient if said patient does not have the first condition or the second condition.

Determination of the scope and content of the prior art

(MPEP 2141.01)

Atz et al. teach methods using inhaled nitric oxide in the **neonate** with cardiac disease, hence an **identified patient** in need of nitric oxide treatment, (title and Abstract) which intrinsically provides pharmaceutically acceptable NO gas for inhalation to a medical provider to provide to the patient. Atz et al. warn that sudden pulmonary vasodilation may produce **pulmonary edema** (page 452, left column). Atz et al. teach that: “Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension.” (page 452, left column). Since pulmonary hypertension is instantly claimed, then the subject intrinsically has hypoxic respiratory failure. Atz et al. continues with: “Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale and exclusively *right to left shunting* at the ductus arteriosus, *NO should be used with extreme caution, if at all.* We and others have reported *adverse outcomes* in this

circumstance.” (page 452, left column) (Examiner added emphasis). Artz et al. thus identify conditions in the patients which is screening of the patient. Thus, Atz et al. fairly teaches excluding patients which include neonates with left ventricular dysfunction from inhaled NO treatment because the Examiner interprets “if at all” to mean no treatment and hence exclusion from treatment. The left ventricular dysfunction is intrinsically pre-existing.

To summarize, the methods disclosed by Atz et al. are interpreted to mean:

- identifying a patient eligible for NO treatment;
- diagnosing/identifying if the patient has left ventricular dysfunction;
- excluding that patient with left ventricular dysfunction from treatment with NO but treating the patient with NO for other conditions discussed by Atz et al. with inhalation of NO thereby reducing the risk of adverse events associated with the medical treatment.

Atz et al. teach neonates with pulmonary hypertension (Abstract and page 442, left column to right column) and it is irrelevant to the Examiner as to how the pulmonary hypertension was diagnosed whether by echocardiographic evidence or clinical evidence. The fact that matters is that the hypertension is diagnosed in the patient population.

Kinsella et al. teach excluding patients (premature neonates) from inhaled nitric oxide treatment if they have fatal congenital anomalies or congenital heart disease (Abstract and page 1062, Methods). Since left ventricular dysfunction is a congenital heart disease, as acknowledged by Applicant, (see specification [0028]), and it would be pre-existing, then the methods of Kinsella et al. intrinsically exclude this patient population from the method. The patients also had pulmonary hypertension which would be associated with the cardiac function (Abstract). Thus,

one or more adverse events are reduced in the neonates excluded from the method. The neonate must breathe oxygen to survive. Furthermore, if the patients are already excluded then any further limitations on the treatment are truly irrelevant. The intended patient population is intrinsically at risk of one or more adverse events. Patients are intrinsically identified for nitric oxide inhalation treatment, diagnosed for congenital heart disease which intrinsically includes left ventricular dysfunction, and if the patient meets the criteria than treatment with NO is performed thereby reducing the risk of adverse events associated with the treatment. The neonate must breathe oxygen to survive.

Loh et al. teach that inhaled nitric oxide in patients with left ventricular dysfunction may have adverse effects in patients with LV failure (Title and Abstract). Loh et al. clearly teaches that patients with pulmonary artery wedge pressure, which is synonymous with the instantly claimed pulmonary capillary wedge pressure, ***of greater than or equal to 18 mm Hg*** had a greater effect of inhaled NO due to the greater degree of reactive pulmonary hypertension present in such patients (page 2784, left column). Loh et al. state: "*Since the degree of reactive pulmonary hypertension is generally related to the severity of hemodynamic compromise in patients with LV failure, it might be anticipated that patients with more severe heart failure will have a more marked hemodynamic response to inhaled NO.*" Loh et al. examined this prediction further and verified it (page 2784, left column).

Ascertainment of the difference between the prior art and the claims

(MPEP 2141.02)

1. The difference between the instant application and Atz et al. is that Atz et al. do not expressly teach identifying patients with a second condition/risk factor and administering iNO to patients that do not have the first or second condition/risk factors of instant claims 20-27 and inform the medical provider that patients with a pulmonary capillary wedge pressure greater than 20 mm Hg that may increase pulmonary edema. This deficiency in Atz et al. is cured by the teachings of Kinsella et al. and Loh et al.

Finding of prima facie obviousness

Rational and Motivation (MPEP 2142-2143)

1. It would have been obvious to one of ordinary skill in the art at the time the claimed invention was made to perform the method of Atz et al. and identify patients with a second condition/risk factor and administer iNO to patients that do not have the first or second condition/risk factors of instant claims 20-27 and inform the medical provider that patients with a pulmonary capillary wedge pressure greater than 20 mm Hg that may increase pulmonary edema, as suggested by Loh et al., and Kinsella et al., and produce the instant invention.

One of ordinary skill in the art would have been motivated to do this because: 1) it is common sense that if the neonate is healthy then iNO therapy can be performed safely; 2) if the neonate is not healthy and has left ventricular dysfunction (LVD), then Atz et al. clearly teach using extreme caution or not using NO at all in the treatment of patients with LVD which would also render obvious all conditions/risk factors associated with LVD; and 3) the art of Kinsella et al. establishes excluding certain patients (premature neonates) from inhaled nitric oxide

treatment if they have fatal congenital anomalies or congenital heart disease. Thus it is no stretch of the imagination to exclude patients with LVD, with right to left shunting of the blood or with or without the myriad number of other conditions/risk factors independent and separate from the first risk factor, such as in instant claim 26, characterized by various medical parameters claimed by Applicant from inhaled nitric oxide therapy in order to avoid adverse outcomes as taught by Atz et al. which intrinsically include all the adverse events recited by Applicant including pulmonary edema as discussed above. The ordinary artisan would err on the side of caution for the benefit of the patient.

Furthermore, it is already known through the teachings of Loh et al. that a pulmonary capillary wedge pressure (PCWP) of greater than 18 mm Hg serves as a guidepost for alerting the artisan to adverse events from inhaled NO. Thus, it is not inventive to exclude patients with a PCWP of greater than 20 mm Hg when the art already suggests the risk of trouble of treating patients with a PCWP of 18 mm Hg because inhaled NO increases the wedge pressure as taught by Loh et al. (see entire document).

In summary, it remains the position of the Examiner, which is in alignment with the written opinion of the international search authority, that it is simply not inventive to 'inform' a medical provider that a neonate with LVD is at risk of adverse/serious adverse events from iNO therapy when the art already has established that fact and the ordinary artisan is alerted to this fact. *If the patient has LVD then they are at risk of adverse and/or serious adverse events from iNO therapy and it is not inventive to further identify other secondary conditions/risk factors associated with LVD and provide further warnings for secondary conditions/risk factors that are separate and independent from the first condition/risk factor but nevertheless associated with*

LVD to the medical provider. Screening for conditions that predispose the patient to adverse/serious adverse effects from medical treatment of iNO is obvious given the teachings above. Respectfully, the instantly claimed method steps are in the realm of common sense and not in the realm of invention because it is already known in the art that patients with pre-existing LVD are at risk of adverse effects from iNO. It is obvious to the ordinary artisan that if the neonate has LVD with or without any number of conditions/risk factors, then in order to avoid the risk of adverse or serious adverse events associated with iNO, to then exclude the neonate from iNO therapy. In other words, given the art as a whole, determination of further conditions/risk factors that would exclude the neonate from iNO therapy is obvious given the teachings in the art as discussed above which direct the artisan to screen neonates about to undergo treatment with NO by inhalation and to exclude those with LVD from such treatment.

In light of the forgoing discussion, the Examiner concludes that the subject matter defined by the instant claims would have been obvious within the meaning of 35 USC 103(a).

From the teachings of the references, it is apparent that one of ordinary skill in the art would have had a reasonable expectation of success in producing the claimed invention. Therefore, the invention as a whole was *prima facie* obvious to one of ordinary skill in the art at the time the invention was made, as evidenced by the references, especially in the absence of evidence to the contrary.

Response to Arguments:

The Examiner has considered Applicants arguments as they pertain to the previous rejections of record. This is a new rejection of record and arguments directed to the previous rejections of record are now moot since those rejections have been rendered moot by the

cancellation of all previously pending claims and introduction of all new claims. As to Atz, the Examiner cannot agree with Applicant that Atz is directed to adults as Atz clearly discusses neonates as well. Furthermore, Atz clearly discusses a right to left shunting of blood which is the same limitation instantly claimed. As to Kinsella, the Examiner is not relying on Kinsella for teaching iNO in non-adult patients having pre-existing LVD as discussed above. As to Loh, the Examiner is not relying on Loh for teaching administration of iNO in children but rather the correlation between PCWP and iNO. As to the INOT22 study, the exclusion criteria was amended to exclude subjects with pre-existing LVD, subjects with a baseline PCWP>20 mm Hg (pages 19-20 of 27 in Remarks), which is in accordance with the knowledge in the art as discussed above. The expected result is a decreased rate of serious adverse events by excluding such patients which is simply common sense.

Applicant asserts that it requires extraordinary skill to recognize the risk of adverse or serious adverse events associated with the use of iNO in study subjects with pre-existing LVD. Respectfully, the Examiner cannot agree because there is clear and convincing evidence of increased risk of adverse or serious adverse events associated with the use of iNO in study subjects with pre-existing LVD as discussed in the rejection above.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the “right to exclude” granted by a patent and to prevent possible

harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

1. Claims 20-27 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 21-28 of copending Application No. 12/820980. Although the conflicting claims are not identical, they are not patentably distinct from each other because the instant subject matter embraces or is embraced by the subject matter of the copending subject matter. Both applications are drawn to methods of reducing one or more

adverse events in a patient population by excluding from treatment anyone with pre-existing left ventricular dysfunction.

The copending application does not expressly teach near-term neonates or neonates.

However the copending broadly teaches children patient population which would include neonates and near-term neonates as clearly neonates are children. The instant specification defines 'children' as being 4 weeks old [0023] which would include newborn and hence neonatal.

Therefore one of ordinary skill in the art would have recognized the obvious variation of the instant application over the copending application.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

2. Claims 20-27 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 21-30 of copending Application No. 12/821020. Although the conflicting claims are not identical, they are not patentably distinct from each other because the instant subject matter embraces or is embraced by the subject matter of the copending subject matter. Both applications are drawn to methods of reducing one or more adverse events in a patient population by excluding from treatment anyone with pre-existing left ventricular dysfunction.

The copending application does not expressly teach the intended population as having one or more conditions.

However the copending application is drawn to the same patient population which intrinsically has one or more conditions/risk factors as instantly claimed.

Therefore one of ordinary skill in the art would have recognized the obvious variation of the instant application over the copending application.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

3. Claims 20-27 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 21-29 and 37 of copending Application No. 12/821041. Although the conflicting claims are not identical, they are not patentably distinct from each other because the instant subject matter embraces or is embraced by the subject matter of the copending subject matter. Both applications are drawn to methods of reducing one or more adverse events in a patient population by excluding from treatment anyone with pre-existing left ventricular dysfunction.

The copending application does not expressly teach the intended population as having one or more conditions.

However the copending application is drawn to the same patient population which intrinsically has one or more conditions/risk factors as instantly claimed.

Therefore one of ordinary skill in the art would have recognized the obvious variation of the instant application over the copending application.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

Conclusion

No claims are allowed.

Applicant is reminded that for any amendments to the claims (including any new claim) that is not encompassed by the preexamination search and accelerated examination support documents previously filed, applicant is required to provide updated preexamination search and accelerated examination support documents that encompass the amended or new claims at the time of filing the amendment. Failure to provide such updated preexamination search and accelerated examination support documents at the time of filing the amendment will cause the amendment to be treated as not fully responsive and not to be entered. See MPEP § 708.02(a) subsection VIII.D. for more information.

If the reply is not fully responsive, the final disposition of the application may occur later than twelve months from the filing of the application.

Any reply or other papers must be filed electronically via EFS-Web so that the papers will be expeditiously processed and considered. If the papers are not filed electronically via EFS-Web, the final disposition of the application may occur later than twelve months from the filing of the application.

Any reply to this communication filed via EFS-Web must include a document that is filed using the document description of "Accelerated Exam - Transmittal amendment/reply."

Applicant is reminded to use proper indexing for documents to avoid any delay in processing of follow on papers. Currently document indexing is not automated in EFS-Web and applicant must select a particular document description for each attached file. An incorrect document description for a particular file may potentially delay processing of the application. A complete

listing of all document codes currently supported in EFS-Web is available at http://www.uspto.gov/ebc/portal/efs/efswweb_document_descriptions.xls.

Any payment of fees via EFS-Web must be accompanied by selection of a proper fee code. An improper fee code may potentially delay processing of the application. Instructions on payment of fees via EFS-Web are available at <http://www.uspto.gov/ebc/portal/efs/quick-start.pdf>.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to ERNST V. ARNOLD whose telephone number is (571)272-8509. The examiner can normally be reached on M-F 7:15-4:45.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Brian Kwon can be reached on 571-272-0581. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Ernst V Arnold/
Primary Examiner, Art Unit 1613

Application/Control Number: 12/820,866
Art Unit: 1613

Page 19

EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	0	"20100330206".pn. and (pressure or pressurized) and inert and hypoxic	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:10
L2	0	"20100330206".pn. and cylinder and inert and hypoxic	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:10
L3	0	"20100330206".pn. and inert and hypoxic	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:11
L4	0	"20100330206".pn. and inert	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:11
L5	1	"20100330206".pn.	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:11
L6	0	"20100330206".pn. and inert	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:11
L7	1	"20100330206".pn. and nitrogen	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:11
L8	1	"20100330206".pn. and (failure or hypoxic or echocardiographic or hypertension)	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 19:39
L9	1	"20100330206".pn. and (child or childre)	US-PGPUB; USPAT; USOCR	OR	OFF	2011/06/01 20:07

6/ 1/ 2011 8:56:55 PM

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866	
	Filing Date		2010-06-22	
	First Named Inventor	James S. Baldassarre		
	Art Unit	1613		
	Examiner Name	Arnold, Ernst V.		
	Attorney Docket Number	I001-0002USC1		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ^{2 i}	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866
	Filing Date		2010-06-22
	First Named Inventor	James S. Baldassarre	
	Art Unit	1613	
	Examiner Name	Arnold, Ernst V.	
	Attorney Docket Number	I001-0002USC1	

/E.A./	1	Delivery of Inhaled Nitric Oxide Therapy through an Adult or Pediatric Nasal Cannula, Reference: UTMB RESPIRATORY CARE SERVICES Reviewed: 05/31/05	<input type="checkbox"/>
/E.A./	2	Ichinose, et al., Inhaled Nitric Oxide - A Selective Pulmonary Vasodilator: Current Uses and Therapeutic Potential, Circulation. 2004;109:3106-3111.	<input type="checkbox"/>
/E.A./	3	Konduri, et al., A Randomized Trial of Early Versus Standard Inhaled Nitric Oxide Therapy in Term and Near-Term Newborn Infants with Hypoxic Respiratory Failure, PEDIATRICS Vol. 113 No. 3 March 2004, pp. 559-564	<input type="checkbox"/>
/E.A./	4	Fraisse, et al., Doppler echocardiographic predictors of outcome in newborns with persistent pulmonary hypertension, Cardiol Young. 2004 Jun;14(3):277-83.	<input type="checkbox"/>
/E.A./	5	Malloy, Nitric Oxide Weaning, RT: For Decision Makers in Respiratory Care, December 2000, 2 pages.	<input type="checkbox"/>
/E.A./	6	Rosenberg, Inhaled nitric oxide in the premature infant with severe hypoxemic respiratory failure: A time for caution, The Journal of Pediatrics, Volume 133, Issue 6 , Pages 720-722, December 1998	<input type="checkbox"/>
/E.A./	7	Soto, et al., Cardiopulmonary Hemodynamics in Pulmonary Hypertension: Pressure Tracings, Waveforms, and More, Advances in Pulmonary Hypertension Winter 2008;7(4)386-393.	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Ernst Arnold/	Date Considered	06/01/2011
--------------------	----------------	-----------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12820866	
	Filing Date		2010-06-22	
	First Named Inventor	James S. Baldassarre		
	Art Unit	1613		
	Examiner Name	Ernst V. Arnold		
	Attorney Docket Number	I001-0002USC1		

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							<input type="checkbox"/>

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

1	Ameduri, et al., Heart Failure in Children, MED-Continuing Medical Education, University of Minnesota. 2009 July 29 (cited 2010 Nov 12); available from URL: http://www.cme.umn.edu/prod/groups/med/@pub/@med/@cme/documents/content/med_content_124593.pdf	<input type="checkbox"/>
2	AU 2009202685 Office Action dated 06/17/10 (3 pages)	<input type="checkbox"/>
3	AU 2009202685 Office Action Response dated 07/29/2010, 19 pages	<input type="checkbox"/>
4	Bates, Inhaled Nitric Oxide: A Selective Pulmonary Vasodilator,	<input type="checkbox"/>
5	Behera, et al., Nesiritide Improves Hemodynamics in Children with Dilated Cardiomyopathy: A Pilot Study, <i>Pediatr Cardiol</i> (2009) 30:26-34	<input type="checkbox"/>
6	Bhagavan, et al., Potential role of ubiquinone (coenzyme Q10) in pediatric cardiomyopathy, <i>Clinical Nutrition</i> (2005) 24, 331-338, pp. 331-338	<input type="checkbox"/>
7	Branson, Inhaled Nitric Oxide in Adults, <i>The Science Journal of the American Association for Respiratory Care</i> 1997 Open Forum Abstracts, December 7, 1997, 2 pages, retrieved at << http://www.rcjournal.com/abstracts/1997/?id=A00000929 >> on 12/22/2010	<input type="checkbox"/>
8	Braunwald, Heart Failure, chapter 233 of <i>Harrison's Principles of Internal Medicine</i> , 14th Edition, 1998, pp. 1287-1291 & 1360	<input type="checkbox"/>
9	Bublik, et al., Pediatric cardiomyopathy as a chronic disease: A perspective on comprehensive care programs, <i>Progress in Pediatric Cardiology</i> 25 (2008) 103-111	<input type="checkbox"/>
10	Clark, et al., Low-Dose Nitric Oxide Therapy for Persistent Pulmonary Hypertension of the Newborn, <i>New England Journal of Medicine</i> , Vol 342, No 7, pp. 469-474	<input type="checkbox"/>
11	Comparison of Supplemental Oxygen and Nitric Oxide for Inhalation in the Evaluation of the Reactivity of the Pulmonary Vasculature During Acute Pulmonary Vasodilator Testing, http://clinicaltrials.gov/archive/NCT00626028/2009_01_12 January 12, 2009	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

12	Cox, et al., Factors Associated With Establishing a Causal Diagnosis for Children With Cardiology, Pediatrics, Vol 118, No 4, October 4, 2006, pp 1519-1531, published online October 2, 2006	<input type="checkbox"/>
13	Cox, et al., Factors Associated with Establishing a Causal Diagnosis for Children with Cardiomyopathy, Pediatrics Vol 118, No 4, October 2006, pp 1519-1531	<input type="checkbox"/>
14	Cuthbertson et al., "UK guidelines for the use of inhaled nitric oxide therapy in adults ICUs", Intensive Care Med (1997), 23, Springer-Verlag, 1997, pp#1212-pp#1218	<input type="checkbox"/>
15	Dermatological Cryosurgery in Primary Care with Dimethyl Ether Propane Spray in Comparison with Liquid Nitrogen, Martinez, et al., Atencion Primaria, Vol. 18, No. 5, (211, 216), September 30, 1996	<input type="checkbox"/>
16	Ivy, et al., "Dipyridamole attenuates rebound pulmonary hypertension after inhaled nitric oxide withdrawal in postoperative congenital heart disease", J Thorac Cardiovasc Surg 1998; 115:875-882.	<input type="checkbox"/>
17	Dronedarone is Less Effective, But Safer Than Amiodarone in Atrial Fibrillation, October 27, 2009, p. 3, << http://www.npci.org.uk/blog/?p=778 >>	<input type="checkbox"/>
18	Early Inhaled Nitric Oxide Therapy in Term and Near Term Infants with Respiratory Failure, from ClinicalTrials.gov archive, NCT00005773, 06/23/2005	<input type="checkbox"/>
19	Ehrenkranz RA, "Inhaled Nitric Oxide in Full-Term and Nearly Full-Term Infants with Hypoxic Respiratory Failure", The Neonatal Inhaled Nitric Oxide Study Group, N Engl J Med, 1997, Vol. 336, No. 9, pp. 597-605.	<input type="checkbox"/>
20	Elbl, et al., Long-term serial echocardiographic examination of late anthracycline cardiotoxicity and its prevention by dexrazoxane in paediatric patients, Eur J Pediatr (2005) 164: 678-684	<input type="checkbox"/>
21	The Encarta Webster's Dictionary of the English Language (2004) is the second edition of the Encarta World Dictionary, published 1999, << http://encarta.msn.com/encnet/features/dictionary/dictionaryhome.aspx >>; used to look up the definitions of "precaution" and "exclusion"	<input type="checkbox"/>
22	EP 09251949 Office Action dated 10/11/2010, 5 pages	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

23	Guideline for Industry; Clinical Safety Data Management: Definitions and Standards for Expedited Reporting, March 1995, 17 pages	<input type="checkbox"/>
24	Harrison's Principles of Internal Medicine, Fauci, et al., p. 1287-1291 and 1360, 12th edition, McGraw Hill, 1998.	<input type="checkbox"/>
25	Headrick, Hemodynamic monitoring of the critically ill neonate, J Perinat Neonatal Nurs 1992; 5(4): 58-67	<input type="checkbox"/>
26	Huddleston, Indications for heart transplantation in children, Progress in Pediatric Cardiology 26 (2009) 3-9	<input type="checkbox"/>
27	Inhaled Nitric Oxide by Oxygen Hood in Neonates, from ClinicalTrials.gov, NCT00732537, 08/08/2008	<input type="checkbox"/>
28	Inhaled Nitric Oxide in Neonates with Elevated A-a DO ₂ Gradients Not Requiring Mechanical Ventilation, from ClinicalTrials.gov archive, NCT00041548, 06/23/2005, 2 pages	<input type="checkbox"/>
29	INO Therapeutics, LLC, "INOflo for Inhalation 800ppm", package leaflet, 2010, 2	<input type="checkbox"/>
30	James, et al., Treatment of heart failure in children, Current Paediatrics (2005) 15, 539-548	<input type="checkbox"/>
31	JP 2009157623 Office Action dated 02/23/2010, 3 pages	<input type="checkbox"/>
32	JP 2009157623 Office Action dated 07/30/2010, 6 pages	<input type="checkbox"/>
33	JP 2009157623 Office Action response filed 06/18/2010, 37 pages (no translation)	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

34	JP 2009157623 request for accelerated exam filed 01/15/2010 (60 pages)	<input type="checkbox"/>
35	JP 2009157623 response filed 11/30/2010, 58 pages	<input type="checkbox"/>
36	JP 2009-157623 Office Action dated 02/15/2011, 3 pages	<input type="checkbox"/>
37	Lavigne, et al., Cardiovascular Outcomes of Pediatric Seroreverters Perinatally Exposed to HAART, Cardiovascular Toxicology (2004) 04 187-197	<input type="checkbox"/>
38	Letter of Acceptance for AU 2010202422, dated 10/7/2010	<input type="checkbox"/>
39	Letter of acceptance of AU application 2009202685, dated 08/10/2010, 3 pages	<input type="checkbox"/>
40	Lipschultz, The effect of dexrazoxane on myocardial injury in doxorubicin-treated children with acute lymphoblastic leukemia, New England Journal of Medicine 2004; 351:145-153.	<input type="checkbox"/>
41	Lipschultz, The incidence of pediatric cardiomyopathy in two regions of the United States, New England Journal of Medicine, April 24, 2003. << http://www.nejm.org/doi/full/10.1056/NEJMoa021715 >>	<input type="checkbox"/>
42	Lipshultz, et al., Cardiovascular status of infants and children of women infected with HIV-1 (P2C2 HIV): a cohort study, The Lancet, Vol 360, August 3, 2002, pp. 368-373.	<input type="checkbox"/>
43	Lipshultz, et al., Cardiovascular Trials in Long-Term Survivors of Childhood Cancer, Journal of Clinical Oncology, Vol 22, Number 5, March 1, 2004, pp. 769-773.	<input type="checkbox"/>
44	Lipshultz, Chronic Progressive Cardiac Dysfunction Years After Doxorubicin Therapy for Childhood Acute Lymphoblastic Leukemia, Journal of Clinical Oncology, Vol 23, No 12, April 20, 2005. 8 pages.	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

