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Mucociliary Clearance and Buffered Hypertonic Saline Solution

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Nasal irrigations have been used for centuries without any scientific data to determine efficacy. For 10 years, the senior author has used buffered hypertonic saline nasal irrigation for patients with acute/chronic sinusitis and for those having undergone sinus surgery. A simple study was undertaken using volunteers without any significant sinonasal disease. Patients served as their own control using a saccharin clearance test before any nasal irrigation was used. Patients then used one of two solutions to irrigate their nose—buffered normal saline or buffered hypertonic saline—and were then retested. On a separate day, the control test was repeated, followed by irrigation with the alternate solution and a second saccharin clearance test. The outcome showed buffered hypertonic saline nasal irrigation to improve mucociliary transit times of saccharin, while buffered normal saline had no such effect.

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INTRODUCTION

For more than a century, physicians have advocated nasal irrigation for patients with sinonasal disease. Several different solutions have been suggested to patients without any documented evidence of significant change in symptomatology. For more than 10 years, the senior author (D.S.P.) has used a solution that can be made very inexpensively by patients at home[1] (Table I). The results, as determined by favorable patient responses, seemed promising, but statistical outcomes were lacking.

Both surgical and nonsurgical patients with a history of chronic sinusitis have been encouraged to use buffered hypertonic saline nasal irrigation. Nasal irrigation aids in the clearance of secretions, debris, and intranasal crusts. This is also important in the postoperative period to reduce the risk of adhesions and to promote ostiomeatal patency.

For many decades, physicians have often prescribed the use of "physiologic" or "normal" saline (0.9%), sometimes buffered to a mildly alkaline solution. A hypertonic solution, however, may actually reduce edema through diffusion of osmolar gradients. This should enhance mucociliary clearance and improve patency of sinus ostia. In vitro studies from Meyers et al.[2] have shown a 12-fold increase in mucociliary clearance (MCC