45	Lipshultz, Clinical research directions in pediatric cardiology, Current Opinion in Pediatrics 2009, 21:585-593	<input type="checkbox"/>
46	Lipshultz, Establishing norms for echocardiographic measurement of cardiovascular structures and function in children, J Appl Physiol 99: 386-388, 2005	<input type="checkbox"/>
47	Lipshultz, Frequency of clinically unsuspected myocardial injury at a children's hospital, American Heart Journal, Vol 151, No 4, pp 916-922	<input type="checkbox"/>
48	Lipshultz, et al., Long-Term Enalapril Therapy for Left Ventricular Dysfunction in Doxorubicin-Treated Survivors of Childhood Cancer, Journal of Clinical Oncology, Vol 20, No 23 (December 1), 2002; pp 4517-4522	<input type="checkbox"/>
49	Madriago, Heart Failure in Infants and Children, Pediatrics in Review, 2010; 31:4-12	<input type="checkbox"/>
50	http://www.medterms.com/script/main/art.asp?articlekey=17824	<input type="checkbox"/>
51	Miller, et al., Nutrition in Pediatric Cardiomyopathy, Prog Pediatr Cardiol, 2007 November; 24(1): 59-71	<input type="checkbox"/>
52	Mone, Effects of Environmental Exposures on the Cardiovascular System: Prenatal Period Through Adolescence, Pediatrics Vol 113, No 4, April 2004, pp 1058-1069	<input type="checkbox"/>
53	Murray, Angiotensin Converting Enzyme Inhibitory Peptides Derived from Food Proteins: Biochemistry, Bioactivity and Production,	<input type="checkbox"/>
54	NIH Clinical Center Services, retrieved at < http://www.cc.nih.gov/ccmd/clinical_services.html > on 08/18/2010	<input type="checkbox"/>
55	NIH Clinical Center, Department Policy and Procedure Manual for the Critical Care Therapy and Respiratory Care Section; Nitric Oxide Therapy, 2000, sections 3.1-3.1.2 & 5.2.3	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

56	Notification of Reason for Rejection, mailed 7/30/2010, from Japanese Patent Application No. 2009-157623 (cites foreign references).	<input type="checkbox"/>
57	Office Action for AU 2010202422 dated 07/09/2010, 3 pages	<input type="checkbox"/>
58	Office Action from AU 2009202685 dtd 03/15/2010	<input type="checkbox"/>
59	Office Action from AU 2010206032 dated 08/16/2010 (3 pages)	<input type="checkbox"/>
60	Office Action Response for AU 2009202685 to 03/15/2010 OA, filed 06/08/2010 (16 pages)	<input type="checkbox"/>
61	Office Action Response for JP2007157623 filed on 11/12/2009 (no English translation)	<input type="checkbox"/>
62	Office Action Response to AU 2010202422 OA dated 07/09/2010, response filed 09/01/2010	<input type="checkbox"/>
63	Translated copy of the Japanese Office Action mailed February 15, 2011 for Japanese Patent Application No. 2009-157623, a counterpart foreign application for US Patent Application No. 12/494,598	<input type="checkbox"/>
64	Pazopanib Plus Lapatinib Compared to Lapatinib Alone in Subjects With Inflammatory Breast Cancer, April 22, 2010, p. 4, ClinicalTrials.gov, << http://clinicaltrials.gov/ct2/show/NCT00558103 >>	<input type="checkbox"/>
65	PCT/US2010/038652 Search Report dated 07/29/2010, 16 pages	<input type="checkbox"/>
66	Ratnasamy, et al., Associations between neurohormonal and inflammatory activation and heart failure in children, American Heart Journal, March 2008, pp. 527-533	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	1001-0002USC1

67	Response filed 08/18/2010 to EP Search Report dated 05/10/10 for EP09251949	<input type="checkbox"/>
68	NIH Clinical Center 2 Critical Care Medicine Department Sample Rotations, Updated January 2007<< http://www.cc.nih.gov/ccmd/prof_opps/rotation.html >>	<input type="checkbox"/>
69	Search Report from EP 09251949 dated 05/10/10	<input type="checkbox"/>
70	Sibutramine-metformin Combination vs. Sibutramine and Metformin Monotherapy in Obese Patients, July 15, 2009, p. 3, ClinicalTrials.gov, << http://clinicaltrials.gov/ct2/showNCT00941382 >>	<input type="checkbox"/>
71	Somarriba, et al., Exercise rehabilitation in pediatric cardiomyopathy, Progress in Pediatric Cardiology 25 (2008) 91-102	<input type="checkbox"/>
72	Strauss, et al., Pediatric Cardiomyopathy - A Long Way to Go, The New England Journal of Medicine, 348; 17, April 24, 2003, pp. 1703-1705	<input type="checkbox"/>
73	Study of Comparative Effects of Oral Clonidine vs. Oral Diazepam Pre-Medication on the Extent and Duration of Sensory Blockade in Patients Undergoing Vaginal Hysterectomy Under Spinal Anaesthesia, Toshniwal, et al., Interenet Journal of Anesthesiology, 2009, << http://www.britannica.com/bps/additionalcontent/18/41575551/Study-of-Comparative-Effects-Oral-Clonidine-vs-Oral-Diazepam-Pre-Medication-on-the-Extent-and-Duration-of-Sensory-Blockade-in-Patients-Undergoing-Vaginal-Hysterectomy-Under-Spinal-Anaesthesia >>	<input type="checkbox"/>
74	The Effects of Nitric Oxide for Inhalation on the Development of Chronic Lung Disease in Pre-Term Infants, from ClinicalTrials.gov archive, NCT00551642, 10/30/2007, 3 pages	<input type="checkbox"/>
75	Towbin, et al., Incidence, Causes, and Outcomes of Dilated Cardiomyopathy in Children, JAMA, October 18, 2006 - Vol 296, No. 15, pp. 1867-1876	<input type="checkbox"/>
76	van Dalen, Treatment for Asymptomatic Anthracycline-Induced Cardiac Dysfunction in Childhood Cancer Survivors: The Need for Evidence, Journal of Clinical Oncology, Vol 21, No 17, (September 11) 2003, pp. 3375-3379	<input type="checkbox"/>
77	Wilkinson, et al., Epidemiological and outcomes research in children with pediatric cardiomyopathy; discussions from the international workshop on primary and idiopathic cardiomyopathies in children, Progress in Pediatric Cardiology 25 (2008) 23-25	<input type="checkbox"/>

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12820866
	Filing Date	2010-06-22
	First Named Inventor	James S. Baldassarre
	Art Unit	1613
	Examiner Name	Ernst V. Arnold
	Attorney Docket Number	I001-0002USC1

78	http://www.cc.nih.gov/ccmd/clinical_services.html	<input type="checkbox"/>
79	www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm073087.pdf	<input type="checkbox"/>
80	Federal Regulations 21 CFR Part 312, <<http://www.gcrf.uci.edu/sa/aer.cfm>>	<input type="checkbox"/>
81	Yoshida, Kiyoshi, " Well-illustrated Diagnostics and Treatment of Heart Failure" Professor of Kawasaki Medical University, cardiovascular internal medicine CIRCULATION Up-to-Date Vol. 2, No. 4, 2007(343), pp. 23-28	<input type="checkbox"/>

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Ernst Arnold/	Date Considered	06/01/2011
--------------------	----------------	-----------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A./

Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	June 22, 2010
Title of Application	Methods of Treating Term and Near-Term Neonates Having Hypoxic Respiratory Failure Associated with Clinical or Echocardiographic Evidence of Pulmonary Hypertension
First Named Inventor	James S. Baldassarre
Assignee	Ikaria, Inc.
Group Art Unit	1616
Examiner	Arnold, Ernst V.
Attorney Docket Number	I001-0002USC1

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT IN REPLY TO ACTION OF JUNE 8, 2011

Please amend the above-identified application as follows:

CERTIFICATE OF MAILING BY EFS-WEB FILING

I hereby certify that this paper was filed with the Patent and Trademark Office using the EFS-WEB system on this date:

Applicant : James S. Baldassarre et al.
Serial No. : 12/820,866
Filed : June 22, 2010
Page : 2 of 23

Attorney's Docket No.: I001-0002USC1

Amendments to the Specification:

Replace paragraph [0020] with the following amended paragraph:

[0020] INOmax® (nitric oxide) for inhalation was approved for sale in the United States by the U.S. Food and Drug Administration (“FDA”) in 1999. Nitric oxide, the active substance in INOmax®, is a selective pulmonary vasodilator that increases the partial pressure of arterial oxygen (PaO₂) by dilating pulmonary vessels in better ventilated areas of the lung, redistributing pulmonary blood flow away from the lung regions with low ventilation/perfusion (V/Q) ratios toward regions with normal ratios. INOmax® significantly improves oxygenation, reduces the need for extracorporeal oxygenation and is indicated to be used in conjunction with ventilatory support and other appropriate agents. The current FDA-approved prescribing information for INOmax® is incorporated herein by reference in its entirety. Section 4 of the prescribing information, Contraindications, states that INOmax® is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood.

Amendments to the Claims

This listing of claims replaces all prior versions and listings of claims in the application.

Listing of Claims:

1-27. (Canceled)

28. (New) A method of reducing the risk of occurrence, in a term or near-term neonate patient, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide gas, said method comprising:

- (a) identifying a term or near-term neonate patient in need of inhaled nitric oxide treatment, wherein the patient is not known to be dependent on right-to-left shunting of blood;
- (b) determining that the patient identified in (a) has pre-existing left ventricular dysfunction; and
- (c) excluding the patient from inhaled nitric oxide treatment based on the determination that the patient has pre-existing left ventricular dysfunction.

29. (New) The method of claim 28, wherein the patient has pulmonary hypertension.

30. (New) The method of claim 28, wherein the patient has a pulmonary capillary wedge pressure that is greater than or equal to 20 mm Hg.

31. (New) The method of claim 28, wherein the patient is a term neonate.

32. (New) A method of reducing the risk of occurrence, in a term or near-term neonate patient, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide gas, said method comprising:

- (a) identifying a term or near-term neonate patient in need of inhaled nitric oxide treatment, wherein the patient is not known to be dependent on right-to-left shunting of blood;
- (b) determining by diagnostic screening that the patient identified in (a) has pre-existing left ventricular dysfunction; and
- (c) excluding the patient from treatment with inhaled nitric oxide based on the determination that the patient has pre-existing left ventricular dysfunction.

33. (New) The method of claim 32, wherein the diagnostic screening comprises echocardiography.

34. (New) The method of claim 32, wherein the patient has pulmonary hypertension.

35. (New) The method of claim 32, wherein the patient has a pulmonary capillary wedge pressure that is greater than or equal to 20 mm Hg.

36. (New) The method of claim 32, wherein the patient is a term neonate.

37. (New) A method of reducing the risk of occurrence, in a plurality of term or near-term neonate patients, of one or more adverse events or serious adverse events associated with medical treatment comprising inhalation of nitric oxide gas, said method comprising:

- (a) identifying a plurality of term or near-term neonate patients who are in need of inhaled nitric oxide treatment, wherein the patients are not known to be dependent on right-to-left shunting of blood;
- (b) determining that a first patient of the plurality has pre-existing left ventricular dysfunction and a second patient of the plurality does not;
- (c) administering the inhaled nitric oxide treatment to the second patient; and
- (d) excluding the first patient from treatment with inhaled nitric oxide, based on the determination that the first patient has pre-existing left ventricular dysfunction.

38. (New) The method of claim 37, wherein the first and second patients have pulmonary hypertension.

39. (New) The method of claim 37, wherein the second patient has congenital heart disease.

40. (New) The method of claim 37, wherein the first patient has a pulmonary capillary wedge pressure that is greater than or equal to 20 mm Hg.

41. (New) The method of claim 37, wherein the first and second patients are term neonates.

42. (New) The method of claim 37, wherein determining that the first patient of the plurality has pre-existing left ventricular dysfunction and the second patient of the plurality does not have pre-existing left ventricular dysfunction comprises diagnostic screening.

REMARKS

The above amendment cancels all of the pending claims and adds new claims 28-42. The new claims are supported throughout the specification and claims as originally filed. For example, the concept of a "plurality" of patients in new claim 37 is supported by the discussion of "patients" (plural) at paragraph [0004] and "a patient population" at paragraph [0007]. Paragraph [0007] also supports the recitation in claim 37 of a first patient who is determined to have left ventricular dysfunction and so is excluded from treatment with inhaled nitric oxide. The claim 37 recitation of a second patient who is determined not to have left ventricular dysfunction and is administered inhaled nitric oxide is supported, e.g., at paragraph [0008]. (Of course, the terms "first" and "second" in claim 37 are merely standard linguistic devices useful to distinguish between two patients, and do not imply any particular temporal order.) The remaining limitations of claim 37 and of the other new claims are supported throughout the specification and original claims, e.g. at paragraphs [0004], [0007], [0008], [0012], [0018], [0020] (as amended), [0028], [0033], [0051], and [0052]. No new matter has been added.

Applicants believe that the subject matter of the present claims is encompassed by the accelerated examination support documents already on file for this application, so that an updated accelerated examination support document should not be needed.

Information Disclosure Statements

The Office action dated June 8, 2011 (the "Office action") states at page 2 that certain references cited in previously-filed information disclosure statements were not considered and their citations were lined-through on the information disclosure statement because the citations did not include dates. The enclosed new information disclosure statement includes complete citations for those references. As copies of the previously-submitted references are already of record, new copies are not being submitted. Applicants will supply new copies if requested. Consideration of the cited references is respectfully requested.

Objection to Specification

The Office action at pages 3-4 objects to the specification, alleging that the attempt to incorporate subject matter into the specification by reference is defective. In the Reply filed with an Request for Continued Examination on May 2, 2011, Applicants had requested that paragraph [0020] of the specification be amended to include certain language quoted from the FDA-approved prescribing information for INOmax®. That Applicants are entitled to do so is clear, because the specification as originally filed included the statement, **“The current FDA-approved prescribing information for INOmax® is incorporated herein by reference in its entirety.”** See paragraph [0020] in the original specification. Applicants understand the current objection to the specification to be based on the requirement under 37 CFR 1.57(f) that the amendment inserting material in the specification be accompanied by a statement that the material being inserted is the material incorporated by reference and the amendment contains no new matter. In fact, such a statement appeared in the Reply filed May 2, 2011. See the first paragraph of the Remarks on page 6 of that Reply.

Because the amendment to paragraph [0020] in the Reply filed May 2, 2011, was apparently not entered, it is repeated in the present amendment above. The amendment adds the following language to [0020]: **“Section 4 of the prescribing information, Contraindications, states that INOmax® is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood.”** The requisite Statement under 37 CFR 1.57(f) is being filed concurrently herewith, along with a copy of the US Food & Drug Administration (FDA)-approved prescribing information for INOmax® that was current as of the June 30, 2009, priority date (included in the accompanying Information Disclosure Statement and as Exhibit 1 of the Statement under 37 CFR 1.57(f)). The language incorporated by reference is quoted from the second page of the prescribing information, left paragraph, Section 4. New independent claims 28, 32, and 37 include a limitation based on the material incorporated by reference: **“wherein the patient(s) is/are not known to be dependent on right-to-left shunting of blood.”**

If something more is needed to effect this amendment, the Examiner is respectfully asked to clarify.

Rejection under 35 USC § 112, first paragraph

Claim 24 was rejected under 35 USC § 112, first paragraph, as allegedly failing to comply with the written description requirement due to recitation of "a pressurized cylinder containing nitric oxide and one or more inert gases." Claim 24 has been canceled. As none of the currently pending claims recites that limitation, the rejection is now moot.

Rejection under 35 USC § 112, paragraph 2

Claims 25-27 were rejected under 35 USC § 112, second paragraph, as being indefinite for reciting "children." Claims 25-27 have been canceled and none of the currently pending claims recites "children," rendering the rejection moot.

Rejection under 35 USC § 103(a)

Claims 20-27 were rejected as obvious over Atz & Wessel (*Seminars in Perinatology* 1997, 21(5), 441-455), Kinsella et al. (*The Lancet* 1999, 354, 1061-1065) and Loh et al. (*Circulation* 1994, 90, 2780-2785). Claims 20-27 are canceled above for reasons unrelated to this rejection, rendering the rejection moot as to them. The new claims explicitly require a step of excluding from therapy with inhaled nitric oxide neonates with left ventricular dysfunction who are not known to be dependent on right-to-left shunting of blood. To the extent the rejection may be applied to the new claims now pending in the application, applicants emphatically traverse.

The prima facie obviousness rejection elaborated in the Office action is based on a scientifically flawed misreading of the three cited references. Furthermore, the rejection improperly fails to give due regard to the powerful objective evidence that is present in this case, where none of the many experts who reviewed and approved the initial study protocol for the

INOT22 study raised any concern about including pediatric patients with left ventricular dysfunction who are not dependent on right-to-left shunting of blood, and where the U.S. Food & Drug Administration (FDA), when informed of the present invention, required that the label for inhaled nitric oxide therapy include an additional warning about the risk for pediatric patients with left ventricular dysfunction who are not known to depend on right-to-left shunting, as first taught by the present inventors.

To further underscore the nonobviousness of the presently claimed subject matter, applicants submit herewith additional factual evidence directly contradicting the Examiner's interpretation of the references:

- (a) A letter from Dr. David L. Wessel stating that neither the Atz & Wessel article, nor the medical literature, taught that a pediatric patient with left ventricular dysfunction who is not dependent on right-to-left shunting of blood would be at additional risk when treated with inhaled NO. Further, Dr. Wessel states that it is ironic that his own publication would be cited to suggest that such a risk would have been obvious to predict the unexpected adverse events within the INOT22 study when he, the senior author of the publication, failed to anticipate or predict these unexpected outcomes when assisting in the drafting of the original INOT22 protocol;
- (b) Evidence that when Dr. Wessel and over 115 other medical experts individually reviewed the original INOT22 study protocol, none of them – *not a single one* - raised any concern regarding the potential for severe adverse events in pediatric patients with left ventricular dysfunction who are not dependent on right-to-left shunting of blood; and
- (c) An elucidation by Douglas A. Greene, M.D., of the scientific concepts behind the passages of the cited references on which the obviousness rejection relies, thoroughly explaining why one of ordinary skill in the art would not have interpreted these passages as does the Examiner.

This evidence is discussed in detail below.

New claims 28, 32, and 37 are independent. Claim 28 reads as follows:

28. A method of reducing the risk of occurrence, in a term or near-term neonate patient, of one or more adverse events or serious adverse events associated with a medical treatment comprising inhalation of nitric oxide gas, said method comprising:

- (a) identifying a term or near-term neonate patient in need of inhaled nitric oxide treatment, wherein the patient is not known to be dependent on right-to-left shunting of blood;
- (b) determining that the patient identified in (a) has pre-existing left ventricular dysfunction; and
- (c) excluding the patient from inhaled nitric oxide treatment based on the determination that the patient has pre-existing left ventricular dysfunction.

Claim 32 is similar to claim 28, adding the phrase "by diagnostic screening" to step (b).

Claim 37 reads as follows:

37. (New) A method of reducing the risk of occurrence, in a plurality of term or near-term neonate patients, of one or more adverse events or serious adverse events associated with medical treatment comprising inhalation of nitric oxide gas, said method comprising:

- (a) identifying a plurality of term or near-term neonate patients who are in need of inhaled nitric oxide treatment, wherein the patients are not known to be dependent on right-to-left shunting of blood;
- (b) determining that a first patient of the plurality has pre-existing left ventricular dysfunction and a second patient of the plurality does not;
- (c) administering the inhaled nitric oxide treatment to the second patient; and
- (d) excluding the first patient from treatment with inhaled nitric oxide, based on the determination that the first patient has pre-existing left ventricular dysfunction.

With respect to the primary reference, Atz & Wessel, the Office action focuses on certain statements that appear in the section entitled "Severe Left Ventricular Dysfunction" at page 452, left column. Page 8 of the Office action provides the following summary of the Examiner's interpretation of Atz & Wessel's disclosures:

"To summarize, the methods disclosed by Atz et al. are interpreted to mean:

- identifying a patient eligible for NO treatment;
- diagnosing/identifying if the patient has left ventricular dysfunction;
- excluding that patient with left ventricular dysfunction from treatment with NO but treating the patient with NO for other conditions discussed by Atz et al. with inhalation of NO thereby reducing the risk of adverse events associated with the medical treatment."

Applicants maintain that this summary does not accurately represent what Atz & Wessel actually disclosed. Rather than teach that all patients with left ventricular dysfunction (LVD) should be excluded from treatment with inhaled nitric oxide, as implied by the Examiner's summary, Atz & Wessel at page 452 discusses two distinct subsets of LVD patients who may be harmed in different ways when their pulmonary hypertension is reduced by treatment with inhaled nitric oxide. These two subsets of LVD patients are:

- (1) adults with severe LVD combined with pulmonary hypertension and ischemic cardiomyopathy; and
- (2) newborns with severe LVD combined with all of the following: pulmonary hypertension, predominantly left to right shunting at the foramen ovale and exclusively right-to-left shunting at the ductus arteriosus.

Neither of these patient populations encompasses the newborns addressed in the present claims, which are specified as not being known to be dependent on a right-to-left shunt.

Regarding the first patient population (i.e., adults with severe LVD combined with pulmonary hypertension and ischemic cardiomyopathy), Atz & Wessel says:

"In adults with ischemic cardiomyopathy, sudden pulmonary vasodilation may occasionally unload the right ventricle sufficiently to increase pulmonary blood flow

and harmfully augment preload in a compromised left ventricle. The attendant increase in left atrial pressure may produce pulmonary edema.”

Note that this teaching from Atz & Wessel pertains solely to adults.

Regarding the second patient population (i.e., newborns with severe LVD combined with pulmonary hypertension, predominantly left to right shunting at the foramen ovale and exclusively right-to-left shunting at the ductus arteriosus), Atz & Wessel states:

“A different but related phenomenon may be operative in the newborn with severe left ventricular dysfunction and pulmonary hypertension. In these patients, the systemic circulation may depend in part on the ability of the right ventricle to sustain cardiac output through a right-to-left shunt across the patent ductus arteriosus. Selective pulmonary vasodilation may redirect the right ventricular output to the lungs and away from the systemic circulation. Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale and exclusively right-to-left shunting at the ductus arteriosus, NO should be used with extreme caution, if at all. We and others have reported adverse outcomes in this circumstance.”

Thus, Atz & Wessel warns that newborns who have severe LVD and are dependent on a right-to-left shunt across the patent (i.e., open) ductus arteriosus may be harmed, rather than helped, if their pulmonary hypertension is diminished by inhaled nitric oxide treatment. As explained in paragraphs 13-14 of the Declaration of Douglas A. Greene, M.D., under 37 CFR § 1.132, submitted as Appendix B with the Reply filed May 2, 2011 (the “First Greene Declaration”), the dysfunctional left ventricle in these newborns cannot do its usual task of pumping blood into the systemic circulation. The affected infant survives without a functioning left ventricle solely because his/her ductus arteriosus remains open after birth, permitting the right ventricle to take over the function of pumping blood through the patent ductus arteriosus into the systemic circulation, bypassing the left ventricle. This is referred to as a right-to-left shunt. Without this shunt through the patent ductus arteriosus, the patient may suffer systemic circulatory collapse. Pulmonary vasoconstriction actually plays a beneficial role in such infants by helping to maintain a post-natal high blood pressure in the pulmonary artery, which in turn helps keep the ductus arteriosus open and the blood flowing through the systemic circulation. If the newborn’s pulmonary hypertension is reduced by treatment with

inhaled nitric oxide, the right ventricle will pump more blood into the newly dilated pulmonary circulation and less into the systemic circulation; also, the reduced pressure in the pulmonary artery may mean the ductus arteriosus will close, cutting off the right-to-left shunt altogether. Atz & Wessel put it this way: **“Selective pulmonary vasodilation may redirect the right ventricular output to the lungs and away from the systemic circulation.”**

Therefore, the warnings of Atz & Wessel about inhaled NO treatment of patients with LVD are limited to (1) adult LVD patients who have cardiomyopathy and may suffer pulmonary edema if treated with inhaled nitric oxide; and (2) newborn LVD patients who are known to be dependent on a right-to-left shunt across the patent ductus arteriosus and may suffer collapse of their systemic circulation if treated with inhaled nitric oxide. Contrary to the Office action's summary of Atz & Wessel quoted above, Atz & Wessel does not teach, not even by implication, that any and all patients diagnosed as having LVD should be excluded from treatment with inhaled NO. In fact, it is clear that the warning in Atz & Wessel regarding excluding certain newborns is based upon their dependence on right-to-left shunt in conjunction with LVD (since that warning focuses on the danger of abrogating the right-to-left shunt by redirecting blood to the lungs and away from the systemic circulation in these newborns), and not because of the LVD itself. Atz & Wessel's teachings regarding such newborns would not apply to newborns who have severe LVD but are not known to be dependent on a right-to-left shunt across the patent ductus arteriosus. That is the category of patients to which the presently claimed methods are limited. If the authors of Atz & Wessel had been aware that newborns with severe LVD who are not dependent on a right-to-left shunt also are at increased risk for adverse events when treated with inhaled nitric oxide, or even had suspected that would be the case, one would expect them to mention it in their publication. In fact, the senior author of Atz & Wessel, Dr. David L. Wessel,¹ explicitly states in the letter to Dr. Douglas A. Greene, M.D., enclosed as Exhibit 2 of the Second Declaration of Douglas A. Greene, M.D., under 37 CFR § 1.132 (attached as Appendix B, the “Second Greene Declaration”). In particular, in his letter, Dr. Wessel states that he and his co-author (Atz) **“did not disclose or predict...that neonatal patients with left ventricular dysfunction who are not dependent on right-to-left shunting of blood would be at greater risk of adverse events.”** This directly contradicts the Examiner's

¹ Dr. Wessel's Curriculum Vitae is attached as Appendix A.

unduly broad interpretation of what Atz & Wessel discloses, undermining the factual basis for the entire prima facie obviousness rejection.

Furthermore, one of ordinary skill in the art would not have extrapolated from what was disclosed in Atz & Wessel about adult LVD to an expectation about what would happen if neonates with LVD were treated with inhaled nitric oxide. That person of ordinary skill in the art would have realized that Atz & Wessel's teachings about adults with LVD and ischemic cardiomyopathy are not applicable to newborns with LVD, because it is well known that LVD in a newborn is very different from LVD associated with ischemic cardiomyopathy in an adult. See, e.g., the explanation of the differences between adult and newborn LVD provided in paragraphs 15-16 of the First Greene Declaration. "LVD" is not a single condition, but rather is a generic label applied to a left ventricle that does not function properly, regardless of what causes the dysfunction (e.g., congenital malformation, viral disease, or coronary artery disease, to name a few causes) and regardless of how the dysfunction is manifested (e.g., stiffness and inability to relax (diastolic dysfunction) or "flabbiness" and inability to contract (systolic dysfunction)). Atz & Wessel's teaching that treatment of pulmonary hypertension with inhaled NO can precipitate pulmonary edema in adults with LVD associated with ischemic cardiomyopathy and diastolic dysfunction tells one of ordinary skill in the art of cardiac disease nothing useful about whether inhaled NO can be used safely in newborns with LVD typical for newborns, e.g., associated with congenital heart disease and systolic dysfunction.

This point is brought home in a very practical sense by a situation related by Dr. Wessel in his letter to Dr. Greene. Dr. Wessel was the Chair of the INOT22 Steering Committee that in 2005 designed the original protocol for the INOT22 Study, the clinical trial that ultimately led to the presently claimed invention. According to Dr. Wessel's letter,

"At the time of the design of the INOT22 Study protocol, neither myself, the other Steering Committee members, nor the study Sponsor appreciated or anticipated that a child with left ventricular dysfunction who is not dependent on right-to-left shunting of blood would be at additional risk when treated with inhaled nitric oxide (iNO). This is the reason such children were not originally excluded from the INOT22 Study entry criteria....

It is ironic that my own publication [i.e., Atz & Wessel] would be cited to suggest that it would have been obvious to predict the adverse events and outcomes of the

INOT22 Study when I, the senior author of Atz & Wessel, failed to anticipate or predict these unexpected outcomes at the time I participated in drafting the original INOT22 Study protocol. If so, I would have been acting either negligently or intentionally to harm babies, and I most certainly was not. Furthermore, to my knowledge, none of the other members of the INOT22 Steering Committee who assisted me in designing the study, nor the approximately 18 Institutional Review Boards and 2 National Health Authorities who reviewed and approved the study prior to its initiation, predicted the adverse events in children with left ventricular dysfunction who are not dependent on right-to-left shunting of blood.

In summary, although it was known that neonates whose systemic circulation was dependent on right-to-left shunt should not receive iNO, and it had been reported that adults with pre-existing left ventricular dysfunction (from coronary artery disease) may be at risk when provided iNO, it was unanticipated and surprising that children with left ventricular dysfunction who are not dependent on right-to-left shunting would be at increased risk of adverse events when administered iNO.”

The evidence supplied by Dr. Wessel regarding the failure of multiple experts to predict that pediatric patients with left ventricular dysfunction who are not dependent on right-to-left shunting should be excluded from treatment with inhaled nitric oxide is fully corroborated by the Second Declaration of James S. Baldassarre, M.D., under 37 C.F.R. § 1.132 (attached as Appendix C; the “Second Baldassarre Declaration”). Dr. Baldassarre, one of the inventors of the present claims, explains in his declaration that the INOT22 study protocol was designed by the study sponsor (INO Therapeutics LLC) and a Steering Committee including internationally-recognized experts in the field of pediatric heart and lung disease. In addition, INO Therapeutics LLC regularly requested input and scientific guidance on clinical trials from its own Scientific Advisory Board. The original study protocol was reviewed by an Institutional Review Board (IRB) and/or Independent Ethics Committee (IEC) at each of the 18 participating study institutions, including review by the principal investigator within each study institution (a detailed explanation of the design, membership and responsibilities of an IRB and IEC are contained within paragraphs 9 and 10 of the Second Baldassarre Declaration). In addition, the original study protocol was reviewed by experts at FDA and each national Health Authority (European equivalent to FDA) within the four European countries participating in the INOT22 study (United Kingdom, France, Netherlands, and Spain). Neither the study sponsor, nor the experts on the Steering Committee, nor the principal investigators, nor the IRBs, nor the IECs, nor the Advisory Board members, nor the FDA experts, nor the European Health

Authority experts suggested that the exclusion criteria for the INOT22 study protocol be amended to exclude study subjects with pre-existing left ventricular dysfunction who are not dependent on right-to-left shunt. Dr. Baldassarre estimates that the original study protocol was reviewed and approved by at least 115 experts, not one of whom raised an issue about potential risk to this population of patients. The Second Baldassarre Declaration also provides evidence that FDA, when informed of the present invention, required that the label include an additional warning, separate and distinct from the existing contraindication, that inhaled nitric oxide "should not be used in treatment of neonates known to be dependent on right-to-left shunting of blood". If the new warning had been "obvious" to those of ordinary skill all along, FDA would have required it long ago. This is further objective evidence that the presently claimed methods would not have been obvious in view of the prior art.

Applicants submit that this evidence provided by Dr. Wessel and Dr. Baldassarre conclusively establishes the nonobviousness of the presently claimed methods to those of ordinary skill. No physician who believed it "obvious" that inhaled nitric oxide treatment would be harmful to patients who have a particular condition would approve a study of inhaled nitric oxide that includes those patients. That is simply common sense. That multiple physicians who are experts in this field participated in designing, approving, and implementing the original protocol for the INOT22 Study, and none suggested excluding patients with LVD who were not dependent on right-to-left shunt, speaks volumes about the nonobviousness of the presently claimed methods. Furthermore, FDA did not require a warning regarding LVD be added to the INOmax® (nitric oxide) for inhalation prescribing information (i.e., the "label") until 2009, i.e., after the present inventors identified the problem (In contrast, the contraindication for neonates dependent on a right-to-left shunt has always appeared in the prescribing information for INOmax®). If the problem in LVD children had indeed been "obvious" to one of ordinary skill at the time Atz & Wessel was published in 1997, then FDA would have required the warning at that time, and would not have approved the INOT22 Study protocol as originally formulated.

All of this objective evidence is countered by nothing more than the Examiner's subjective interpretation of what Atz & Wessel disclosed. The Examiner is engaging in impermissible hindsight reconstruction of the prior art by deeming obvious what none of the experts in this field

was able to recognize at the time of the present invention. Given that Atz & Wessel did not disclose what the Office action claims it disclosed, the rejection fails on this ground alone.

The secondary references, Kinsella et al. and Loh et al., also do not support the rejection. The Office action at page 8 cites Kinsella et al. as teaching:

“ ... excluding patients (premature neonates) from inhaled nitric oxide treatment if they have fatal congenital anomalies or congenital heart disease....Since left ventricular dysfunction is a congenital heart disease...and it would be pre-existing, then the methods of Kinsella et al. intrinsically exclude this patient population from the method.”

As explained in the Second Declaration of Douglas A. Greene, M.D, paragraph 17, the patients included in the Kinsella et al. trial are differentiated from the term and near-term neonates of the present claims by age, etiology and pathophysiology. In particular, unlike the term and near-term neonates of the present claims, the premature neonates (“preemies”) of Kinsella suffer from severe respiratory failure due to immature lungs and surfactant deficiency, not pulmonary hypertension. Indeed, none of the premature neonates enrolled in Kinsella et al. suffered from pulmonary hypertension. Thus, the patients included in Kinsella et al. were clinically dissimilar from the term and near-term neonates addressed in the present claims.

Additionally, and more importantly, the exclusion of patients from a clinical study may occur for a variety of reasons other than safety concerns. While fatal congenital anomalies or congenital heart disease were indeed reported to be exclusion criteria for the Kinsella et al. study in premature infants, this does not mean the authors taught, or even hypothesized, that inhaling nitric oxide would be particularly risky for these or other patients with these congenital conditions. The exclusion criteria were most likely designed to eliminate variables (here, underlying potentially fatal conditions unrelated to the condition being studied) that would complicate interpretation of the trial results. As explained in paragraphs 18-20 of the Second Greene Declaration:

“For example, clinical trial inclusion and exclusion criteria are often chosen to define or restrict the study population in order to maximize homogeneity, thereby minimizing the presence of potentially confounding factors. This exclusion greatly facilitates the interpretation of the study results, and increases the soundness of the conclusions reached in the study. Accordingly, patients with

background disease sufficiently severe to overwhelm or confound an expected treatment effect are systematically identified and excluded quite independently from considerations of anticipated safety or efficacy of the test article in this particular patient group. For example, patients with malignancy are often excluded from non-oncologic clinical trials, not because the test agents are unsafe, pose any specific risk in this population, or will not work, but rather because the clinical results will be confounded by the wholly unrelated effects of the underlying malignancy, thereby reducing the power of the clinical trial to answer a specific hypothesis regarding the test treatment. As a specific example, exclusion of patients with malignancy or advanced heart failure from cholesterol lowering trials does not imply that statins are unsafe or ineffective in these patients, but rather that their inclusion would confound the potential effects of statins on overall mortality or cardiovascular events. In the specific case of Kinsella et al., it is clear that one of ordinary skill in the art would understand that the patients having fatal congenital anomalies or congenital heart disease were excluded not because of a suspected safety risk of treating these patients with inhaled NO (e.g., a risk of pulmonary edema), but rather solely because the inclusion of such patients would have made it much more difficult – if not impossible – for Kinsella et al. to interpret the target outcomes of the study (i.e., would have “confounded” the results).”

That Dr. Greene's above-described view of Kinsella et al. is the view that would be shared by those of ordinary skill in the art upon reading Kinsella et al. is clear from other objective evidence. See, for example, Fraise & Wessel, “Acute pulmonary hypertension in infants and children: cGMP-related drugs,” *Pediatr Crit Care Med* 2010, Vol. 11, No. 2 (Suppl.), pages S37-S40, a copy of which is included in the accompanying Information Disclosure Statement. The abstract of this article states, **“Inhaled nitric oxide is extremely efficacious in increasing cGMP and selectively reducing mean pulmonary arterial pressure in pediatric cardiac patients. It is considered standard treatment in most centers.”** See also the first full sentence in the middle column of page S37: **“Inhaled NO is extremely efficacious in selectively reducing mean pulmonary arterial pressure (PAP) in cardiac patients and is considered standard treatment in most centers.”** These statements extolling the usefulness of inhaled nitric oxide in pediatric cardiac patients, most of whom have congenital heart disease, were made by the authors in 2010, *eleven years* after Kinsella et al. was published. If those of skill in the art in the years following Kinsella et al.'s publication had believed that infants with congenital heart disease in general should be excluded from treatment with

inhaled nitric oxide, this treatment would certainly not have achieved its present status of a "standard treatment" for pediatric cardiac patients. The quoted statements from Fraisse & Wessel are cogent, objective evidence that the Office action misinterpreted Kinsella et al.'s rationale for excluding congenital heart disease patients from their study and made an inaccurate assessment of how those of ordinary skill in the art would have understood Kinsella et al.'s exclusion criteria. Properly interpreted, Kinsella et al. does not support the present rejection at all.

The Office action at page 9 cites Loh et al. as allegedly teaching:

" .. that inhaled nitric oxide in patients with left ventricular dysfunction may have adverse effects in patients with LV failure...Loh et al. clearly teaches that patients with pulmonary artery wedge pressure...of greater than or equal to 18 mm Hg had a greater effect of inhaled NO due to the greater degree of reactive pulmonary hypertension present in such patients.... Loh et al. state: "Since the degree of reactive pulmonary hypertension is generally related to the severity of hemodynamic compromise in patients with LV failure, it might be anticipated that patients with more severe heart failure will have a more marked hemodynamic response to inhaled NO." (Emphasis as shown in the Office action's original text.)

On page 13, the Office action responds to applicants' prior arguments regarding Loh et al. by saying "As to Loh, the Examiner is not relying on Loh for teaching administration of iNO in children but rather the correlation between PCWP and iNO."

Though the Examiner is plainly aware that Loh et al. does not teach administration of inhaled nitric oxide to children, what the Office action fails to note is that Loh et al.'s study is solely within adult patients, and thus the alleged correlation between PCWP and inhaled nitric oxide observed by Loh et al., has little if any relevance to the presently claimed methods. Loh et al.'s patients had class III or class IV (congestive) heart failure secondary to left ventricular dysfunction from ischemic cardiomyopathy or idiopathic dilated cardiomyopathy (see, page 2780, right column). As explained by Dr. Greene in the Second Greene Declaration at paragraph 22, one cannot predict from Loh et al.'s observations in adults that there would have been any risk to neonates, who typically have a very different form of LVD:

"The underlying etiologies and hemodynamic characteristics of both the primary heart disease and the increased pulmonary vascular resistance are drastically

different from adults, as compared to non-adults, such that one cannot readily assume or anticipate clinical results within adults to translate into neonates or children. In particular, left ventricular dysfunction in neonates with congenital heart disease is primarily due to developmental structural disease of the heart, inborn errors of metabolism that impair energy generation in the heart muscle, or viral infection. Class III or class IV congestive heart failure in adults (in contrast to congenital heart disease in neonates or children) is due to ischemic or dilated cardiomyopathy, mostly secondary to coronary artery disease and/or chronic systemic hypertension. Pulmonary hypertension associated with neonatal congenital heart disease is secondary to chronic hypoxemia, developmental abnormalities of the pulmonary blood vessels and/or pulmonary vascular damage from abnormally high blood flow and/or pressure through the pulmonary vasculature, resulting in evident disease of the lung vasculature. In contrast, increased pulmonary vascular resistance in adult Class III or IV congestive heart failure is due to reactive pulmonary vasoconstriction secondary to increased sympathetic tone or circulating vasoactive molecules (Loh et al., p. 2780, left column) in otherwise structurally normal blood vessels. Therefore, the hemodynamic responses to pulmonary vasodilation by inhaled NO in children or neonates, without right-to-left shunting of blood, but with significant pulmonary hypertension and left ventricular dysfunction cannot be reasonably predicted from the hemodynamic responses to pulmonary vasodilation by inhaled NO of adults with advanced atherosclerotic congestive heart failure and reactive neuro-humoral pulmonary vascular constriction (with or without pulmonary hypertension) as described by Loh et al.”

Given these marked physiological differences between Loh et al.'s adult LVD patients with congestive heart failure and the neonate LVD patients recited in the present claims, one of ordinary skill in the art would not have simply assumed, as the Examiner apparently does,² that results reported by Loh et al. for adults would obviously apply to neonates as well. Supporting applicants' position in this regard is the evidence offered above in the discussion of Atz & Wessel that those of ordinary (and even extraordinary) skill in the art did not consider it “obvious,” even several years after Loh et al.'s 1994 publication date, that neonatal patients with LVD who are not dependent on right-to-left shunt are at increased risk for adverse events when given inhaled nitric oxide. If this

² See, the carryover paragraph of pages 11-12 of the Office action:

[It] is simply not inventive to “inform” a medical provider that a neonate with LVD is at risk of adverse/serious adverse events from iNO therapy when the art already has established that fact and the ordinary artisan is alerted to this fact. *If the patient has LVD then they are at risk of adverse and/or serious adverse events from iNO therapy....* (Italics in the original)

were indeed “obvious” to those of ordinary skill, the INOT22 Study protocol would have explicitly excluded these neonatal LVD patients from the start; other post-1994 clinical trials of inhaled nitric oxide in neonates would have done likewise; and FDA would have required a warning about LVD be added to the prescribing information for INOmax® (nitric oxide) for inhalation over a decade before the warning was actually added (following analysis of the INOT22 Study results).

Physicians are by nature conservative about putting their patients at risk. Any “obvious” or “predictable” risk of harm would be avoided, not ignored—to do otherwise would be tantamount to medical malpractice. If those in the art had indeed understood from the cited references (all published prior to 1999) that neonates who are not dependent on right-to-left shunt with LVD should not be treated with inhaled nitric oxide, such an understanding would of course have been explicitly memorialized in clinical trial protocols and prescribing information long before the present invention, and clearly before the INOT22 study. Since that did not occur, the logical conclusion is that practitioners did not consider such an exclusion to be medically justified.

Contrary to the assertions in the Office action about what would have been “in the realm of common sense” to predict the unexpected adverse events that occurred within the INOT22 study, it would not have been “common sense” for a physician to exclude his or her neonatal LVD patient from a potentially life-saving treatment with inhaled nitric oxide without a legitimate medical justification for doing so. The information available in the art about risk of inhaled nitric oxide in adult LVD was certainly not such a justification. Further, the Examiner’s position in this regard appears to require the unjustified assumption that *none* of the individuals (at least 115) tasked with designing or reviewing and approving the original INO22 study protocol exercised “common sense”, and that by failing to do so, these professionals failed to predict the unexpected serious adverse events that occurred in INOT22. This unsupported conclusion cannot stand in view of the weight of objective evidence provided prior and herein.

In view of the above arguments and cogent objective evidence of nonobviousness, applicants submit that the claims are not obvious in view of the combination of Atz & Wessel, Kinsella et al., and Loh et al.

Rejection for Nonstatutory Obviousness-type Double Patenting

Claims 20-27 stand provisionally rejected for alleged obviousness-type double patenting over claims 21-28 of copending Application No. 12/820980, claims 21-30 of copending Application No. 12/821020, and claims 21-29 and 37 of copending Application No. 12/821041. Claims 20-27 of the present application have been canceled and replaced with new claims 28-42. As the claims of all of the cited applications remain under prosecution and the obviousness-type double patenting rejections are provisional, it is premature to determine whether a terminal disclaimer is appropriate. Applicants will consider that question at the point that the claims are deemed otherwise allowable.

CONCLUSION

Applicants have conclusively established, based on scientific reasoning and objective evidence that includes written statements by Dr. Wessel, that Atz & Wessel failed to teach one skilled in the art to avoid the use of inhaled nitric oxide in the patients recited in the present claims (neonates with left ventricular dysfunction who are not dependent on a right-to-left shunt). Indeed, even Dr. Wessel, the senior author of Atz and Wessel, expressly states that at the time of the original design of the INOT22 protocol, neither he, the study Sponsor, nor the other Steering Committee members appreciated or anticipated that a pediatric patient with left ventricular dysfunction who is not dependent on right-to-left shunting of blood would be at additional risk when treated with inhaled NO. Further evidence provided herein demonstrates that the opinion of Dr. Wessel is not an isolated one, as at least 115 additional medical experts who reviewed the original INOT22 protocol failed to suggest that the exclusion criteria be amended to exclude study subjects with pre-existing left ventricular dysfunction who are not dependent on right-to-left shunting of blood.

Moreover, applicants have explained, based on scientific reasoning and objective evidence, that one of ordinary skill in the art would not have read Kinsella et al. as teaching that infants with congenital heart disease are at risk for adverse events if treated with inhaled nitric oxide; indeed, the Fraise & Wessel article proves that it is well known in the art that inhaled nitric oxide is a "standard" treatment for pediatric cardiac patients. Finally, applicants have elucidated in detail why one of ordinary skill in the art would not have derived from Loh et al.'s statements about adults with

Applicant : James S. Baldassarre et al.
Serial No. : 12/820,866
Filed : June 22, 2010
Page : 23 of 23

Attorney's Docket No.: I001-0002USC1

class III or class IV congestive heart failure and LVD anything of relevance to term or near-term neonates. The science-based explanations provided by applicants are fully supported by the objective evidence of nonobviousness of record in this application. Applicants submit that the claims are in condition for allowance, and such action is respectfully requested.

Please apply any additional necessary charges or credits to deposit account **12-0769**, referencing Attorney Docket No. I001-0002USC1.

Respectfully submitted,

/Jonathan N. Provoost, Reg. No. 44,292/
Jonathan N. Provoost
Attorney for Applicant and Assignee
Associate General Counsel
Ikaria
6 Route 173
Clinton, NJ 08809
Direct phone: (908) 238-6392
Cell: (908) 391-3440
Fax (legal dept.): (908) 238-6773
jonathan.provoost@ikaria.com

Dated: July 8, 2011

Applicant : James S. Baldassarre et al.
Serial No. : 12/820,866
Filed : June 22, 2010
Page : 24 of 23

Attorney's Docket No.: I001-0002USC1

APPENDIX A

(curriculum vitae of Dr. David L. Wessel)

CURRICULUM VITAE

1) PERSONAL DATA

Date prepared: April 2011

Name: David Lloyd Wessel

Home address: 3251 Prospect St. NW, Suite 404 Washington, D.C. 20007

Home phone: 202-342-0908

Office Address: Children's National Medical Center
111 Michigan Ave, NW Suite 3W-100 Washington, DC 20007
TEL: 202 476 5047 FAX: 202 476-5868

E-Mail Address: dwessel@childrensnational.org

Place of Birth: Newton, Iowa U.S.A.

Citizenship: United States

2) EDUCATION:

1972 B.S. College of William and Mary (Physics), Williamsburg, VA
1974 B.A. Oxford University (Physiology), Oxford, England
1978 M.D. Yale University School of Medicine (Medicine), New Haven, CT
1983 M.A. Oxford University (Physiology), Oxford, England

POSTDOCTORAL TRAINING:

Internship and Residencies:

1978-79 Intern in Pediatrics, Yale-New Haven Hospital, New Haven, CT
1979-80 Resident in Pediatrics, Yale-New Haven Hospital, New Haven, CT
1981-83 Resident in Anesthesia, Massachusetts General Hospital, Boston, MA

Fellowships:

1980-81 Fellow in Pediatric Cardiology and Intensive Care, Yale-New Haven Hospital, New Haven, CT
1983-84 Fellow in Pediatric Cardiology, Children's Hospital, Boston, MA
1984-85 Fellow in Anesthesia and Intensive Care, Children's Hospital, Boston, MA

3) EMPLOYMENT

CHILDREN'S HOSPITAL, BOSTON

1985-87 Assistant in Anesthesia
1985-88 Assistant in Cardiology
1987-00 Associate in Anesthesia
1988-89 Associate in Cardiology
1988-07 Associate in Cardiovascular Surgery
1988-02 Chief, Cardiovascular Intensive Care Unit
1989-07 Senior Associate in Cardiology
1995-02 Division Chief
2000-07 Senior Associate in Anesthesia
2002-03 Honorary Consultant, Royal Brompton Hospital, London, U.K.

CHILDREN'S NATIONAL MEDICAL CENTER, WASHINGTON, DC

- 2007- Interim Chief, Division of Critical Care Medicine
- 2007-09 Executive Director, Center for Hospital Based Specialties
- 2009- Senior Vice President, Center for Hospital Based Specialties
- 2010- IKARIA Distinguished Professor of Critical Care Medicine, Children's National Medical Center, Washington, DC

ACADEMIC APPOINTMENTS:

- 1980-81 Fellow in Pediatrics (Cardiology), Yale School of Medicine, New Haven, CT
- 1981-83 Clinical Fellow in Anaesthesia, Harvard Medical School, Boston, MA
- 1983-84 Clinical Fellow in Pediatrics, Harvard Medical School, Boston, MA
- 1984-85 Clinical Fellow in Anaesthesia, Harvard Medical School, Boston, MA
- 1985-86 Instructor in Anaesthesia, Harvard Medical School, Boston, MA
- 1987-93 Assistant Professor of Anaesthesia (Pediatrics), Harvard Medical School, Boston,
- 1987-94 Assistant Professor of Pediatrics (Anaesthesia), Harvard Medical School, Boston, MA
- 1994-99 Associate Professor of Pediatrics, Harvard Medical School, Boston, MA
- 1999-02 Associate Professor of Pediatrics (Anaesthesia), Harvard Medical School, Boston, MA
- 2002-03 Visiting Professor Imperial College, University of London, London UK (4/02-4/03)
- 2002-07 Professor of Pediatrics (Anaesthesia), Harvard Medical School, Boston, MA
- 2011- Professor of Pediatrics, George Washington University School of Medicine and Health Sciences, Washington, DC (pending)

4) LICENSURE AND CERTIFICATION:

- 1979 National Board of Medical Examiners
- 1985-07 Massachusetts License Registration
- 1985 American Board of Pediatrics (Permanent)
- 1985 American Board of Pediatrics, Sub-board of Pediatric Cardiology (Permanent)
- 1986 American Board of Anesthesiology (Permanent)
- 1987 American Board of Pediatrics, Sub-board of Critical Care (Re-certified 1996, 2004, 2010)

5) PROFESSIONAL SOCIETIES & HONORS:

- 1982- American Society of Anesthesiologists
- 1982-2007 Massachusetts Medical Society
- 1986- American Academy of Pediatrics
- 1987- Society of Critical Care Medicine
- 1987- American Society of Critical Care Anesthesiologists
- 1987- Society of Pediatric Anesthesia
- 1989- American Heart Association (Fellow)
- 1991- Society of Cardiovascular Anesthesiologists
- 1995- Society of Pediatric Research
- 1999- Pediatric Cardiac Intensive Care Society - President 2000-2004; Vice President, Development 2010-

AWARDS, HONORS AND NAMED LECTURES:

- 1968 Maytag Scholar (industry sponsored competitive college scholarship)
- 1971 Phi Beta Kappa
- 1971 Omicron Delta Kappa
- 1971 National Physics Honor Society (President)
- 1972 General Honors (William and Mary)
- 1972 Drapers' Scholar (Oxford)
- 1972 Mathematics Honor Society
- 1974 Balliol College Prize (Oxford)
- 1974 First Class Honours (Oxford)
- 1978 Cum Laude (Yale)
- 1978 Alpha Omega Alpha Honor Medical Society
- 1978 Harry S. Greene Prize (Yale)

- 1994 Katkov-Lundeen Memorial Lecture, Minneapolis Children's Hospital, Minneapolis, MN
- 1994 Saul Usher Memorial Lecture, Montreal Children's Hospital, Montreal, Canada
- 1994 Farouk Idriss Memorial Lecture, Children's Memorial Hospital, Chicago, IL
- 1995 A. W. Conn Lecture, Hospital for Sick Children, Toronto, Canada
- 1995 DiCerbo Foundation Lectureship in Pediatric Critical Care, North Shore University Hospital, New York, NY
- 1996 Teaching Award, Pediatric Cardiology, Children's Hospital Boston
- 1997- Listed, *Best Doctors in America*, continuously since inception
- 1999 29th Annual Jennifer B. Lalin Lecture, Babies Hospital, Columbia University College of Physicians and Surgeons, New York, NY
- 2000 Tenth Anniversary Lecture, Taiwan Pediatric Association, Critical Care Sub Committee, Kaohsiung Veterans General Hospital, Taipei, Taiwan
- 2001 Recipient, Papas Gift Award for Outstanding Clinical Care (\$25,000 to Children's Hospital Boston)
- 2002 M.A. (Honorary) Harvard University, Cambridge, MA
- 2004 Keynote Address, Opening Ceremony, Annual Meeting of the European Society of Pediatric and Neonatal Intensive Care, London, United Kingdom
- 2004 Leadership & Mentor Award: "In recognition of your contributions toward improving children's heart health," *The Fifth International Symposium on Pediatric Cardiac Intensive Care* co-sponsored by the Pediatric Cardiac Intensive Care Society and the Texas Children's Heart Center
- 2005 Jared Ellsworth Memorial Lecture, Rainbow Babies and Children's Hospital, Cleveland, Ohio
- 2006 Eddie Farrell Memorial Lecture, Massachusetts Society of Respiratory Care
- 2007 Robert A. Boxer, M.D. Memorial Lecture, Schneider Children's Hospital LIJ, North Shore
- 2010 John J. Downes, Jr., M.D. Lecture, Cardiology 2010, Orlando, FL. Sponsored by Children's Hospital Philadelphia.
- 2010 Outstanding Research Award in Pediatric Cardiology (Council on Cardiovascular Disease in the Young), AHA Scientific Sessions, Chicago, IL
- 2010 Anthony Chang Honorary (Inaugural) Lecture. Pediatric Cardiac Intensive Care Society.

6) ADMINISTRATIVE DUTIES & UNIVERSITY ACTIVITIES

HOSPITAL AND HEALTH CARE ORGANIZATION SERVICE RESPONSIBILITIES:

CHILDREN'S HOSPITAL, BOSTON

- 1985-91 Attending Physician and Associate Director, Multidisciplinary Intensive Care Unit
- 1985-07 Attending Physician in Cardiology (Intensive Care)
- 1985-07 Attending Physician in Anesthesia (Cardiac)
- 1985-07 Associate in Cardiovascular Surgery (teaching)

CHILDREN'S NATIONAL MEDICAL CENTER, WASHINGTON, DC

- 2007- Attending Physician in Critical Care Medicine, Cardiology, Cardiac Anesthesia
- 2007- Member, Children's National Heart Institute

MAJOR ADMINISTRATIVE RESPONSIBILITIES:

CHILDREN'S HOSPITAL, BOSTON

- 1988-02 Director, Cardiac Intensive Care Unit
- 1990 Associate Director, Critical Care Pediatrics Training Program
- 1993-02 Treasurer, Board of Directors, Boston Children's Heart Foundation including investigative and forensic accounting responsibilities surrounding departed chairman (1993-96)
- 1997-98 Board of Directors, Children's Hospital Physicians' Organization, Boston, MA
- 1998-03 Physician Leadership Council, Children's Hospital, Boston, MA
- 1999-02 Medical Director, Pharmacy, Children's Hospital, Boston, MA
- 2000-02 Clinical Sponsor, Critical Care Clinical Information System, Children's Hospital, Boston, MA
- 2003-04 Interdisciplinary Peer Review Assignments and Presentation of Critical Events to JCAHO
- 2004-05 Board of Directors, Boston Children's Heart Foundation
- 2004-05 Physician Leadership Council, Children's Hospital, Boston, MA

CHILDREN'S NATIONAL MEDICAL CENTER, WASHINGTON DC

- 2007- Accountable executive for clinical Center of Excellence; \$200M revenue, more than 700 full time employees. Includes divisions and departments of critical care medicine (both cardiac and pediatric ICU neonatology; hospitalist medicine (inpatient general pediatrics); emergency medicine; radiology; respiratory care services (respiratory therapy); infectious disease, hospital infection control and epidemiology; endocrinology and the diabetes care complex; transport medicine, fetal and transitional medicine, ECMK
- 2007- Leadership Council
- 2007- Children's Hospital Foundation Board of Directors
- 2007- Critical Care Committee (Co-Chair)
- 2007- Executive Committee of the Medical Staff
- 2007- Executive Directors Council (Senior Vice President Council 2008-)
- 2007- Hospital Based Specialties (HBS) Leadership Committee (Chair)
- 2007- HBS Campaign Council (Chair)
- 2007- Strategic Planning Council
- 2007- Interim Chief, Division of Critical Care Medicine
- 2008- Healthcare Review Committee (risk management financial governance)
- 2009- Steering Committee Strategic Planning Council (2010-15)

MAJOR COMMITTEE ASSIGNMENTS:HARVARD MEDICAL SCHOOL

- 1996-98 Futility of Care Task Force, Harvard Medical School
- 1999 Search Committee, Chief of Pediatric Pulmonary Medicine, Children's Hospital, Boston, MA
- 2005-07 Ad Hoc Evaluation Committee for Professorial Promotion

CHILDREN'S HOSPITAL, BOSTON

- 1988-93 Multidisciplinary Intensive Care Committee
- 1989-90 Chairman, Hospital Task Force on Sedation
- 1990-92 Hospital HMO Committee
- 1991-92 Medical Staff Quality Improvement Committee
- 1991-93 Department Quality Improvement Officer
- 1991 Hospital Review Committee for Department of Clinical Laboratories
- 1992 Chairman, Nominating Committee, Medical Staff Association
- 1992-99 Chairman, Special Care Units Committee
- 1992 Hospital Search Committee for Director of Clinical Laboratories
- 1992 Physician Advisory Committee on Computers
- 1992 Operations Improvement Committee
- 1993 Hospital Search Committee for MICU Director
- 1993-01 Cardiovascular Program, Quality Improvement Committee
- 1996-98 Product Standardization Council
- 1998-01 Planning and execution committee for ICU electronic clinical information system
- 1998-01 Clinical Oversight Committee for Transport
- 2000 Nominating Committee, Physician's Organization
- 2000-02 Chairman, Pharmacy and Therapeutics Committee
- 2000-02 Hospital Task Force on Clinical Building and New Construction
- 2000-06 ICU Committee
- 2004-05 Committee on Pension Investments, Physicians' Organization
- 2004-07 Quality and Outcomes Measurement, Physicians' Organization
- 2005-07 Program for Patient Safety and Quality Implementation Committee
- 2006 Hospital Search Committee for Non-invasive Cardiology Division Chief
- 2006-07 Hospital Peer Review Panel
- 2006-07 Physician Profile Task Force

DEPARTMENT OF CARDIOLOGY, CHILDREN'S HOSPITAL, BOSTON

1988-01 Fellowship Selection Committee
 1998-02 Audit and Finance Committee
 1998-02 Computing Committee
 2004-05 Audit and Finance Committee

CHILDREN'S NATIONAL MEDICAL CENTER, WASHINGTON DC

2007-09 Facilities Leadership Committee
 2007- Growth Management/ CARE
 2007- NICU Steering Committee
 2007- Quality and Clinical Effectiveness Committee
 2007- Quality and Safety Council
 2007- Information Technology Oversight Committee
 2007-09 CTI Clinical Advisory Council (electronic medical record)
 2007- Task Force on Access/Referral
 2007-08 Hospital Search Committee for Cardiology Division Chief
 2007- Safety Transformation Advisory Council
 2009- Executive Oversight Committee (post graduate education)
 2009- Physicians Advisory Committee (third party payor contracts)
 2011- Physician Productivity Committee (Chair)
 2011- Internal Advisory Board, GWU / CNMC, for NIH funded CTSI Award (Chair)

NATIONAL & INTERNATIONAL

1995 Clinical Trials Review Committee (*Ad hoc* reviewer), National Institutes of Health
 1995-98 Invited Speaker, Cardio-renal Advisory Panel, U.S. Food and Drug Administration
 2004-06 Task Force ACC AHA AAP: Requirements for Pediatric Cardiac Critical Care Training
 2005-06 Multi-Societal Committee (PCICS/EACTS/STS) Complications in Pediatric and Congenital Cardiac Surgery Project
 2008- National Institute of Allergy and Infectious Disease Transplant Data and Safety Monitoring Board (DSMB) - Member
 2010 FDA Invited Speaker, Continuing Education Series
 2010 International Liaison Committee on Resuscitation (ILCOR): 2010 Consensus Statement and Treatment Recommendations.
 2011 Joint American Heart Association (AHA) – American Thoracic Society Expert Guidelines Statement on Pediatric Pulmonary Hypertension.

INDUSTRY

1994-97 Scientific Advisory Board on Nitric Oxide, Ohmeda Pharmaceuticals
 1998-02 Curriculum Development Committee, INO Therapeutics
 1999-01 Steering Committee, Prophylactic use of Primacor® in pediatric patients at high risk of developing low cardiac output syndrome following cardiac surgery. PRIMACORP study-Prophylactic intravenous use of milrinone after cardiac operation in pediatrics. Sanofi-Synthelabo Inc.
 2001-06 Chairman, Advisory Panel INOTherapeutics
 2001-02 Scientific Advisory Board AGA-Linde
 2001-03 Protocol Planning Committee (PDE V inhibitors) Pfizer
 2001-09 Scientific Advisory Board for pulmonary hypertension research development, Pfizer
 2003 Steering Committee for Multicenter Trial on Diagnostic Use of Inhaled Nitric Oxide
 2005-07 Steering Committee for Multicenter Trial on Use of Nesiritide in Children, SCIOS (Johnson & Johnson)
 2005-07 Advisory Committee on Iloprost and Treatment of Pulmonary Hypertension in Children, Cotherix
 2005-07 Advisory Board, Eli Lilly Vardenafil for Pediatric Pulmonary Hypertension
 2006- Steering Committee (Chairman) for Multicenter Trial on Use of Clopidogrel in Children (CLARINET), Bristol-Myers Squibb & Sanofi-Aventis
 2009 Advisory Panel, Nesiritide Use in Pediatric Cardiovascular patients, Johnson & Johnson

COMMUNITY SERVICE RELATED TO PROFESSIONAL WORK:

- 1994-97 Lecturer, Human Body Curriculum, Wellesley Public School System, Wellesley, MA
- 1996 Hospital Spokesman, Boston/Filenes' Holiday Festival
- 1996 Campaign for William & Mary, 25th Anniversary Committee
- 2000-02 Hospital Spokesman, Capital Campaign and Children's Hospital Boston Fundraising, including keynote speaker, 2000
- 2007- Multiple CNMC Fundraising and Community Benefit Events, presentations to Emeritus and Lady Visitor Boards, etc.
- 2008 Speaker, CNMC Corporate Leadership Council "What's Up, Doc?" Breakfast, World Bank, Washington, D.C.

EDITORIAL BOARDS/REVIEW COMMITTEES:

Ad Hoc Reviewer:

Acta Paediatrica

American Journal of Cardiology, American Journal of Physiology

American Review of Respiratory Diseases and Critical Care

Anesthesia & Analgesia, Anesthesiology

Annals of Thoracic Surgery

Archives of Diseases of Childhood

Cardiovascular and Interventional Radiology

Chest

Circulation

Critical Care Medicine

European Heart Journal

Future Cardiology

Journal of Intensive Care Medicine

Journal of Pediatrics

Journal of Thoracic and Cardiovascular Surgery

Mayo Clinic Proceedings

Pediatrics, Pediatric Cardiology, Pediatric Critical Care Medicine, Pediatric Research

Proceedings of the National Academy of Science

Invited consultant, to review and make recommendations to institutional programs for pediatric cardiovascular care (national and international)

Asked by Children's Hospital Boston to chair ad hoc committees reviewing sentinel events, other critical incidents and report the hospital's analysis and action to the Hospital's Board of Trustees, JCAHO, etc.

7) EDUCATIONAL ACHIEVEMENTS

REPORT OF TEACHING

1. LOCAL CONTRIBUTIONS

a) MEDICAL SCHOOL

Yale University School of Medicine, New Haven, CT

1975-76 Program leader, Cardiovascular physiology core lectures in Physician's Associate Program
Designed lecture series for new PA program; 20 hours/year

Harvard Medical School, Boston, MA

1983-98 Instructor, Cardiovascular Physiology Animal Laboratory, Harvard Medical School
Approximately 60 medical students; one day per year

1985-89 Cardiovascular Pathophysiology, Laboratory section on congenital heart disease
Approximately 30 medical students; half day per year

1985-89 PGY clerkship in Pediatrics
 Lecturer in Critical Care (Multidisciplinary ICU)
 2 medical students each lecture; 12 hours/year

b) GRADUATE MEDICAL EDUCATION (LOCAL)

- 1985-89 Didactic seminars on cardiovascular pathophysiology for pediatric critical care fellows and rotating residents
 Lecture once per week, 1 hour, 6 trainees per lecture
- 1986-93 Developed and taught core curriculum: introduction to anesthesia and critical care for cardiologists
 Lecture once per week, 1 hour, six weeks, 20 fellows and junior faculty. Preparation, 40 hours per year
- 1985-89 Co-developed tutorials on congenital heart disease and supervised core staff (3 tutors) for instruction of cardiology and cardiac ICU fellows during ICU rotation
 Lectures three mornings per week, 1/2 hour, 3-4 fellows; preparation, 2 hours per week
- 1985-07 CICU attending rounds
 3 pediatric residents (1985-1989), 4-8 fellows and senior surgical residents; 18 hours/week, 16-40 weeks/year (varies with year)
- 1990-96 Chiefs' Ward Rounds
 3 medical students, 3 pediatric residents, 1 cardiology fellow; monthly 12 hours/year
- 1996-07 Didactic lectures to cardiology fellows teaching program
 20 fellows 3 times per year
- 2002-03 Didactic lectures (monthly) to trainees at Royal Brompton Hospital. London

c) BOSTON INVITED TEACHING PRESENTATIONS (SELECTED)

- 1984 Anesthesia Grand Rounds, Children's Hospital, Boston, MA
 1991 Anesthesia Grand Rounds, Children's Hospital, Boston, MA
 1992 Surgical Grand Rounds, Children's Hospital, Boston, MA
 1992 Medical Grand Rounds, Children's Hospital, Boston, MA
 1994 Anesthesia Grand Rounds, Children's Hospital, Boston, MA
 1996 Anesthesia Grand Rounds, Massachusetts General Hospital, Boston, MA
 1996 PICU Teaching Sessions, Massachusetts General Hospital, Boston, MA
 1997 Surgical Grand Rounds, Children's Hospital, Boston, MA
 1997 Medical Grand Rounds, Children's Hospital, Boston, MA
 1998 Anesthesia Grand Rounds, Children's Hospital, Boston, MA
 2003 Grand Rounds and teaching rounds, Royal Brompton Hospital, London, UK
 2004 Neonatology Clinical Working Group, Children's Hospital, Boston, MA
 2004 Department of Respiratory Therapy Clinical Working Group, Children's Hospital, Boston, MA
 2005 Department of Cardiology, Didactic Series, Children's Hospital Boston, Boston, MA

d) WASHINGTON DC AREA INVITED TEACHING PRESENTATIONS (SELECTED)

- Chief Rounds Monthly to ICU & Cardiology fellows and staff (15-20 physicians, 2hrs/month), CNMC, DC
- ICU Attending Rounds, Children's National Medical Center, DC
- Clinical Research Presentation to ICU/Cardiology Fellows 2 times per year, Children's National Medical Center, DC
- Grand Rounds, Children's National Medical Center, DC
- Grand Rounds, Mary Washington Hospital, VA
- Grand Rounds, Anne Arundel Medical Center, MD
- Teaching Rounds, Division of Critical Care Medicine, National Institutes of Health

e) CONTINUING MEDICAL EDUCATION (LOCAL)

- 1988 Lecturer
Harvard Medical School, Continuing Education Course in Pediatric Anesthesia
"Anesthesia for Congenital Heart Disease"
- 1990 Lecturer
Harvard Medical School Continuing Education Course in Pediatric Anesthesia
"Common Congenital Cardiac Lesions"
- 1989 Moderator
Harvard Medical School, Continuing Education Course in Pediatric Cardiovascular Disease
- 1993 Lecturer
Symposium on Brain Injury and Cardiac Surgery, Harvard Medical School, Boston, MA
"Choreoathetosis After Cardiopulmonary Bypass"
- 1996 Lecturer
Harvard Medical School Continuing Education Course in Pediatric Anesthesia
"New Vasoactive Drugs"
- 1998 Co-director, First Annual Course: Frontiers in the Diagnosis and Management of Congenital Heart Disease, Children's Hospital, Boston, Harvard Medical School, Boston, MA
- 1999 Co-director, Second Annual Course: Frontiers in the Diagnosis and Management of Congenital Heart Disease, Children's Hospital, Boston, Newport, Rhode Island
- 2001 Co-director, Third Annual Course: Frontiers in the Diagnosis and Management of Congenital Heart Disease, Children's Hospital, Boston, Newport, Rhode Island

f) ADVISORY AND SUPERVISORY RESPONSIBILITIES (LOCAL)

- 1987- Responsible for clinical supervision and educational component of critical care for cardiology fellows in a large pediatric cardiology training program (two months each year for each of 18 fellows spread over 2-3 years of training).
- 1990-02 Responsible as mentor for clinical, educational and clinical research activities of 2-3 senior clinical fellows each year.
- 1985- Shared responsibilities for cardiovascular education and clinical supervision of pediatric critical care fellows in the CICU (3-5 months per year for 5-6 fellows spread over 2-3 years of training).
- 1985-02 Shared responsibilities for critical care educational component of pediatric cardiovascular surgical training program (10 surgical residents each year rotating for 6 months each).
- 1987-02 Responsible for medical education and clinical advisory tasks for continuing education seminars for 80 critical care nurses.

g) LEADERSHIP ROLE (LOCAL)

- 1998-01 Program Co-Director
Annual Course, "Frontiers in Diagnosis and Management of Congenital Heart Disease" Shared responsibility for organizing and executing post graduate course attended by 200 pediatric cardiologists cardiovascular surgeons and nurses from the US and abroad.

h) NAMES OF SELECTED TRAINEES AND/OR FORMER CICU STAFF WHO HAVE CURRENT LEADERSHIP POSITIONS

- 1985-88 Gil Wernovsky, MD, FACC *†§
 Director of Program Development
 Former Director, Cardiac Intensive Care Unit
 The Children's Hospital of Philadelphia
 Professor of Pediatrics
 University of Pennsylvania School of Medicine
 Philadelphia, Pennsylvania
- 1988-89 Ling Chen, MD *
 Director, Cardiac Intensive Care Unit
 Shanghai Children's Medical Center
 Shanghai, China
- 1989-92 Pierre C. Wong, MD *†
 Cardiology Medical Director, Transplantation
 Children's Hospital of Los Angeles
 Los Angeles, California
- 1989-92 Stephen J. Roth, MD, MPH *†
 Director, Cardiac Intensive Care Unit
 Lucile Packard Children's Hospital
 Associate Professor of Pediatrics
 Stanford University School of Medicine
 Palo Alto, California
- 1989-92 Nancy Bridges, MD
 Chief, Transplantation Immunology Branch, Division of Allergy, Immunology, and
 Transplantation
 National Institute of Allergy and Infectious Disease
 Bethesda, Maryland
- 1990-92 Howard A. Zucker, MD, FACC*
 Deputy Director of the World Health Organization
 Geneva, Switzerland
- 1990-93 Kevin B. Churchwell, MD
 Chief Executive Officer (CEO) for Nemours/Alfred I. duPont Hospital for Children
 Wilmington, DE.
- 1990-93 Anthony C. Chang, MD *†§
 Medical Director, CHOC Children's Heart Institute
 Children's Hospital Orange County
 Orange, California
- 1991-94 Ian Adatia, MB, ChB, MRCP (UK), FRCP (C) *†
 Director, Pediatric Cardiac Critical and Intermediate Care Program,
 Director, Pediatric Pulmonary Hypertension Clinic,
 Stollery Children's Hospital,
 Professor of Pediatrics
 University of Alberta
 Edmonton, Alberta, Canada

- 1992-96 Andrew M. Atz, MD *†§
Director, Pediatric Cardiac Intensive Care Unit
The Children's Heart Program
Associate Professor of Pediatrics
Medical University of South Carolina
Charleston, South Carolina
- 1992-96 David P. Nelson, MD, PhD *
Director, Cardiac Intensive Care
Cincinnati Children's Hospital Medical Center
Professor of Pediatrics
Cincinnati, Ohio
- 1992-97 Sarah Tabbutt, MD, PhD *
Director, Pediatric Cardiac Intensive Care Unit
UCSF Children's Hospital
San Francisco, California
- 1994-97 Ricardo A. Muñoz, MD *†§
Director, Pediatric Cardiac Intensive Care
Director, Global Business and Telemedicine
Children's Hospital Pittsburgh
Associate Professor of Pediatrics
University of Pittsburgh
Pittsburgh, Pennsylvania
- 1994-99 Melvin C. Almodovar, MD *†§
Medical Director, Cardiac Intensive Care Unit
Boston Children's Hospital
Assistant Professor
Harvard Medical School
Boston, Massachusetts
- 1995-96 Brendan O'Hare, MD *
Consultant in Anesthesia and Critical Care
Our Lady's Hospital for Sick Children
Crumlin, Dublin, Ireland
- 1995-96-Steven Schwartz, MD
Director of Cardiac Intensive Care
Hospital for Sick Children
Assistant Professor of Pediatrics
University of Toronto
Toronto, Ontario, Canada
- 1996-97 Alain Fraisse, MD *†
Chief, Clinical Pediatric Cardiology
Hopital D'Enfants de la Timone
Professor of Pediatrics
Universitaire de Marseille
Marseille, France

- 1997-98 Guillermo Palacio, MD
Director Pediatric Cardiac Intensive Care Unit
Fundacion Cardio Infantil
Bogota, Colombia
- 1997-98 Mary B. Taylor, MD *
Director, Pediatric Cardiac Critical Care
Cardiology and Critical Care
Vanderbilt Children's Hospital
Associate Professor of Pediatrics
Vanderbilt University Medical Center
Nashville, Tennessee
- 1997-99 Rajiv Chaturvedi, MB BChir, MRCP (UK), MD *
Pediatric Cardiology
Hospital for Sick Children
Assistant Professor
University of Toronto
Toronto, Ontario, Canada
- 1998-01 Ravi Thiagarajan, M.D.* † §
Director, Cardiac ECMO Program
Children's Hospital Boston
Associate Professor of Pediatrics
Harvard Medical School
Boston, Massachusetts
- 1998-02 Peter C. Laussen, MBBS §
Chief, Division of Cardiovascular Intensive Care
D.D. Hansen Chair in Pediatric Anesthesia
Senior Associate in Cardiology
Children's Hospital Boston
Professor of Anesthesia
Harvard Medical School
Boston, Massachusetts
- 1998-99 Mary P. Mullen, MD, PhD *§
Director, Pulmonary Hypertension Program
Assistant in Cardiology
Children's Hospital Boston
Assistant Professor in Pediatrics
Harvard Medical School
Boston, Massachusetts
- 1999 Janet M. Simsic, M.D.*
Director, Pediatric Cardiac Intensive Care Unit
Nationwide Children's Hospital
Columbus, Ohio
- 2000 Erica A. Kirsch, MD*
Director of Pediatric ECMO Program
Associate Professor of Pediatrics
University of Missouri-Kansas City School of Medicine
Kansas City, Missouri

2003-05 Margarita Burmester, MBBS* †
Consultant in Pediatric Intensive Care
Royal Brompton Hospital
Imperial College
London, United Kingdom

* Clinical Trainees
† Research Trainees
§ Faculty in CICU, Children's Hospital Boston
during my tenure as Chief

TEACHING AND EDUCATIONAL LEADERSHIP ROLES (LOCAL AND INTERNATIONAL)

- 1987 Critical Care Consultant for Project Hope and the Cardiac Intensive Care Unit, Xin Hua, Shanghai, China. Developed teaching program for critical care and supervised clinical training of physicians during 2-6month exchange programs.
- 1996- Abstract and Program Reviewer for many National and International Societies including SPR, AHA, ACC, PCICS, World Congress
- 2000 Invited faculty and cardiovascular program curriculum track convener III International Congress of Pediatric Intensive Care, Montreal, Canada.
- 2002 Scientific Programme, Coordinator
The Third Special Topics in Paediatric Cardiac Intensive Care, The Failing Myocardium
Royal Brompton Hospital, Imperial College, London, United Kingdom
- 2003 Invited faculty and cardiovascular program curriculum track convener IV International Congress of Pediatric Intensive Care, Boston, MA
- 2004 Discussant Leader and Co-author (after Tom Kulik) on Critical Care Training Guidelines in Cardiology (SCCM, PCICS, AHA, ACC)
- 2005 Scientific Program Committee Pediatric Cardiac Intensive Care Symposium 2005 (PCICS 2005), Miami, FL
- 2006 Planning Committee, First International Conference on Childhood Pulmonary Vascular Disease, San Francisco, CA 2007
- 2008 Critical Care Consultant, University of Mississippi Medical Center, Jackson, MS

TEACHING AWARD(S) RECEIVED

- 1996 Faculty Teaching Award, Dept. Cardiology, Children's Hospital, Harvard Medical School
2010 Top rated faculty teacher for division of critical care medicine in trainee survey

MAJOR CURRICULUM OFFERING, TEACHING CASES OR INNOVATIVE EDUCATIONAL PROGRAMS DEVELOPED

- 1990-02 Developed a senior clinical fellowship training program for cardiac intensive care with short term training experience available through formal training program relationships with the MICU, Children's Hospital; PICU, Massachusetts General Hospital; Neonatology, Children's Hospital; Neonatology, University of Vermont. Long term (6-36 month) training program applicants accepted (2-3 per year) from candidates in advanced levels of fellowship training from national and international programs.

- 1988-90 In collaboration with the Cardiovascular Nursing Director, developed, reviewed and edited algorithms for care, nursing practice and clinical practice guidelines and quality improvement manuals for the Cardiovascular Program, Children's Hospital, Boston.
- 2004 In collaboration with Pediatric Cardiac Intensive Care Society and the Training Program Directors for Pediatric Cardiology, coauthored (with T. Kulik and others) the report to the Joint Committee on Training Programs (AHA/ACC) on training requirements in critical care for pediatric cardiology trainees.
- 2008 As interim division chief of critical care medicine at Children's National Medical Center, I implemented and supervised a reorganization of the fellowship training program, its leadership and aspects of its curriculum

8) CONSULTANT APPOINTMENTS

VISITING PROFESSORSHIP:

- 1986 Visiting Professor
"Critical Care of the Child with Congenital Heart Disease"
Department of Cardiology, Children's National Medical Center, Washington, D.C.
- 1993 Visiting Professor,
"Perioperative Care of the Neonate with Congenital Heart Disease"
University of Southern California, Children's Hospital of Los Angeles
- 1993 Visiting Professor
"Nitric Oxide and ECMO Therapies for Persistent Pulmonary Hypertension of the Newborn"
Schneider Children's Hospital, Albert Einstein College of Medicine, New York, NY
- 1994 Visiting Professor
"Perioperative Care of the Critically Ill Neonate with Congenital Heart Disease; Perioperative Management of Low Cardiac Output"
Medical University of South Carolina, Charleston, SC
- 1994 Visiting Professor
"Inhaled Nitric Oxide in the Treatment of Children with Congenital Heart Disease"
Dennison Young Memorial Symposium, Montefiore Medical Center, New York, NY
- 1994 Visiting Professor
"Care of the Critically Ill Neonate"
Minneapolis Children's Hospital, Minneapolis, MN
- 1994 Visiting Professor
"Therapeutic Applications of Inhaled Nitric Oxide"
Children's Memorial Hospital, Chicago, IL
- 1994 Visiting Professor
Grand Rounds: "Treatment of Pulmonary Hypertension"
Montreal Children's Hospital, Montreal, Canada
- 1995 Visiting Professor
"Multidisciplinary Management of Complex Congenital Heart Disease"
Anesthesia and Critical Care Grand Rounds, Hospital for Sick Children
University of Toronto, Toronto, Canada

- 1995 Visiting Professor
"Controversy in Critical Care: New Views of Simple Gases (O₂, CO₂, H₂ and NO)"
Anesthesia Grand Rounds, Children's Hospital of Philadelphia, Philadelphia, PA
- 1995 Visiting Professor
"Nitric Oxide: Magic and Medicine"
Medical College of Georgia, Augusta, GA
- 1995 Visiting Professor
"Controversy in Critical Care: New Views of Simple Gases"
Children's Hospital of Pittsburgh, Dept of Surgery, University of Pittsburgh, Pittsburgh, PA
- 1995 Visiting Professor
"Perioperative Care of the Newborn with Congenital Heart Disease"
Division of Pediatric Cardiology, Yale University School of Medicine, New Haven, CT
- 1997 Visiting Professor
"Perioperative Care in the Child with Congenital Heart Disease"
Pediatric Grand Rounds, Vanderbilt Children's Hospital, Nashville, TN
- 2000 Visiting Professor
"Newborns with Heart Disease: Extending the Limits of Intervention"
Columbia-Presbyterian Medical Center, Babies Hospital, New York, NY
- 2003 Visiting Professor
"Treatment of Low Cardiac Output"
Cardiovascular Rounds, Hospital for Sick Children, Great Ormand Street,
London, United Kingdom
- 2005 Visiting Professor
Multiple lectures. University of Pittsburgh, Department of Critical Care Medicine, University of
Pittsburgh Medical
Center and the Children's Hospital of Pittsburgh
- 2005 Visiting Professor
"Progress and problems in the treatment of critical heart disease"
Ellsworth Memorial Lecture, Pediatric Grand Rounds, Rainbow Babies & Children's Hospital,
Cleveland, OH
- 2006 Visiting Professor
"Navigating a career in Medicine". Health Careers Club, College of William & Mary,
Williamsburg, VA
- 2009 Visiting Professor
"The Challenges of Postoperative Care of the Child with CHD"
Pediatric Grand Rounds, Vanderbilt Children's Hospital, Nashville, TN

9) PRESENTATIONS

NATIONAL

- 1990 Seminar Moderator
"Cardiovascular Disease"
Fourth Pediatric Critical Care Colloquium, Waterville, NH

- 1991 **Invited Lecture**
"Perioperative Management of Congenital Heart Disease"
Annual Meeting, Society of Pediatric Anesthesia, San Francisco, CA
- 1992 **Workshop Faculty**
"Anesthesia for Congenital Heart Disease"
Annual Meeting of the Society of Cardiovascular Anesthesiologists, Boston, MA
- 1992 **Invited Lectures**
"Perioperative Management & Decision making in the Neonate with Congenital Heart Disease"
Critical Care Pediatrics Symposium, Arnold Palmer Hospital, Orlando, FL
- 1992 **Invited Lectures**
Multiple topics on Critical Care of Children with Heart Disease and
"Treatment of Pulmonary Hypertension with Inhaled Nitric Oxide"
First World Congress of Pediatric Critical Care, Baltimore, MD
- 1992 **Anesthesia Grand Rounds**
"Postoperative Care of the Child with Congenital Heart Disease"
Maine Medical Center, Portland, ME
- 1992 **Invited Faculty**
"Postoperative Management of the Open Heart Surgery Patient"
Society of Critical Care Medicine, Pediatric Critical Care Clinical Review Series,
San Antonio, TX
- 1993 **NIH Invited Lecture**
"Nitric Oxide in Congenital Heart Disease"
National Institutes of Health Workshop: The effects of Nitric Oxide on the Lung, Bethesda, MD
- 1993 **NIH Invited Lecture**
"Indications for NO in the Newborn with Heart Disease"
National Institutes of Health Workshop on Nitric Oxide and the Perinatal Period, Bethesda, MD
- 1993 **Symposium**
"Nitric Oxide Gas in the Evaluation and Management of Pulmonary Hypertension"
Annual Meeting of the American College of Cardiology, Anaheim, CA
- 1993 **Invited Lecture**
"New Strategies for Treating Pulmonary Hypertension"
Annual Meeting, American Academy of Pediatrics, Washington, DC
- 1993 **Invited Lecture**
"Use of Inhaled Nitric Oxide for the Acute Treatment of Pulmonary Hypertension in Patients
with Congenital Heart Disease" Annual Meeting, American Heart Association, Atlanta, GA
- 1993 **NIH Workshop Lecture**
"Nitric Oxide in the Perinatal Period" National Institutes of Health, Bethesda, MD
- 1993 **Invited Lecture**
"Inhaled Nitric Oxide for the Treatment of Persistent Pulmonary Hypertension of the Newborn"
Fourth Annual New England ECMO Symposium, Children's Hospital, Boston, MA

- 1993 **Symposium**
"Vasodilator Therapy and Inhaled Nitric Oxide in Children" Infant Hearts and Lungs-
Transplantation and Alternative Strategies.
Children's Hospital of Los Angeles, Long Beach, CA
- 1994 **Symposium**
"Update on Nitric Oxide"
Annual Meeting, Society of Critical Care Medicine, Orlando, FL
- 1994 **Symposium**
"Nitric Oxide Gas in the Evaluation and Management of Pulmonary Hypertension"
Annual Meeting of the American College of Cardiology, Atlanta, GA
- 1994 **Invited Lecture**
"Nitric Oxide for Pulmonary Hypertension"
Post Graduate Course on Congenital Heart Disease
American Association of Thoracic Surgery, New York, NY
- 1994 **Plenary Session**
"Inhaled Nitric Oxide for the Treatment of Pulmonary Hypertension in Children"
International Conference on Biochemistry and Molecular Biology of Nitric Oxide, University of
California, Los Angeles, CA
- 1994 **Guest Faculty**
"Nitric Oxide in the Treatment of Pulmonary Hypertension in Congenital Heart Disease"
Pediatric Cardiology-The Failing Heart Conference, Given Biomedical Institute, University of
Colorado, Aspen, CO
- 1994 **Invited Lecture**
"Perioperative Use of Inhaled Nitric Oxide"
Annual Meeting of the American Academy of Pediatrics, Dallas, TX
- 1994 **Invited Faculty**
"Serious Heart Disease of the Neonate: Management"
American Academy of Pediatrics Neoprep Course, St. Louis, MO
- 1994 **Invited Faculty**
"Perioperative Care of the Critically Ill Child with Congenital Heart Disease"
Society of Critical Care Medicine, Pediatric Critical Care Clinical Review Series, San
Francisco, CA
- 1995 **Invited Lecture**
"Pulmonary Hypertension and Nitric Oxide"
Annual Meeting, American College of Cardiology, New Orleans, LA
- 1995 **Invited Lecture**
"Current Therapeutic Applications of Inhaled Nitric Oxide"
International Business Communications, Nitric Oxide Conference, Philadelphia, PA
- 1995 **Invited Lecture**
"Choreoathetosis After Cardiopulmonary Bypass"
Annual Meeting, American Society of Extra-Corporeal Technology, Boston, MA
- 1995 **Invited Lecture**
"Nitric Oxide for Perioperative Management of Congenital Heart Disease"
Annual Meeting of the American College of Surgeons, New Orleans, LA

- 1995 **Invited Lecture**
Controversy in Critical Care: New Views of Simple Gases
DiCerbo Foundation Lectureship in Pediatric Critical Care, North Shore University Hospital, New York, NY
- 1995 **Dinner Speaker**
"Diagnostic and Therapeutic Applications of Inhaled Nitric Oxide"
Annual Dinner Meeting, New York Society of Pediatric Critical Care Medicine, New York, NY
- 1995 **Pediatric Grand Rounds**
"Controversy in Critical Care: New Views of Simple Gases"
Cornell University Medical Center, New York, NY
- 1995 **FDA Invited Lecture**
"Inhaled Nitric Oxide for the Treatment of Persistent Pulmonary Hypertension of the Newborn"
Open Meeting, Cardiovascular and Renal Drugs Advisory Committee, United States Food & Drug Administration, Bethesda, MD
- 1995 **FDA Invited Discussant**
"Use of Inhaled Nitric Oxide in Pediatrics"
Division of Cardiorenal Drug Products, U.S. Food & Drug Administration Rockville, MD
- 1996 **Invited Lecture**
"Persistent Pulmonary Hypertension and Alveolar/Capillary Dysplasia"
Pediatric Grand Rounds, Elliot Hospital, Manchester, NH
- 1996 **Invited Lecture**
"Clinical Use of Inhaled Nitric Oxide"
International Business Communications Nitric Oxide Conference, Philadelphia, PA
- 1996 **Seminar Speaker**
"Postoperative Management of Pulmonary Hypertension in Pediatric Patients with Congenital or Acquired Heart Disease" Annual Meeting, American College of Cardiology, Orlando, FL
- 1996 **Invited Lecture**
"Inhaled Nitric Oxide-Clinical Experience"
First International Meeting on Pediatric Cardiac Intensive Care, Miami, FL
- 1996 **Invited Lecture**
"Pre and Postoperative Manipulation of the Vascular Resistance"
Annual Meeting, American Heart Association, New Orleans, LA
- 1996 **Invited Lecture**
"Current Concepts in Neonatology"
Section on Perinatology, American Academy of Pediatrics and the Joint Program in Neonatology, Harvard Medical School, Boston, MA
- 1997 **Seminar**
"Medical Management of Perioperative Pulmonary Hypertension"
Annual Meeting, Society of Critical Care Medicine, San Diego, CA
- 1997 **Invited Lecture**
"Nitric Oxide and the Treatment of Postoperative Pulmonary Hypertension"
Second World Congress of Pediatric Cardiology and Cardiac Surgery, Honolulu, Hawaii

- 1997 **Invited Lecture**
"Inhaled Nitric Oxide for the Treatment of Persistent Pulmonary Hypertension of the Newborn"
Open Meeting, Division of Cardioresenal Drugs, United States Food & Drug Administration,
Bethesda, MD
- 1997 **Invited Lecture**
"Perioperative Care of the Child with Congenital Heart Disease: New Treatment
Strategies for Pulmonary Hypertension"
Cardiothoracic Anesthesia Meeting, Washington University, St. Louis, MO
- 1997 **Plenary Session**
"Advances and Controversies in Cardiac Management"
Tenth Annual Pediatric Critical Care Colloquium, Hot Springs, AR
- 1997 **Invited Faculty**
"Critical Care of the Child with Congenital Heart Disease" (moderator lecturer, judge)
Second International Symposium on Pediatric Cardiac Intensive Care, Palm Beach, FL
- 1997 **Invited Speaker**
"Nitric Oxide in Neonatal Care"
Topics in Neonatal and Respiratory Care, Brigham & Women's Hospital, Boston, MA
- 1998 **Invited Lectures**
"Cardiac Surgery in Neonates: Morbidity and Mortality"
Charleston Symposium on Congenital Heart Disease, Medical University of South Carolina,
Charleston, SC
- 1998 **Symposium**
"Advances in ICU Management for Congenital Heart Disease"
Annual Meeting, American College of Cardiology, Atlanta, GA
- 1998 **Invited Lecture**
"Intensive Care After Neonatal Cardiac Surgery: State-of-the-Art"
First Annual Course on Frontiers in Diagnosis and Management of Congenital Heart Disease,
Boston, MA
- 1999 **Invited Faculty**
"Myocardial Support for Low Cardiac Output"
Society of Critical Care Medicine
Current Concepts in Pediatric Critical Care Course, San Francisco, CA
- 1999 **Invited Lecture**
"Nitric Oxide and the Treatment of Pulmonary Hypertension"
Oral Presentation Moderator, Walk Rounds with the Professor
28th Scientific Symposium, Society of Critical Care Medicine, San Francisco, CA
- 1999 **Symposium**
"The Airway, Mechanical Ventilation and Cardiopulmonary Interaction"
Annual Meeting, American Heart Association, Atlanta, GA
- 1999 **Invited Speaker**
"Nitric Oxide and New Therapies"
Third International Symposium on Pediatric Cardiac Intensive Care, Miami, FL

- 2000 **Invited Faculty**
"Nitric Oxide in the Perioperative Management of CHD"
Cardiology Y2K, Annual Update on Pediatric Cardiovascular Disease, Orlando, FL
- 2000 **Symposium**
"Intensive Care Unit Management After Surgery for Single Ventricle HLHS Syndrome"
Annual Meeting, American College of Cardiology, Anaheim, CA
- 2000 **Invited Lecture**
"Perioperative Care of the Premature Newborn with Congenital Heart Disease"
Castañeda Society Meeting, Boston, MA
- 2000 **Invited Faculty**
"Perioperative Care of the Premature Newborn with Congenital Heart Disease"
Tenth Charleston Symposium on Congenital Heart Disease, Charleston, SC
- 2001 **Invited Faculty**
"Clinical Research"
The Changing Face of Pediatric Cardiology 1950-2000: A Tribute to Alexander S. Nadas, M.D.
The Cardiovascular Program at Children's Hospital, Boston, MA
- 2001 **Invited Faculty**
"Cardiopulmonary Support in the Pediatric Cardiac Intensive Care Unit"
Third Course on Frontiers in Diagnosis and Management of Congenital Heart Disease,
Newport, RI
- 2001 **Invited Faculty**
Diverse Topics
Fourth International Symposium on Pediatric Cardiac Intensive Care, Palm Beach, FL
- 2002 **Invited Speaker**
"Sildenafil for Treatment of Pulmonary Hypertension"
ECMO Meeting, Children's National Medical Center, Keystone, Colorado
- 2002 **Invited Speaker**
"Novel Pediatric Applications of Commonly Used Adult Drugs"
Back to our Future: Establishing Safety and Evidence in Pediatric Research
Duke University, FDA & Industry, Washington, DC
- 2002 **Invited Lecturer**
"The Future of Inhaled Nitric Oxide for Children with Congenital Heart Disease"
CME Course in Hematology, Northwestern University Medical School
Chicago, Illinois
- 2002 **Invited Faculty**
"Manipulating Vascular Resistance in the Newborn: Is it Feasible?"
3rd International Pediatric Cardiovascular Symposium, Atlanta, Georgia
- 2002 **Invited Speaker**
"Viagra for Pulmonary Hypertension"
Hot Topics in Neonatology, Washington, DC

- 2003 Plenary Speaker
"Changes in Worldwide Activity and Mortality in Cardiac Intensive Care"
Debate: "Cardiac Patients Need Their Own ICU"
Symposium Chairman: "New Strategies in Treatment of Pulmonary Hypertension"
4th World Congress of Pediatric Intensive Care. Boston, Massachusetts
- 2004 Invited Faculty
"Pharmacologic Management of Low Cardiac Output Syndrome After Congenital Heart Surgery" Current Concepts in Pediatric Critical Care Medicine Course
Society for Critical Care Medicine, Orlando, Florida
- 2004 Invited Faculty
"Structure of a Training Program in Pediatric Cardiac Intensive Care"
33rd Annual Meeting of the Society for Critical Care Medicine, Orlando, Florida
- 2004 Invited Faculty
"Reconciling FDA, Academic, and Industry Objectives in Pediatric Clinical Trials"
Cardiology 2004, Orlando, Florida (Children's Hospital of Philadelphia)
- 2004 Invited Speaker
"Cardiac and Central Nervous System Interactions"
15th Annual Pediatric Critical Care Colloquium, New York City, New York
- 2004 Invited Faculty
"Advances in the Management of Pulmonary Hypertension"
"Physician Perspective on Electronic Billing:"
Congenital Cardiovascular Surgery Symposium, San Diego, California
- 2004 Invited Participant in "How To" Session
"How to Evaluate and Manage Pediatric Patients with Pulmonary Hypertension"
American Heart Association, Scientific Sessions 2004, New Orleans, LA
- 2004 Invited Faculty, Special Session
"Twenty Year Retrospective: The Early Years and Later"
Pediatric Cardiac Intensive Care Symposium, Miami, FL
- 2004 Invited Faculty
"Nitric Oxide and the Intensive Care Setting"
Pediatric Cardiac Intensive Care Symposium, Miami, FL
- 2004 Invited Faculty
"How to Design and Conduct Drug Trials"
Pediatric Cardiac Intensive Care Symposium, Miami, FL
- 2005 Invited Faculty
"Therapies to Enhance the Effect of Inhaled Nitric Oxide"
Symposium on New Directions in Nitric Oxide Therapy, Baylor College of Medicine, Texas
Children's Hospital, Houston, Texas
- 2005 Invited Speaker
"Pulmonary Hypertension: Approaches to Management", 21st Annual Fetus and Newborn
Conference, Boston, MA

- 2005 Invited Moderator
 "Low Birth Weight Neonates with Congenital Heart Disease", Pediatric Cardiac Intensive Care Symposium 2005 (PCICS 2005), Miami, FL
- 2005 Invited Faculty
 Consensus Report on Treatment of Myocarditis. Pediatric Cardiac Intensive Care Symposium 2005 (PCICS 2005), Miami, FL
- 2006 Invited Faculty
 "Challenges in Industry Sponsored Trials" and "Management of PVR in the Neonate" Ninth Annual Update on Pediatric Cardiovascular Disease (Children's Hospital of Philadelphia), Scottsdale, AZ
- 2006 Invited Speaker
 Eddie Farrell Memorial Lecture, Massachusetts Society of Respiratory Care, Sturbridge, MA
- 2006 Invited Faculty
 Second International Conference on Heart Failure in Children and Young Adults. Children's Hospital Orange County, Laguna Niguel, CA
- 2007 Invited Speaker
 "Pulmonary Vascular Alterations in CHD" & "Drug Treatment for Pulmonary Hypertension". First International Conference on Childhood Pulmonary Vascular Disease, San Francisco, CA
- 2008 Invited Speaker
 "Cardiac Critical Care: What's New and What Matters "STS Congenital Surgical Symposium, Ft. Lauderdale, FL.
- 2008 Invited Speaker
 Session Chair "Anticipating the Growing ACHD Population"
 Update on Pediatric Cardiovascular Disease - New and Evolving Concepts and Practices,
 Speaker: "Considerations for Caring for Adult Patients in a Pediatric ICU" & "Current Status of Inpatient Therapy"
 Scottsdale, AZ
- 2008 Invited Speaker
 Forum Moderator: "Inhaled Nitric Oxide in the OR"
 ASA 2008 Annual Meeting, Orlando, FL
- 2008 Invited Speaker
 "Postoperative Management and Outcome of the Term vs. Premature Newborn with Congenital Heart Disease"
 Management of Congenital Heart Disease in the Fetus & Neonate Symposium, Washington, DC
- 2008 Invited Speaker
 "Pulmonary Hypertension"
 NPCNA Annual Fall Conference, Innovation and Inquiry in Pediatric Cardiology Nursing, Washington, DC
- 2008 Invited Speaker
 "Critical Treatment Strategies for Acute Pulmonary Hypertension in Infants and Children cGMP-related Drugs »
 PCICS Annual Symposium 2008, Miami, FL

- 2009 **Invited Speaker**
Session Moderator. "Cardiac Surgery"
38th Annual Critical Care Congress of the Society of Critical Care Medicine, Nashville, TN
- 2009 **Invited Speaker**
Session Moderator. "Cardiac ECMO: State-of-the-Art"
The 25th Annual CNMC Symposium: ECMO & The Advanced Therapies for Respiratory Failure
Keystone, CO
- 2009 **Invited Speaker**
Session Moderator. "Pulmonary Vascular Alterations in Congenital Heart Disease"
The 2nd International Neonatal and Childhood Pulmonary Vascular Disease Conference
San Francisco, CA
- 2009 **Invited Speaker**
"Advances in Cardiac Intensive Care"
9th Annual Cardiac Research Symposium – A.I. DuPont Hospital for Children, Nemours
Symposia, Wilmington, DE
- 2010 **Invited Speaker**
"Cardiac Intensive Care: Celebrating Successes, Meeting Challenges"
3rd Annual John J. Downes Lecture in Pediatric Anesthesia and Critical Care Medicine
Orlando, FL
- 2010 **Invited Speaker**
"A Randomized Trial of Clopidogrel to Reduce Mortality and Shunt-Related Morbidity in Infants
Palliated with a Systemic to Pulmonary Artery Shunt"
Outstanding Research Awards (Council on Cardiovascular Disease in the Young)
AHA Scientific Sessions, Chicago, IL
- 2011 **Invited Speaker**
"Working with the FDA & Industry in Designing Pediatric Trials"
The 27th Annual CNMC Symposium: ECMO & The Advanced Therapies for Respiratory Failure
Keystone, CO
- 2011 **Invited Speaker**
"Resuscitation of the Patient with Pulmonary Hypertension"
4th International Neonatal and Childhood Pulmonary Vascular Disease
San Francisco, CA

INTERNATIONAL

- 1986 **Invited Lecture**
"Recent Advances in the Intensive Treatment of Neonates with Congenital Heart Disease,"
A Week with the Experts, Ospedale Pediatrico Bambino Gesù, Rome, Italy
- 1988 **Invited Lecture**
"Perioperative Care of the Patient with HLHS"
European Congress on Hypoplastic Left Heart Syndrome, Ospedale Pediatrico Bambino
Gesù, Rome, Italy

- 1990 **Invited Lecture**
"Perioperative Care of the Neonate with Congenital Heart Disease"
Pediatric Critical Care Conference, Hospital for Sick Children, University of Toronto, Toronto
Canada
- 1991 **Invited Lecture**
"Perioperative Intensive Care of the Child with Congenital Heart Disease"
First International Pediatric Intensive Care Congress, Buenos Aires, Argentina
- 1993 **Invited Faculty**
"Regulation of the Pulmonary Circulation: Therapeutic Implications"
First European Postgraduate Course in Neonatal and Pediatric Intensive Care, Berne,
Switzerland
- 1993 **Invited Faculty**
"Pulmonary Hypertension: Pathophysiologic and Therapeutic Implications in Post Surgical
Patients" Third International Meeting on Pediatric Intensive Care, University of Padova, Italy
- 1993 **Invited Lecture**
"Nitric Oxide to Test Pulmonary Vascular Reactivity to Control Hypertensive Crises and as a
Potential Chronic Therapy" Canadian Cardiovascular Society, Vancouver, Canada
- 1993 **Invited Lecture**
"Nitric Oxide Inhalation after Correction of Congenital Heart Defects"
International Conference on ARDS, Tutzing, Germany
- 1994 **Plenary Presentation**
"Perioperative Care of the Neonate"
Cardiac Surgery Today: State of the Art, Onassis Medical Center, Athens, Greece
- 1995 **Invited Faculty**
"Nitric Oxide in the Treatment of Congenital Heart Disease"
Annual Meeting of the Austrian Society for Lung Diseases, Gmunden, Austria
- 1995 **Plenary Speaker**
"Inhaled Nitric Oxide for Perioperative Management of Congenital Heart Disease"
The VII Brazilian Congress of Intensive Care Medicine, Recife, Brazil
- 1996 **Invited Lecture**
"Nitric Oxide in Pulmonary Hypertension after Surgery for Congenital Heart Defects"
Annual Meeting, European Society of Cardiology, Birmingham, United Kingdom
- 1997 **Symposium**
"The Failing Heart—Pediatric Aspects"
The 7th World Congress of Intensive & Critical Care Medicine, Ottawa, Canada
- 1997 **Plenary Session**
"Inhaled Nitric Oxide"
XXX Brazilian Pediatrics Congress and International Pediatric Symposium, Rio de Janeiro,
Brazil
- 1998 **Invited Faculty**
Multiple lectures and workshops
Pediatric Cardiac Intensive Care at the European Heart House
European Society of Cardiology, Nice, France

- 1998 **Invited Faculty**
Lectures on Congenital Heart Disease
Argentine Congress of Cardiology, Buenos Aires, Argentina
- 1999 **Invited Lecture**
"Critical Aortic Stenosis in the Neonate"
Second Postgraduate Course on Congenital and Acquired Heart Disease, Modena, Italy
- 1999 **Invited Lecture**
"Pathophysiology and Treatment of Pulmonary Hypertension
Lund University Hospital, Lund, Sweden
- 1999 **Invited Lecture**
"Pulmonary Hypertension and Mechanical Support in Children with Heart Disease"
Lindgren Children's Hospital at the Karolinska Institute, Stockholm, Sweden
- 1999 **Plenary Speaker**
"Frontiers in Pediatric Intensive Care"
Annual Meeting, Society of Anesthesia and Critical Care, Gothenburg, Sweden
- 1999 **Invited Faculty**
"ICU Management of Two Stage Arterial switch"
"The Role of Nitric Oxide in the Cardiac Patient"
The First Hispano Latin American Course, Diagnosis and Management of Congenital Heart Disease, San Juan, Puerto Rico
- 1999 **Invited Lecture**
"Current Concepts in Post-operative Management"
"ECMO in the New Millennium"
Symposium on Pediatric Cardiology, Cordoba, Argentina
- 1999 **Invited Speaker**
"Inhaled Nitric Oxide"
"Perioperative Care of the Newborn"
The First Sino-American Symposium: New Developments in the Care of Children with Congenital Heart Disease, Shanghai Children's Medical Center, Shanghai, China
- 2000 **Invited Faculty and Track Convener**
"Issues in Perioperative Care" and multiple lectures
The Third International Symposium on Pediatric Cardiac Intensive Care, Montreal, Canada
- 2000 **Invited Lecture**
"Endothelial Cell Function During Cardiopulmonary Bypass"
5th World Congress on Trauma, Shock, Inflammation and Sepsis, Munich, Germany
- 2000 **Invited Lecture**
"Inhaled Nitric Oxide Therapy in Children after Cardiac Surgery"
American Thoracic Society, 96th International Conference, Toronto, Canada
- 2000 **Invited Lecture**
"Pulmonary Hypertension and its Impact on Hemodynamics"
Special Topics in Pediatric Cardiac Intensive Care Symposium, Royal Brompton & Harefield NHS Trust, London, United Kingdom

- 2000 **Invited Faculty**
"Critical Care and Congenital Heart Disease"- diverse topics
Pediatric FCCS Course, Taipei, Taiwan
- 2000 **Invited Lecture**
"Advances in Perioperative Care of the Child with Congenital Heart Disease"
Tenth Anniversary Lecture, Kaohsiung Veterans General Hospital, Taiwan
- 2000 **Invited Lecture**
"Postoperative Care of the Child with AV Septal Defect"
European Cardiovascular Surgery's Postgraduate Course, Frankfurt, Germany
- 2000 **Seminar**
"Postoperative Care of Patients with Hypoplastic Left Heart Syndrome"
European Association of Cardio-Thoracic Surgery, Annual Meeting, Frankfurt, Germany
- 2000 **Plenary Lecture**
"Diagnosis and Treatment of Pulmonary Hypertension"
XIX Pan American Congress of Pediatrics, Montevideo, Uruguay
- 2000 **Invited Lecture**
"Postoperative Management of the Child with D-Transposition of the Great Arteries"
"Diagnosis and Management of Pulmonary Arterial Hypertension"
I Pediatric Cardiology Symposium, Dr. Aldo Castañeda, Guatemala City, Guatemala
- 2001 **Invited Faculty**
"Pulmonary Hypertension and Nitric Oxide"
"Assessing and Managing Premature Newborns for Surgical and Catheter Intervention"
Harvard Winter Course in Congenital Heart Management, Dubai, United Arab Emirates
- 2001 **Invited Lecture**
"Brain Protection During CPB"
V European Postgraduate Course in Neonatal and Pediatric Intensive Care, Bern, Switzerland
- 2001 **Invited Lecture**
"Strategic Management of the Patient after Surgery"
Third World Congress of Pediatric Cardiology and Cardiac Surgery, Toronto, Canada
- 2001 **Invited Faculty**
Special Topics in Paediatric Cardiac Intensive Care – 2001, The Challenging Neonate,
The Royal Brompton Hospital & The National Heart & Lung Institute, London, England
- 2002 **Moderator**
European Consensus Meeting on Inhaled Nitric Oxide
European Society of Pediatric and Neonatal Intensive Care, Rome, Italy
- 2002 **Invited Faculty**
"Assessment of Myocardial Function in the ICU"
"Postoperative Management After Staged Repair of HLHS"
"ECMO Management of the Single Ventricle Circulation"
New Era in Congenital Heart Management
Universidad Complutense Madrid and Real Colegio Complutense en Harvard, The Heart
Institute Hospital, Universitario "12 de Octubre", Madrid, Spain

- 2002 **Guest Lecturer**
"Failing Hearts: The Paediatric Problem and Current Treatments"
"Inhaled Nitric Oxide and Pulmonary Vasodilators for the Failing Right Heart"
"Routine ECMO for Resuscitation"
The Third Special Topics in Paediatric Cardiac Intensive Care, The Failing Myocardium
Royal Brompton Hospital, Imperial College, London, United Kingdom
- 2003 **Invited Faculty**
"Support for the Failing Ventricle"
"Management of Pulmonary Hypertension: From the OR to the Home"
Debate: "Early Extubation is the Best Defense Against Postoperative Complications"
First Asia Pacific Symposium on Pediatric Cardiac Intensive Care, Phuket, Thailand
- 2003 **Guest Lecturer**
"Pharmacologic Management of Pulmonary Hypertension" and Other Topics
IX Curso de Actualización en Cardiología Pediátrica, Madrid, Spain
- 2003 **Guest Lecturer**
"Recent Advances in the Use of Inhaled Nitric Oxide in Patients with Congenital Heart Disease". Inhaled Nitric Oxygen Symposium for Neonatologists. Madrid, Spain
- 2003 **Invited Participant**
Third World Symposium on Pulmonary Arterial Hypertension (WHO). Venice, Italy
- 2003 **Special Guest Lecturer**
"Indications for Inhaled Nitric Oxide in the Neonatal and Postoperative Care of Critically Ill Children"
Annual Meeting of the German Society of Pediatric Cardiology. Weimar, Germany
- 2003 **Invited Speaker**
"Predicting and Treating Low Cardiac Output in the Postoperative Patient"
Annual Meeting of the European Association of Cardiothoracic Surgeons. Vienna, Austria
- 2003 **Invited Faculty**
"The Paperless ICU"
"Pulmonary and Systemic Vasodilators"
"Genetic Basis for Heterotaxy"
Harvard Medical International, Children's Hospital Boston Course in Congenital Heart Disease
Abu Dhabi, United Arab Emirates
- 2003 **Invited Speaker**
"Extracorporeal Membrane Oxygenation for Cardiopulmonary Resuscitation in Children"
Hammersmith Hospital Workshop on Perfusion. London, United Kingdom
- 2004 **Keynote Speaker**
"Pulmonary Hypertension Therapy—Now and in the Future"
Pulmonary Hypertension in Early Life, St. Guys and St. Thomas' Hospital
London, United Kingdom
- 2004 **Keynote Address**
"Pulmonary Hypertension: State of the Art"
Opening Ceremony, Annual Meeting of the European Society of Pediatric and Neonatal Intensive Care, London, United Kingdom

- 2005 Plenary Speaker
"Recent Advances in Heart Failure and Pulmonary Hypertension", The Fourth World Congress of Pediatric Cardiology and Cardiac Surgery, Buenos Aires, Argentina.
- 2005 Invited Speaker
Controversy Session: "Inhaled Iloprost is the Best Pulmonary Vasodilator?", The Fourth World Congress of Pediatric Cardiology and Cardiac Surgery, Buenos Aires, Argentina.
- 2005 Invited Speaker
Chair, Oral Presentations: "Cardiac Intensive Care", The Fourth World Congress of Pediatric Cardiology and Cardiac Surgery, Buenos Aires, Argentina.
- 2006 Invited Faculty
"Outcomes of Heart Failure in the ICU: Mechanisms of Postoperative Dysfunction." Congress of Ventricular Dysfunction in Childhood, OPBG Cardiovascular International. Rome, Italy
- 2007 Invited Speaker
Multiple Oral Presentations and Panel Chair
Fifth World Congress on Pediatric Critical Care, Geneva, Switzerland
- 2007 Invited Speaker
"Cuidado perioperatorio del recién nacido con enfermedad cardiaca congénita", VI Annual Colombian Critical Care Congress, Medellín, Colombia
- 2007 Invited Speaker
"Postoperative Treatment of Pulmonary Hypertension," & "Postoperative Care of Hypoplastic Left Heart: Comparing Norwood with BT Shunt vs. Sano from Birth through the Fontan."
International Cardiology Meeting, Avignon, France
- 2008 Invited Faculty
Plenary Lecture: "Pediatric Cardiac Intensive Care: Past, Present and Future"; "Dedicated Training Pathways in Pediatric Cardiac Intensive Care" & "How to plan a Research Study in ICU"
PCICS Europe Symposium, Monte Carlo, Monaco
- 2009 Invited Speaker
"Acute Heart Failure Pathophysiology", Treatment of Postoperative Acute Cardiac Failure", "Mechanical Support of Acute Cardiac Failure"
International Pediatric Cardiology Conference
Cartagena, Colombia
- 2010 Invited Faculty
Session Moderator: Pulmonary Hypertension, Right Ventricular Function and Congenital Heart Disease
3rd International Conference Neonatal and Childhood Pulmonary Vascular Disease
Banff, Alberta, Canada
- 2010 Invited Speaker
"Intraoperative Care and Perioperative Management for Transposition"
The World Society for Pediatric and Congenital Heart Surgery
Antigua, Guatemala

10) GRANTS AWARDED**FUNDING INFORMATION**

- 1987-89 The effects of ventilation on pulmonary vascular resistance in infants following cardiopulmonary bypass. Principal Investigator, American Society of Anesthesiologists Research Starter Grant.
- 1988-91 Infant heart surgery: CNS sequelae of circulatory arrest. Co-Investigator, National Institutes of Health. Grant No. HL41786.
- 1993-96 Ischemic neonatal brain injury: clinical and basic science. Co-investigator, National Institutes of Health. Grant No. P20 NS32570
- 1994-96 Inhaled nitric oxide for the treatment of pulmonary hypertension and acute respiratory failure in children. Principal Investigator, Clinical Research Grant-in-Aid Award, Children's Hospital, Boston, Massachusetts. Grant No. CH 89430.
- 1994-99 Pathogenesis of brain injury in infant heart surgery. Clinical advisor / mentor to Dr. Adre J. DuPlessis, National Institutes of Health. Grant No. K08 NS01721
- 1996-99 Dose response of inhaled nitric oxide in congenital heart disease. Principal Investigator, U.S. Food and Drug Administration. Grant No. FD R-001316.
- 1997-99 Neurodevelopmental follow up of patients with PPHN in a randomized trial of nitric oxide. Principal Investigator, Industry Sponsored.
- 1997-00 Echocardiographic assessment of right ventricular function in patients with pulmonary hypertension. Sponsor for Dr. Ricardo Munoz (MCAP), National Institutes of Health Grant No. M01 RR02172.
- 2000-01 Prophylactic use of Primacor® in pediatric patients at high risk of developing low cardiac output syndrome following cardiac surgery. Principal Investigator, Industry Sponsored.
- 2004-06 Principal Investigator (Boston) on three industry sponsored trials of sildenafil for treatment of pediatric pulmonary hypertension (see below).
- 2004-08 A Randomized, Double-Blind, Placebo Controlled, Dose Ranging, Parallel Group Study of Oral Sildenafil in the Treatment of Children, Aged 1-16 Years, With Pulmonary Hypertension. Principal Investigator, Industry Sponsored
- 2004-08 Multicenter, Long-Term Extension Study to Assess Safety of Oral Sildenafil in the Treatment of Subjects Who Have Completed Study A1481131. Principal Investigator, Industry Sponsored
- 2004-06 7-Day, Open-Label, Multicenter, Pharmacokinetic Study (Part 1) of IV Sildenafil in the Treatment of Neonates With Persistent Pulmonary Hypertension of the Newborn (PPHN) or Hypoxic Respiratory Failure and at Risk for PPHN. Principal Investigator, Industry Sponsored
- 2006-08 Pilot Study of the Effects of Nesiritide on Hemodynamics and Urine Output Following Cardiopulmonary Bypass in Children. Co-investigator and mentor (John M. Costello); American Heart Association.
- 2006-10 Multinational Trial on the Efficacy and Safety of Clopidogrel in Infants with Cyanotic Congenital Heart Disease Palliated with a Systemic to Pulmonary Shunt (CLARINET). (Chair, Steering Committee, Institutional Co-investigator). Industry Sponsored (Sanofi-Aventis).

- 2009-14 Collaborative Pediatric Critical Care Research Network (CPCCRN). NIH-NICHD U10410HD049981. Principal Investigator; 20% effort. Base award over 5 years \$925,000 direct costs plus annual awards for protocol funds (e.g. 2010 = \$200,000)
- Critical Pertussis in US Children. Protocol #001
 - The Critical Illness Stress-induced Immune Suppression Prevention Trial (CRISIS). Protocol #003
 - Development of a Quantitative Functional Status Scale (FSS) for Pediatric Patients. Protocol #004
 - Therapeutic Hypothermia after Pediatric Cardiac Arrest Trials (THAPCA). Protocol #010
 - Cortisol Quantification Investigation. Protocol #012
 - Measuring Opioid Tolerance Induced by Fentanyl (or Other Opioids). Protocol #026
 - Physician's Perspectives on the Physician-Parent Follow-Up Conference.
 - Pediatric Intensive Care Unit Bereavement Study
 - CPCCRN Asthma Study

REPORT OF CURRENT RESEARCH ACTIVITIES

1. My primary current research activity involves designing and executing national and international pediatric clinical trials.
2. Safety and efficacy of type V phosphodiesterase inhibitors in children as selective pulmonary vasodilators and to augment vasodilatory potential of nitric oxide and attenuate rebound pulmonary hypertension. I was the overall primary scientific advisor in the development and execution of international multicenter randomized trials on type V inhibitors in pediatrics, Industry sponsored. Final publications in press.
3. Outcome studies evaluating ventilator management, inotropic agents, mechanical support of the circulation and new strategies in the critical care management and perioperative care of
 - a) premature newborns with congenital heart disease
 - b) newborns after reparative surgery involving the right ventricle
 - c) extracorporeal membrane oxygenation resuscitation of children with congenital heart disease.
4. Multinational Trial on the Efficacy and Safety of Clopidogrel in Infants with Cyanotic Congenital Heart Disease Palliated with a Systemic to Pulmonary Shunt (CLARINET). (Chair, Steering Committee, Institutional Co-investigator). Industry Sponsored.
5. I am the Principal Investigator (CNMC) and steering committee member for the NIH funded clinical research network with multiple active protocols listed above.

11) PUBLICATIONS

PAPERS IN REFEREED JOURNALS

1. Hickey PR, Hansen DD, Wessel DL, Lang P, Jonas RA. Pulmonary and systemic hemodynamic responses to fentanyl in infants. *Anesth Analg* 1985;64:483-6.
2. Hickey PR, Hansen DD, Wessel DL, Lang P, Jonas RA. Blunting of stress responses in the pulmonary circulation by fentanyl. *Anesth Analg* 1985;64:1137-42.
3. Wessel DL, Keane JF, Fellows KE, Robichaud H, Lock JE. Fibrinolytic therapy for femoral arterial thrombosis after cardiac catheterization in infants and children. *Am J Cardiol* 1986;58:347-51.
4. Wessel DL, Lock JE. Transcatheter umbrella closure of congenital cardiac defects: technical considerations. *Adv Bioeng (ASME)*. 1987;12:143-144.
5. Wessel DL, Keane JF, Parness I, Lock JE. Outpatient closure of the patent ductus arteriosus. *Circulation* 1988;77:1068-1071.

6. Castaneda AR, Mayer JE, Jonas RA, Lock JE, Wessel DL, Hickey PR. The neonate with critical congenital heart disease: repair - a surgical challenge. *J Thorac Cardiovasc Surg* 1989;98:869-75.
7. DiDonato RM, Wernovsky G, Walsh EP, Colan SD, Lang P, Wessel DL, Jonas RA, Mayer JE Jr, Castaneda AR. Results of the arterial switch operation for transposition of the great arteries with ventricular septal defect: Surgical considerations and midterm follow-up data. *Circulation* 1989;80:1689-1705.
8. Wernovsky G, Jonas RA, Colan SD, Sanders SP, Wessel DL, Castaneda AR, Mayer JE: Results of the arterial switch operation in patients with transposition of the great arteries and abnormalities of the mitral valve or left ventricular outflow tract. *J Am Coll Cardiol* 1990;16:1446-1454.
9. Bellinger DC, Wernovsky G, Rappaport LA, Mayer JE Jr, Castaneda AR, Farrell DM, Wessel DL, Lang P, Hickey PR, Jonas RA, Newburger JW. Cognitive development of children following early repair of transposition of the great arteries using deep hypothermic circulatory arrest. *Pediatrics* 1991;87:701-707.
10. Chang AC, Wernovsky G, Kulik TJ, Jonas RA, Wessel DL. Management of the neonate with transposition of the great arteries and persistent pulmonary hypertension. *Am J Cardiol* 1991;68:1253-1256.
11. Chang AC, Hanley FL, Weindling SN, Wernovsky G, Wessel DL. Left heart support with a ventricular assist device in an infant with acute myocarditis. *Crit Care Med* 1992;20:712-715.
12. Hickey PR, Wessel DL, Streitz SL, Fox ML, Kern FH, Bridges, ND, Hansen, DD. Transcatheter closure of atrial septal defects: Hemodynamic complications and anesthetic management. *Anesth Analg* 1992;74:44-50.
13. Wernovsky G, Giglia TM, Jonas RA, Mone SM, Colan SD, Wessel DL. Course in the intensive care unit after 'preparatory' pulmonary artery banding and aortopulmonary shunt placement for transposition of the great arteries with low left ventricular pressure. *Circulation* 1992;86[suppl II]:II133-139.
14. Wong PC, Barlow CF, Hickey PR, Jonas RA, Castaneda AR, Farrell DM, Lock JE, Wessel DL. Factors associated with choreoathetosis after cardiopulmonary bypass in children with congenital heart disease. *Circulation* 1992;86[suppl II]:II118-II126.
15. Chang AC, Wernovsky G, Wessel DL, Freed MD, Parness IA, Perry SB, O'Brien P, Van Praagh R, Hanley FL, Jonas RA, Castaneda AR, Mayer JE. Surgical management for late right ventricular failure after Mustard or Senning repair. *Circulation* 1992;86[suppl II]:II-140-II-149.
16. Chang AC, Kulik TJ, Hickey P, Wessel DL. Real-time gas exchange measurement of oxygen consumption in neonates and infants after cardiac surgery. *Crit Care Med* 1993;21:1287-1295.
17. Irazuzta J, Pearlman N, Pascucci R, Wessel DL. Effects of fentanyl administration on respiratory system compliance in infants. *Crit Care Med* 1993;21:1001-1004.
18. Chang AC, Hanley FL, Wernovsky G, Rosenfeld H., Wessel DL, Jonas RA, Mayer JE, Castaneda AR. Early bidirectional cavopulmonary shunt in young infants: postoperative course and early results. *Circulation* 1993; 86[suppl II]:II-149-II158.
19. Hanley FL, Heinemann MK, Jonas RA, Mayer JE, Cook NR, Wessel DL, Castaneda AR. Repair of truncus arteriosus in the neonate. *J Thorac Cardiovasc Surg* 1993;105:1047-1056.
20. Wessel DL. Hemodynamic responses to perioperative pain and stress in infants. *Crit Care Med* 1993; 21[suppl]:S361-S362.

21. Newburger JW, Jonas RA, Wernovsky G, Wypij D, Hickey PR, Kuban KCK, Farrell DM, Holmes GL, Helmers SL, Constantinou J, Carrazana E, Barlow JK, Walsh AZ, Lucius KC, Share JC, Wessel DL, Hanley FL, Mayer, JE, Castaneda AR, Ware JH. A comparison of the perioperative neurologic effects of hypothermic circulatory arrest versus low-flow cardiopulmonary bypass in infant heart surgery. *N Engl J Med* 1993;329:1057-1064.
22. Wessel DL. Inhaled nitric oxide for the treatment of pulmonary hypertension before and after cardiopulmonary bypass. *Crit Care Med* 1993;21[*suppl*]:S344-S345.
23. Adatia I, Thompson J, Landzberg M, Wessel DL. Inhaled nitric oxide in chronic obstructive lung disease. *Lancet* 1993;341:307-308. (Letter)
24. Wessel DL, Adatia I, Giglia TM, Thompson JE, Kulik TJ. Use of inhaled nitric oxide and acetylcholine in the evaluation of pulmonary hypertension and endothelial function after cardiopulmonary bypass. *Circulation* 1993;88:2128-2138.
25. Wessel DL, Adatia I, Thompson JE, Hickey PR. Delivery and monitoring of inhaled nitric oxide in patients with pulmonary hypertension. *Crit Care Med* 1994;22:930-938.
26. Drucker N, Colan S, Lewis AB, Beiser A, Wessel DL, Takahashi M, Rosen FS, Baker A, Perez A, Newburger JW. Gamma globulin treatment of acute myocarditis in the pediatric population. *Circulation* 1994;89:252-257.
27. Jonas RA, Hansen DD, Cook N, Wessel DL. Anatomic subtype and survival after reconstructive operation for hypoplastic left heart syndrome. *J Thoracic Cardiovasc Surg* 1994;107:1121-1128.
28. du Plessis AJ, Treves ST, Hickey PR, O'Tauma L, Barlow CF, Costello J, Castaneda AR, Wessel DL. Regional cerebral perfusion abnormalities after cardiac operations. *J Thoracic Cardiovasc Surg* 1994;107:1036-1043.
29. Chang AC, Hanley FL, Lock JE, Wessel DL. Management and outcome of low birth weight neonates with congenital heart disease. *J Pediatr* 1994;124:461-466.
30. Adatia I, Lillehei C, Arnold JH, Thompson JE, Palazzo R, Fackler JC, Wessel DL. Inhaled nitric oxide in the treatment of postoperative graft dysfunction after lung transplantation. *Ann Thor Surg* 1994;57:1311-1318.
31. du Plessis AJ, Kramer U, Jonas RA, Wessel DL, Riviello JJ. West syndrome following deep hypothermic infant cardiac surgery. *Pediatr Neurol* 1994;11:245-251.
32. Lillehei CW, Shamberger RC, Mayer JE, Burke RP, Koka BV, Arnold J, Wessel DL, Landzberg M, Palazzo R. Size disparity in pediatric lung transplantation. *J Pediatr Surg* 1994;29(8):1152-1155.
33. Chang, AC, Zucker HE, Hickey PR, Wessel DL. Pulmonary vascular resistance in infants after cardiac surgery: role of carbon dioxide and hydrogen ion. *Crit Care Med* 1995;23:568-574.
34. Adatia I, Perry S, Landzberg M, Moore P, Thompson JE, Wessel DL. Inhaled nitric oxide and hemodynamic evaluation of patients with pulmonary hypertension before transplantation. *J Am Coll Cardiol* 1995;25:1656-1664.
35. du Plessis AJ, Chang AC, Wessel DL, Lock JE, Wernovsky G, Newburger JW, Mayer JE. Cerebrovascular accidents following the Fontan operation. *Pediatr Neurol* 1995;12:230-236.
36. Wernovsky G, Wypij D, Jonas RA, Mayer JE, Hanley FL, Hickey PR, Walsh AZ, Chang AC, Castaneda AR, Newburger JW, Wessel DL. Postoperative course and hemodynamic profile after the arterial switch operation in neonates and infants: A comparison of low-flow cardiopulmonary bypass and circulatory arrest. *Circulation* 1995;92:2226-2235.

37. Betit P, Adatia I, Benjamin P, Thompson JE, Wessel DL. Inhaled nitric oxide: evaluation of a continuous titration delivery technique for infant mechanical and manual ventilation. *Resp Care* 1995;40(7):706-715.
38. Chang AC, Atz AM, Wernovsky G, Burke RP, Wessel DL. Milrinone: Systemic and pulmonary hemodynamic effects in neonates after cardiac surgery. *Crit Care Med* 1995;23:1907-1914.
39. Curran RD, Mavroudis C, Backer CL, Sautel M, Zales VR, Wessel DL. Inhaled nitric oxide for children with congenital heart disease and pulmonary hypertension. *Ann Thorac Surg* 1995;60:1765-1771.
40. Adatia I, Atz AM, Jonas RA, Wessel DL. Diagnostic use of inhaled nitric oxide after neonatal cardiac surgery. *J Thoracic Cardiovasc Surg* 1996;112:1403-1405.
41. Atz AM, Adatia I, Jonas RA, Wessel DL. Inhaled nitric oxide in children with pulmonary hypertension and congenital mitral stenosis. *Am J Cardiol* 1996;77:316-319.
42. Atz AM, Adatia I, Wessel DL. Rebound pulmonary hypertension following inhalation of nitric oxide. *Ann Thorac Surg* 1996;62:1759-1764.
43. Betit P, Grenier B, Thompson JE, Wessel DL. Evaluation of four analyzers used to monitor nitric oxide and nitrogen dioxide concentrations during inhaled nitric oxide administration. *Res Care* 1996;41(9):817-825.
44. Wessel DL. Simple Gases and Complex Single Ventricles. *J Thoracic Cardiovasc Surg* 1996;112:655-7.
45. Hornberger LK, Colan SD, Lock JE, Wessel DL, Mayer JE. Outcome of patients with Ectopia Cordis and significant intracardiac defects. *Circulation* 1996;94[suppl II] :II-32-II-37.
46. du Plessis AJ, Jonas RA, Wypij D, Hickey PR, Rivielo J, Wessel DL, Roth SJ, Burrows FA, Walter G, Farrell DM, Walsh AZ, Plumb CA, del Nido P, Burke RP, Castaneda AR, Mayer JE Jr., Newburger JW. Perioperative effects of alpha-stat versus pH-stat strategies for deep hypothermic cardiopulmonary bypass in infants.
47. Christou H, Adatia I, Van Marter LJ, Kane JW, Thompson JE, Stark AR, Wessel DL, Kourembanas S. Effect of inhaled nitric oxide on endothelin-1 and cyclic guanosine 5'-monophosphate plasma concentrations in newborns with persistent pulmonary hypertension. *J Pediatrics* 1997;130(4):603-611.
48. Walsh EP, Saul P, Sholler G, Triedman JK, Jonas RA, Mayer JE, Wessel DL. Evaluation of a staged treatment protocol for rapid junctional ectopic tachycardia after surgery for congenital heart disease. *J Am Coll Cardiol* 1997;29(5):1046-1053.
49. Tabbutt S, Duncan BW, McLaughlin D, Wessel DL, Jonas RA, Laussen PC. Delayed sternal closure after cardiac operations in a pediatric population. *J Thorac Cardiovasc Surg* 1997;113(5):886-893.
50. Wessel DL, Adatia I, Thompson JE, Van Marter L, Kane JW, Stark AR, Kourembanas S. Improved oxygenation in a randomized trial of inhaled nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics* 1997;100(5):1-7.
51. Atz AM, Wessel DL. Inhaled nitric oxide in sickle cell disease with acute chest syndrome. *Anesthesiology* 1997;87(4):988-990.
52. Atz AM, Wessel DL. Inhaled nitric oxide and heparin for infantile primary pulmonary hypertension. *The Lancet* 1998;351:1701.
53. Duncan BW, Ibrahim AE, Hraska V, del Nido PJ, Laussen PC, Wessel DL, Mayer JE Jr, Bower LK, Jonas RA. Use of rapid-deployment extracorporeal membrane oxygenation for the resuscitation of pediatric patients with heart disease after cardiac arrest. *J Thorac Cardiovasc Surg* 1998;116(2):305-311.

54. Weindling SN, Saul JP, Gamble WJ, Mayer JE, Wessel DL, Walsh EP. Duration of complete atrioventricular block after congenital heart disease surgery. *Am J Cardiol* 1998;82(2):525-527.
55. Atz AM, Adata I, Lock JE, Wessel DL. Combined effects of nitric oxide and oxygen during acute pulmonary vasodilator testing. *J Am Coll Card* 1999;33(3):813-819.
56. Christou H, Magnani B, Morse DS, Allred EN, Van Marter LJ, Wessel DL, Kourembanas. Inhaled nitric oxide does not affect adenosine 5'-diphosphate-dependent platelet activation in infants with persistent pulmonary hypertension of the newborn. *Pediatrics* 1998;102:1390-1393.
57. Duncan BM, Hraska V, Jonas RA, Wessel DL, del Nido, PJ, Laussen PC, Mayer JE, Lapierre RA, Wilson JM. Mechanical circulatory support in children with cardiac disease. *J Thorac Cardiovasc Surg* 1999;117:529-542.
58. del Nido PJ, Duncan BW, Mayer JE, Wessel DL, LaPierre R, Jonas RA. Left ventricular assist device improves survival in children with left ventricular dysfunction after repair of anomalous origin of the left coronary artery from the pulmonary artery. *Ann Thorac Surg* 1999;67(1):169-172.
59. Atz AM, Feinstein JA, Perry SB, Wessel DL. Preoperative management of pulmonary venous hypertension in hypoplastic left heart syndrome with restrictive atrial septal defect. *Am J Card* 1999;83:1224-1228.
60. Atz AM, Wessel DL. Sildenafil ameliorates effects of inhaled nitric oxide withdrawal. *Anesthesiology* 1999;91:307-310.
61. Munoz R, Laussen PC, Palacio G, Zienko L, Piercey G, Wessel DL. Changes in whole blood lactate levels during cardiopulmonary bypass for surgery for congenital cardiac disease: An early indicator of morbidity and mortality. *J Thorac Cardiovasc Surg* 2000;119:155-162.
62. Munoz R, Laussen PC, Palacio G, Zienko L, Piercey G, Wessel DL. Whole blood ionized magnesium: Age-related differences in normal values and clinical implications of ionized hypomagnesemia in patients undergoing surgery for congenital cardiac disease. *J Thorac Cardiovasc Surg* 2000;119:891-898.
63. Cataltepe S, Van Marter LJ, Kozakewich H, Wessel DL, Lee PJ, Levy HL. Pulmonary hypertension associated with nonketotic hyperglycinemia. *J Inher Metab Dis* 2000;23:137-144.
64. Munoz R, Marcus E, Palacio G, Gauvreau K, Wessel DL, Colan SD. Reconstruction of three dimensional right ventricular shape and volume from three orthogonal planes. *J Am Soc Echocardiogr* 2000;13 (3):177-185.
65. Marcus EN, Munoz RA, Palacio G, Wessel DL, Colan SD. A new quantitative method for the diagnosis of right ventricular hypertensive disorders in 3 dimensions. *J Am Soc Echocardiogr* 2000;13(3):186-193.
66. Christou H, Van Marter LJ, Wessel DL, Allred EN, Kane JW, Thompson JE, Stark AR, Kourembanas S. Inhaled nitric oxide reduces the need for extracorporeal membrane oxygenation in infants with persistent pulmonary hypertension of the newborn. *Crit Care Med* 2000;28(11):3722-3727.
67. Ellington M Jr., O'Reilly D, Allred EN, McCormick MC, Wessel DL, Kourembanas S. Child health status, neurodevelopmental outcome, and parental satisfaction in a randomized, controlled trial of nitric oxide for persistent pulmonary hypertension of the newborn. *Pediatrics* 2001;107:1351-1356.
68. Bacha EA, Almodovar MC, Zurakowski D, Wessel DL, Mayer JE Jr., Jonas RA, del Nido PJ. Surgery for coarctation of the aorta in infants weighing less than 2 kg. *Ann Thorac Surg*. 2001;71(4):1260-4.
69. Duncan BW, Bohn DJ, Atz AM, French JW, Laussen PC, Wessel DL. Mechanical circulatory support for the treatment of children with acute fulminant myocarditis. *J Thorac Cardiovasc Surg* 2001; 122(3):440-8.

70. Rosales AM, Walsh EP, Wessel DL, Triedman JK. Postoperative ectopic atrial tachycardia in children with congenital heart disease. *Am J Cardiol* 2001; 88(10):1169-72.
71. Hoffman TM, Wernovsky G, Atz AM, Bailey JM, Akbary A, Kocsis JF, Nelson DP, Chang AC, Kulik TJ, Spray TL, Wessel DL. Prophylactic intravenous use of milrinone after cardiac surgery in pediatrics. (PRIMACORP) Study. *Am Heart J* 2002; 143:15-21.
72. du Plessis AJ, Bellinger D, Gauvreau K, Plumb C, Newburger JW, Jonas RA, Wessel DL. Choreoathetosis following cardiac surgery in children. Long-term neurologic, cognitive, and behavioral outcome. *Ped Neurol* 2002; 27:9-17.
73. Menache CC, du Plessis AJ, Wessel DL, Jonas RA, Newburger JW. Current incidence of acute neurologic complications following open-heart surgery in children. *Ann Thorac Surg* 2002; 73:1752-8.
74. Booth KL, Roth SJ, Perry SB, del Nido PJ, Wessel DL, Laussen PC. Cardiac catheterization of patients supported by extracorporeal membrane oxygenation. *J Am Coll Cardiol* 2002; 40:1681-6.
75. Marcus EN, Munoz RA, Margossian R, Colan SD, Wessel DL. Echocardiographic assessment of the right ventricular response to hypertension in neonates on the basis of average-shaped contraction models. *J Am Soc Echocardiogr* 2002; 15:1145-53.
76. Hoffman TM, Wernovsky G, Atz AM, Kulik TJ, Nelson DP, Chang AC, Bailey JM, Akbary A, Kocsis JF, Kaczmarek R, Spray TL, Wessel DL. Efficacy and safety of milrinone in preventing low cardiac output syndrome in infants and children after corrective surgery for congenital heart disease. *Circulation* 2003; 107:996-1002.
77. Atz AM, Munoz RA, Adatia I, Wessel DL. Diagnostic and therapeutic uses of inhaled nitric oxide in neonatal Ebstein's anomaly. *Am J Cardiol*. 2003 Apr 1;91(7):906-8.
78. Newburger JW, Wypij D, Bellinger DC, du Plessis AJ, Kuban KC, Rappaport LA, Almirall D, Wessel DL, Jonas RA, Wernovsky G. Length of stay after infant heart surgery is related to cognitive outcome at age 8 years. *J Pediatr*. 2003 Jul;143(1):67-73.
79. Bailey JM, Hoffman TM, Wessel DL, Nelson DP, Atz AM, Chang AC, Kulik TJ, Spray TL, Akbary A, Miller RP, Wernovsky G. A population pharmacokinetic analysis of Milrinone in pediatric patients after cardiac surgery. *Journal of Pharmacokinetics and Pharmacodynamics*, Vol 31, No 1, 2004
80. Fraise A, Geva T, Gaudart J, Wessel DL. Predictive factors of Doppler echocardiography in persistent pulmonary artery hypertension of the neonate (French). *Arch Mal Coeur Vaiss*, 2004; May;97(5):501-506.
81. Fraise A, Geva T, Gaudart J, Wessel DL. Doppler echocardiographic predictors of outcome in newborns with persistent pulmonary hypertension. *Cardiology in the Young* 2004 Jun;14(3):277-283.
82. Adatia I, Atz AM, Wessel DL. Inhaled nitric oxide does not improve systemic oxygenation after the bidirectional cavopulmonary anastomosis. *J Thorac Cardiovasc Surg* 2005; 129(1):217-9.
83. Kulik T, Giglia TM, Kocis KC, Mahoney LT, Schwartz SM, Wernovsky G, Wessel DL. ACCF/AHA/AAP recommendations for training in pediatric cardiology. Task forces 5: requirements for pediatric cardiac critical care. *J Am Coll Cardiol* 2005; vol 46(7): 1396-1399.

84. Graham TP, Beekman RH, Allen HD, Bricker JT, Wessel DL, et al. ACCF/AHA/AAP recommendations for training in pediatric cardiology. A report of the American College of Cardiology Foundation/American Heart Association/American College of Physicians Task Force on Clinical Competence (ACCF/AHA/AAP Writing Committee to Develop Training Recommendations for Pediatric Cardiology). *Circulation* 2005;vol 112(16):2555-2580.
85. Costello JM, Thiagarajan RR, Dionne RE, Allan CK, Booth KL, Burmester M, Wessel DL, Laussen PC. Initial experience with fenoldapam following cardiac surgery in neonates with an insufficient response to conventional diuretics. *Pediatr Crit Care Med* 2006;7:28-33
86. Cua C.L., Thiagarajan R.R., Gauvreau K., Lai L., Costello J.M., Wessel D.L., del Nido P.J., Mayer Jr J.E., Newburger J.W., Laussen P.C.. Post-operative outcomes in a concurrent series of infants with hypoplastic left heart syndrome undergoing stage I palliation operation with either modified Blalock-Taussig shunt or right ventricle to pulmonary artery conduit.. *Pediatr Crit Care Med* 2006;7:238-244.
87. Allen HD, Bricker JT, Freed MD, Hurwitz RA, McQuinn TC, Schieken RM, Strong WB, Zahka KG, Sanders SP, Colan SD, Cordes TM, Donofrio MT, Ensing GJ, Geva T, Kimball TR, Sahn DJ, Silverman NH, Sklansky MS, Weinberg PM, Beekman RH 3rd, Hellenbrand WE, Lloyd TR, Lock JE, Mullins CE, Rome JJ, Teitel DF, Vetter VL, Silka MJ, Van Hare GF, Walsh EP, Kulik T, Giglia TM, Kocis KC, Mahoney LT, Schwartz SM, Wernovsky G, Wessel DL, Murphy DJ Jr, Foster E, Benson DW Jr, Baldwin HS, Mahoney LT, McQuinn TC; American College of Cardiology Foundation; American Heart Association; American Academy of Pediatrics. ACC/AHA/AAP recommendations for training in pediatric cardiology. *Pediatrics*. 2005 Dec;116(6):1574-96.
88. Wessel, DL. Testing new drugs for heart failure in children. *Ped Crit Care Med* 2006. 7(5):493-4..
89. Schwartz SM, Wessel DL. Medical cardiovascular support in acute viral myocarditis in children. *Ped Crit Care Med* 2006;7:S12-S16.
90. Lai L, Laussen PC, Cua CL, Wessel DL, Costello JM, del Nido PJ, Mayer JE, Thiagarajan RR. Outcomes After Bidirectional Glenn Operation: Blalock-Taussig Shunt Versus Right Ventricle-to-Pulmonary Artery Conduit. *Ann Thorac Surg* 2007;83:1768-73.
91. Mullen MP, Wessel DL, Thomas KC, Gauvreau K, Neufeld EJ, McGowan FX Jr, Dinardo JA. The Incidence and Implications of Anti-Heparin-Platelet Factor 4 Antibody Formation in a Pediatric Cardiac Surgical Population. *Anesth Analg*. 2008 Aug;107(2):371-8.
92. Scheurer MA, Salvin JW, Vida VL, Fynn-Thompson F, Bacha EA, Pigula FA, Mayer JE Jr, del Nido PJ, Wessel DL, Laussen PC, Thiagarajan RR. Survival and Clinical Course at Fontan after Stage One Palliation with either a Modified Blalock-Taussig Shunt or a Right Ventricle to Pulmonary Artery Conduit. *J Am Coll Cardiol*. 2008 Jul 1;52(1):52-9.
93. Bacha EA, Cooper D, Thiagarajan R, Franklin RC, Krogmann O, Deal B, Mavroudis C, Shukla A, Yeh T, Barach P, Wessel DL, Stellin G, Colan SD. Cardiac Complications Associated with the Treatment of Patients with Congenital Heart Disease: Consensus Definitions from the Multi-Societal Database Committee for Pediatric and Congenital Heart Disease. *Cardiol Young*. 2008 Dec; 18 Suppl 2:196-201.
94. Larovere JM, Jeffries HE, Sachdeva RC, Rice TB, Wetzel RC, Cooper DS, Bird GL, Ghanayem NS, Checchia PA, Chang AC, Wessel DL. Databases for Assessing the Outcomes of the Treatment of Patients with Congenital and Paediatric Cardiac Disease – the Perspective of Critical Care. *Cardiol Young*. 2008 Dec; 18 Suppl 2:130-6.
95. Steinhorn R, Kinsella JP, Butrous G, Dilleen M, Oakes M, Wessel DL. Intravenous sildenafil in the treatment of neonates with persistent pulmonary hypertension. *J Pediatr*. 2009 Dec;155(6):841-847.e1.

96. Fraisse A, Butrous G, Taylor MB, Oakes M, Dilleen M, Wessel DL. Intravenous Sildenafil for Postoperative Pulmonary Hypertension in Children with Congenital Heart Disease. *Intensive Care Medicine* 2010 Nov 11.
97. Barst RJ, Agnoletti G, Fraisse A, Baldassarre J, Wessel DL for the NO Diagnostic Study Group. Vasodilator Testing with Nitric Oxide and/or Oxygen in Pediatric Pulmonary Hypertension. *Pediatr Cardiol*. 2010 Jul;31(5):598-606. Epub 2010 Apr 20.
98. Fraisse A, Wessel DL. Acute Pulmonary Hypertension in Infants and Children: cGMP-related drugs. *Pediatr Crit Care Med*. 2010 Vol. 11, No. 2 (Suppl.)
99. Pediatric basic and advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Kleinman, ME and the Pediatric Basic and Advanced Life Support Chapter Collaborators. *Circulation* 2010 Oct 19; 122 (16 Suppl 2):S466-515.
100. Macrae D, Wessel DL. Iceberg or pyramid? *Pediatr Crit Care Med*. 2010 Mar;11(2 Suppl):S1-2.
101. Barst RJ, Ivy DD, Gaitan G, Szatmari A, Rudzinski A, Garcia A, Sastry BKS, Pulido T, Layton GR, Serdarevic-Pehar M, Wessel DL. A Double-Blind, Placebo-Controlled, Dose-Ranging Study of Oral Sildenafil Citrate in the Treatment of Children With Pulmonary Arterial Hypertension. Revised for *Circulation* 2010.
102. DL Wessel;F Berger; J S Li; S Fontecave; A Rakhit; J W Newburger; for the CLARINET Investigators. A Randomized Trial of Clopidogrel to Reduce Mortality and Shunt-Related Morbidity in Infants Palliated with a Systemic to Pulmonary Artery Shunt. *Circulation*. 2010;122:A19459. Publication pending.

CHAPTERS, REVIEWS:

2. Hickey PR, Wessel DL. Anesthesia for repair of congenital heart disease. In: Kaplan JA, ed. *Cardiac anesthesia*. 2nd ed. New York: Grune and Stratton, 1987.
3. Crone RK, Hickey PR, Wessel DL. Development of the cardiovascular system. In: Shoemaker WC, Thompson WL, Holbrook PR, eds. *Textbook of critical care*. 2nd ed. Philadelphia: W.B. Saunders, 1988.
4. Hickey PR, Wessel DL. Anesthesia for congenital heart disease. In: Gregory FA, ed. *Pediatric anesthesia*. 2nd ed. New York: Churchill Livingstone, 1989.
5. Hansen DD, Wessel DL. The neonatal pulmonary circulation. *Current opinion in anesthesiology* 1988;1:38-44.
6. Wernovsky G, Erickson LC, Wessel DL. Cardiac emergencies. In: May HL, Aghababian RV, Fleisher, eds. *Emergency Medicine*. Boston: Little, Brown and Company, 1992;1914-1927.
7. Wessel DL. Postoperative management of the open heart surgery patient. In: *Pediatric Critical Care Review Series*. Anaheim: Critical Care Medicine, 1992.
8. Hickey PR, Wessel DL, Reich DL. Anesthesia for treatment of congenital heart disease. In: Kaplan JA, ed. *Cardiac Anesthesia* 3rd ed. Philadelphia: W. B. Saunders, 1993.
9. Wessel DL, Hickey PR. Anesthesia for congenital heart disease. In: Gregory GA, ed. *Pediatric Anesthesia* 3rd ed. New York: Churchill Livingstone, 1994.
10. Wessel DL. Perioperative management of the infant and neonate with congenital heart disease. In: Castaneda AR, Jonas RA, Mayer JE, Hanley FL, eds. *Cardiac surgery of the neonate and infant*. W.B. Saunders, 1994.

11. Wernovsky G, Chang AC, Wessel DL. Intensive Care. In: Adams FH, Emmanouilides GC, Riemenschneider TA, eds. Moss and Adams heart disease in infants, children, and adolescents. 5th ed. Williams & Wilkins, 1995.
12. Adatia I, Wessel DL. Therapeutic use of inhaled nitric oxide. *Current Opinion in Pediatrics*, 1994;6:583-590.
13. Wessel DL, Adatia I. The use of inhaled nitric oxide in the treatment of pulmonary hypertension in children. In: *Advances in Pharmacology*, Ignarro I, Murad F, eds. Nitric oxide: biochemistry, molecular biology, and therapeutic implications. Academic Press, 1995.
14. Adatia I, Wessel DL. The use of inhaled nitric oxide in congenital heart disease. In: Reeves J, Archer SL, Weir K, eds. Nitric oxide and radicals in the pulmonary vasculature. Armonk, NY: Futura Publishing Company, Inc. 1996.
15. Rykerson S, Thompson J, Wessel DL. Inhalation of nitric oxide: an innovative therapy for treatment of increased pulmonary vascular resistance. In: Hickey PA, ed. *The Nursing Clinics of North America*. 1995;30(2):381-389.
16. Wessel DL, Newburger JW. Research in the cardiac intensive care unit. *Progress in Pediatric Cardiology* 1995;(4):177-184.
17. Adatia I, Wessel DL. Diagnostic and therapeutic uses of inhaled nitric oxide in congenital heart disease. In: Zapol WM, Bloch KD, eds. *Nitric Oxide and the Lung*. Marcel Dekker, Inc., New York, NY 1997;165-392.
18. Atz AM, Wessel DL. Delivery and monitoring of nitric oxide. *Current Opinion in Critical Care* 1997;3:243-249.
19. Atz AM, Wessel DL. Inhaled nitric oxide in the neonate with cardiac disease. In: D'Alton ME, Gross I, eds. *Seminars in Perinatology*. WB Saunders. 1997;21(5):441-455.
20. Atz AM, Wessel DL. Inhaled nitric oxide in the neonate with cardiac disease. *Seminars in Perinatology* 1997;21(5):441-455.
21. Atz AM, Wessel DL. Nitric oxide inhalation. In: Rubanyi GM, Furchgott R, Moncada S, eds. *The Pathophysiology and Clinical Application of Nitric Oxide*. Humana Press, 1998.
22. Nelson DP, Wessel DL. Normal physiology of the respiratory system. In: Chang AC, Hanley FL, Wernovsky G, Wessel DL, eds. *Pediatric Cardiac Intensive Care*. Williams & Wilkins, Baltimore, MD. 1998;67-81.
23. Wernovsky G, Chang AC, Wessel DL. Intensive Care. In: Adams FH, Emmanouilides GC, Riemenschneider TA, eds. Moss and Adams heart disease in infants, children, and adolescents. 6th ed. Williams & Wilkins, Baltimore, MD. 1999.
24. Wessel DL. Postoperative care of the patient with congenital heart disease—nitric oxide. In: Mohan OE, Fineman JR, eds. *Current concepts in pediatric critical care-1999*. Society of Critical Care Medicine, Anaheim, CA. 1999;9-14.
25. Laussen PC, Wessel DL. Anesthesia for congenital heart disease. In: Gregory GA, ed. *Pediatric Anesthesia* 4th ed. New York: Churchill Livingstone, 2001.
26. Wessel DL, Almodovar MC, Laussen, PC. Intensive care management of cardiac patients on extracorporeal membrane oxygenation. In: Duncan BW, ed. *Mechanical Support for Cardiac Respiratory Failure in Pediatric Patients*. Marcel Dekker, Inc. 2001;75-111.
27. Wessel DL. Current and future strategies in the treatment of childhood pulmonary hypertension. In: Barst R, ed. *Progress in Pediatric Cardiology*. Elsevier Science Ireland Ltd. 2001;289-318

28. Wessel DL. Managing low cardiac output syndrome after congenital heart surgery. In: Crit Care Med 2001 (10 Suppl):S220-30.
29. Barst R, Ivy D, Bridges H, Wessel DL. Controversies and Concerns: Pulmonary Arterial Hypertension in Congenital Heart Disease; In: Advances in Pulmonary Hypertension, vol 2, No. 2, 2003.
30. Wessel DL. Pharmacologic management of low cardiac output syndrome after congenital heart surgery. In: Shanley TB, ed. Current Concepts in Pediatric Critical Care 2004. Society of Critical Care Medicine, Des Plaines, IL 2004: 59-72.
31. Wessel DL and Laussen PC. Critical care for congenital cardiac disease. In: Furhman BP, Zimmerman JJ, ed. Pediatric Intensive Care 3rd Edition. Elsevier Science, St. Louis, MO, 2006.
32. Wessel DL, Laussen PC. Intensive Care Unit. In: Keane JF, Lock JE, Fyler DC, eds: Nadas' Pediatric Cardiology. 2nd ed. Elsevier, 2006.
33. Wessel DL. Treatment of postoperative pulmonary hypertension. In: Beghetti M, eds. Pulmonary Arterial Hypertension Associated with Congenital Heart Disease. Urban & Fischer Verlag. 2006.
34. Wernovsky G, Chang AC, Wessel DL, Ravishankar, C. Intensive care. In: Adams FH, Emmanouilides GC, Riemenschneider TA, eds. Moss and Adams Heart Disease in Infants, Children, and Adolescents. 7th ed. Williams & Wilkins, 2008.
35. Wessel DL, Mullen MP. Pulmonary vasodilators. In: Munoz R, Schmitt C, Roth S, Da Cruz E, eds. Handbook of Pediatric Cardiovascular Drugs. Springer London. 2008.
36. Fraisse A, Wessel DL. Preoperative Care of the Pediatric Cardiac Surgical Patient. In: Nichols David G ed. The Rogers Textbook of Pediatric Intensive Care, 4th Edition. Lippincott Williams & Wilkins. 2008; 1149-1158.
37. Fraisse A, Wessel DL. Postoperative Care of the Pediatric Cardiac Surgical Patient: General Considerations. In: Nichols David G ed. The Rogers Textbook of Pediatric Intensive Care, 4th Edition. Lippincott Williams & Wilkins. 2008; 1159-1179.
38. Rotta AT, Laussen PC, Wessel DL, Critical Care for Congenital Cardiac Disease. In: Furhman BP, Zimmerman JJ, ed. Pediatric Intensive Care. Elsevier Science, St. Louis, MO, 2011. In Press

BOOKS EDITED OR WRITTEN:

1. Pediatric Cardiac Intensive Care. Chang AC, Hanley FL, Wernovsky G, Wessel DL, eds. Williams and Wilkins, 1998.

OTHER PUBLICATIONS

PROCEEDINGS OF MEETINGS:

1. Lang P, Wessel DL, Wernovsky G, Jonas RA, Mayer JE, Castaneda AR. Hemodynamic effects of amrinone in infants after cardiac surgery. In Curpi G, Parenzan L, Anderson RH (eds.). Perspectives in pediatric cardiology, vol. 2, pediatric cardiac surgery, part 2. Futura Publishing Co., Inc., Mount Kisco, NY; 1989.
2. Wessel DL, du Plessis, AJ. Choreoathetosis. In: Jonas RA, Newburger JW, Volpe JJ, eds. Brain Injury and Pediatric Cardiac Surgery. Butterworth-Heinemann, Newton, MA. 1995.
3. Wessel DL, Atz AM. Inhaled nitric oxide. In: Yasuharu I, Kazuo M, eds. Proceedings of the Second World Congress of Pediatric Cardiology and Cardiac Surgery. Futura, Armonk, NY. 1998 332-334.

4. Wessel DL; editor. Proceedings from the World Congress in Pediatric Critical Care Symposium on "New strategies in the treatment of pulmonary hypertension. University of Colorado Continuing Medical Education. 2004.

CLINICAL COMMUNICATIONS:

1. Belko J, Wessel DL, Malley R. Endocarditis due to *Corynebacterium Diphtheriae*: A case report and review of the literature. *Pediatr Infect Dis J* 2000;19:159-63.
2. Kulik TJ, Giglia TM, Mahoney LT, Schwartz SM, Wernovsky G, Wessel DL. Reply to letter to the editor. *J Am Coll Cardiol*. 2006 Jul 4;48(1):222-223.
3. Allen HD, Bricker JT, Freed MD, Hurwitz RA, McQuinn TC, Schieken RM, Strong WB, Zahka KG, Sanders SP, Colan SD, Cordes TM, Donofrio MT, Ensing GJ, Geva T, Kimball TR, Sahn DJ, Silverman NH, Sklansky MS, Weinberg PM, Beekman RH 3rd, Hellenbrand WE, Lloyd TR, Lock JE, Mullins CE, Rome JJ, Teitel DF, Vetter VL, Silka MJ, Van Hare GF, Walsh EP, Kulik T, Giglia TM, Kocis KC, Mahoney LT, Schwartz SM, Wernovsky G, Wessel DL, Murphy DJ Jr, Foster E, Benson DW Jr, Baldwin HS, Mahoney LT, McQuinn TC; American College of Cardiology Foundation; American Heart Association; American Academy of Pediatrics. Author reply. *Pediatrics*. 2005 Dec;116(6):1574-96.
4. Olivieri, L. et al, Hypoplastic Left Heart Syndrome with Intact Atrial Septum: Sequelae of Left Atrial Hypertension in Utero, *JACC*, in press

NONPRINT MATERIALS:

1. Wessel DL, Atz AM. Therapeutic use of inhaled nitric oxide. In: *Am Coll Cardiol. ACC Self-Assessment Programs on CD-ROM*. 1998.
2. Wessel DL; Session Chair, Inhaled nitric oxide therapy in newborns: reaching a European consensus. *ESPNIC, Rome 2002. CD-ROM*.
3. Kinsella J, Steinhorn R, Clark R, Wessel D, ed. Hypoxic respiratory failure in the neonate: diagnosis and treatment. . *CD-ROM and Slide Kit. iNO 2003*.
4. Wessel DL; editor. Proceedings from the World Congress in Pediatric Critical Care Symposium on "New strategies in the treatment of pulmonary hypertension." Monograph and CD-ROM. University of Colorado Continuing Medical Education.

Applicant : James S. Baldassarre et al.
Serial No. : 12/820,866
Filed : June 22, 2010
Page : 25 of 23

Attorney's Docket No.: 1001-0002USC1

APPENDIX B

(Declaration of Dr. Douglas A Greene)

UNITED STATES PATENT AND TRADEMARK OFFICE	
Application Serial Number	12/820,866
Confirmation Number	2913
Filing Date	22-JUN-2010
Title of Application	METHODS OF TREATING TERM AND NEAR-TERM NEONATES HAVING HYPOXIC RESPIRATORY FAILURE ASSOCIATED WITH CLINICAL OR ECHOCARDIOGRAPHIC EVIDENCE OF PULMONARY HYPERTENSION
First Named Inventor	JAMES S. BALDASSARRE
Assignee	IKARIA, INC.
Group Art Unit	1616
Examiner	ARNOLD, ERNST V.
Attorney Docket Number	I001-0002USC1

Mail Stop Amendment
 Commissioner for Patents
 P.O. Box 1450
 Alexandria, VA 22313-1450

DECLARATION OF DOUGLAS A. GREENE, M.D.
UNDER 37 C.F.R. § 1.132

I, Douglas A. Greene, do hereby declare the following:

1. I currently hold the position of Executive Vice President and Head of Research and Development at INO Therapeutics LLC (“INO”), which is a wholly-owned subsidiary of Ikaria, Inc. A copy of my *curriculum vitae* is attached as **Exhibit 1**.

2. I received an undergraduate degree in biology (*cum laude*) from Princeton University in 1966 and a doctoral degree in medicine (M.D.) from Johns Hopkins School of Medicine in 1970.

3. I spent the next thirty years of my medical career (1970-2000) practicing and teaching medicine at some of America’s foremost academic medical centers, including Johns Hopkins, Penn, Pitt, and the University of Michigan. At Michigan, I was a full professor of internal medicine, director of the Michigan Diabetes Research and Training Center, and chief of the Division of Endocrinology and Metabolism.

4. In 2000, I left Michigan to join Merck as Executive Vice President in charge of clinical sciences and product development. In this role, I supervised and directly managed all clinical research at Merck Research Laboratories, among other duties.

5. In 2003, I left Merck for Sanofi-Aventis, where I became a Senior Vice President and Chief Medical Officer. My duties at Sanofi-Aventis included overseeing all aspects of pre-clinical and clinical regulatory development of the company's products and overseeing all medical aspects of the company's US business.

6. In 2010, I joined INO, where – as noted above – I am presently Executive Vice President and Head of Research and Development.

7. I have been shown a Non-Final Office Action issued by the United States Patent and Trademark Office (USPTO) on June 8, 2011 in a pending patent application having US serial number 12/820,866. This Non-Final Office Action rejected the pending claims of 12/820,866 as “obvious” based on clinical interpretations presented by the USPTO regarding the teaching and disclosure of Atz & Wessel. (Seminars in Perinatology 1997, 21(5), 441-455), Kinsella et al. (Lancet 1999, 354 1061-1065) and Loh et al. (Circulation 1994, 90, 2780-2785). Below is my professional opinion and interpretation of the arguments and clinical interpretations presented by the USPTO within the Non-Final Office Action of June 8, 2011, for 12/820,866 (the “Office Action”).

8. On page 7 of the Office Action, the Examiner states:

“Atz et al. teach that: ‘Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension.’ (page 452, left column).”

A more complete excerpt from Atz & Wessel, p. 452, left column is as follows:

“Caution should be exercised when administering NO to patients with severe left ventricular dysfunction and pulmonary hypertension. In adults with ischemic cardiomyopathy, sudden pulmonary vasodilation may occasionally

unload the right ventricle sufficiently to increase pulmonary blood flow and harmfully augment preload in a compromised left ventricle. The attendant increase in left atrial pressure may produce pulmonary edema. ... A different but related phenomenon may be operative in the newborn" (emphasis added)

Thus, although Atz & Wessel warns that "[c]aution should be exercised when administering nitric oxide (NO) to patients with severe left ventricular dysfunction and pulmonary hypertension[.]" this caution is specifically limited to two populations of patients. In the first population, the statement in Atz & Wessel p. 452, left column, is directed to adult patients with ischemic cardiomyopathy who also exhibit severe left ventricular dysfunction and pulmonary hypertension. This patient population is clearly different from the neonatal population that is the object of the teaching of the present claims.

9. Further in the same paragraph, Atz & Wessel specifically refers to a second patient population, which is also distinct from that of the present patent application, to whom inhaled NO should not be administered, namely, neonates depending on right-to-left shunting of blood:

"A different but related phenomenon may be operative in the newborn with severe left ventricular dysfunction and pulmonary hypertension. In these patients, the **systemic circulation may depend in part on the ability of the right ventricle to sustain cardiac output through a right-to-left shunt across the patent ductus arteriosus**. Selective pulmonary vasodilation may redirect the right ventricular output to the lungs and away from the systemic circulation." (emphasis added)

For this second patient population, Atz & Wessel state that these patients exhibit a "different but related phenomenon" from that observed in adults with ischemic cardiomyopathy. This second population of patients consists of newborn patients with congenital heart disease and left ventricular dysfunction who are **dependent on a right-to-left shunt through a ductus arteriosus** in order to maintain peripheral circulation necessary to survive. In these patients, a patent ductus provides the only alternate pathway for blood being pumped by the right ventricle to **bypass the dysfunctional left ventricle** and thereby substitute for the dysfunctional left ventricle in providing life-sustaining blood flow to the peripheral circulation. Blood emerging

from the right ventricle has only two possible pathways, either through the pulmonary circulation and then back to the dysfunctional left ventricle, or to pass through the patent ductus arteriosus in a right-to-left shunt to reach the systemic circulation. Inhaled NO dilates the pulmonary circulation, and therefore would divert blood to the lungs at the expense of the patent ductus arteriosus and systemic circulation, causing systemic vascular collapse and death. Again, this second patient population described by Atz & Wessel is also completely different from the patient population addressed in the present claims, which is term or near term neonates with left ventricular dysfunction who are **NOT dependent upon right-to-left shunting**.

10. The risk of circulatory collapse in the subset of newborns with congenital heart disease and severe left ventricular dysfunction **who are dependent upon a right-to-left shunt** through a patent ductus arteriosus was well known in this field long before the Atz & Wessel publication, as evidenced by the contraindication stated in the US Food and Drug Administration (FDA) prescribing information for INOMAX[®] (nitric oxide) for inhalation from the time of its initial approval by the FDA in 1999: “**CONTRAINDICATIONS:** Neonates known to be dependent on right-to-left shunting of blood”.

11. As a result of the INOT22 study, it was recognized that a second population of neonates existed, distinct from the population described in Atz & Wessel, that had an increased risk of adverse events when inhaled NO was administered, namely: pediatric patients with left ventricular dysfunction **who are not dependent upon right-to-left shunting of blood**. In view of this newly identified risk, the FDA imposed the addition of a distinct and separate precaution to the prescribing information for INOMAX specifically cautioning about an additional risk of pulmonary edema for patients with left ventricular dysfunction (see paragraph 15). It is important to note that patients covered in the pre-existing contraindication (specifically neonates known to be dependent on right-to-left shunting of blood) were completely excluded from INOT22 by virtue of the labeled contraindication. The newly discovered risk of adverse events in neonates and children with left ventricular dysfunction **who are not dependent on right-to-left shunting** was not addressed, suggested or otherwise inferred from the teachings of Atz & Wessel, because when Atz and Wessel recommend that inhaled NO should be used with caution

“if at all”, that warning relates to neonates **who are dependent upon right-to-left shunting of blood** – a completely different population of patients than the population that is addressed in the present claims.

12. On page 7 of the Office Action, the Examiner further states:

“Since pulmonary hypertension is instantly claimed, then the subject intrinsically has hypoxic respiratory failure.”

This statement is not medically accurate. Pulmonary hypertension occurs in many conditions other than hypoxic respiratory failure, such as congenital heart disease, maternal use of serotonin reuptake inhibitors, idiopathic pulmonary hypertension, etc.

13. On page 7 and 8 of the Office Action, the Examiner states:

“Atz et al. continues with: ‘Therefore, in newborns with severe left ventricular dysfunction, predominantly left to right shunting at the foramen ovale and exclusively right to left shunting at the ductus arteriosus, NO should be used with extreme caution, if at all. We and others have reported adverse outcomes in this circumstance.’ (p. 452, left column) (emphasis differing from original).”

This statement merely reiterates the “caution” delivered by Atz & Wessel for the second population of patients identified in that publication, namely neonates **dependent upon a right-to-left shunt** at the ductus arteriosus. In this statement, Atz & Wessel simply teach that patients with severe left ventricular dysfunction dependent upon an exclusively right-to-left shunt at the ductus arteriosus often have coexistent predominantly left-to-right shunt at the foramen ovale. This additional left-to-right shunt at the foramen ovale, upstream from the dysfunctional left ventricle, permits blood to bypass the dysfunctional left ventricle and enter the right side of the heart, thereby enhancing the ability of the right ventricle to pump sufficient blood through the ductus arteriosus to maintain the systemic circulation. The population of patients dependent upon right-to-left shunting of blood (with or without shunting at the foramen ovale) was already excluded by the pre-existing FDA-mandated contraindication for inhaled NO, and is distinct from the patient population addressed in the present claims.

14. On page 8 of the Office Action, the Examiner states:

"Atz et al. thus identify conditions in the patients which is screening of the patient. Thus, Atz et al. fairly teaches excluding patients which include neonates with left ventricular dysfunction from inhaled NO treatment because the Examiner interprets "if at all" to mean no treatment and hence exclusion from treatment. The left ventricular dysfunction is intrinsically pre-existing."

This statement misinterprets the teaching of Atz & Wessel. Specifically, "if at all" refers to the second patient population, wherein no treatment is allowed in the population of newborn "patients dependent upon right-to-left shunting of blood" who are at risk for circulatory collapse. Because these patients were already contraindicated in the drug labeling for inhaled NO prior to INOT22 (see paragraph 10 above), they were excluded from INOT22 and more importantly, are distinct from the patients identified in the new inhaled NO safety warnings mandated by the FDA in view of the risk that was newly identified as a result of the INOT22 study.

15. On February 25, 2009, INO Therapeutics LLC (owner of NDA 20845) submitted a label supplement to the FDA seeking to amend the prescribing information (i.e., the "label") for INOMAX® (nitric oxide) for inhalation, to include a new warning statement based on the unexpected outcome of the INOT22 study. On August 28, 2009, the FDA approved the INOMAX® label supplement to include the following new information:

WARNINGS AND PRECAUTIONS

Heart Failure: In patients with pre-existing left ventricular dysfunction, inhaled nitric oxide may increase pulmonary capillary wedge pressure leading to pulmonary edema (5.4).

5 WARNINGS AND PRECAUTIONS

5.4 Heart Failure: Patients who had pre-existing left ventricular dysfunction treated with inhaled nitric oxide, even for short durations, experienced serious adverse events (e.g., pulmonary edema).

Thereafter, similar warnings were added to the INOMAX label by Health Authorities in Japan, Europe, Canada and Australia. The FDA (and its counterparts in foreign nations) would

not add new warnings and precautions to the label of an approved drug that merely restate a known contraindication already existing on the approved drug label. Indeed, the new FDA-approved warnings for the use of nitric oxide are clinically distinct from the existing, original INOMAX contraindication disclosed by Atz & Wessel, with respect to neonates dependent on right-to-left shunt.

16. On page 8 and 9 of the Office Action, the Examiner states:

"Kinsella et al. teach excluding patients (premature neonates) from inhaled nitric oxide treatment if they have fatal congenital anomalies or congenital heart disease (Abstract and p. 1062, Methods). Since left ventricular dysfunction is a congenital heart disease, as acknowledged by Applicant, (see specification [0028]), and it would be pre-existing, then the methods of Kinsella et al. intrinsically exclude this patient population from the method. ... The intended patient population is intrinsically at risk of one or more adverse events. Patients are intrinsically identified for nitric oxide inhalation treatment, diagnosed for congenital heart disease which intrinsically includes left ventricular dysfunction, and if the patient meets the criteria then treatment with NO is performed thereby reducing the risk of adverse events associated with the treatment."

Based on these statements, it is clear that the Examiner fails to understand several critical aspects of the study of Kinsella et al.

17. First and foremost, the patients included in the Kinsella et al. trial were premature neonates who have severe respiratory failure due to immature lungs and surfactant deficiency, rather than term and near-term neonates suffering from pulmonary hypertension. In addition, none of the premature neonates enrolled in Kinsella et al. suffered from pulmonary hypertension. Thus, the patients included in Kinsella et al. were clinically differentiated, by age, etiology and pathophysiology, from the term and near-term neonates addressed in the present claims.

18. Secondly, exclusion of patients from a particular study may occur for a variety of reasons. For example, clinical trial inclusion and exclusion criteria are often chosen to define or restrict the study population in order to maximize homogeneity, thereby minimizing the presence of potentially confounding factors. This exclusion greatly facilitates the interpretation of the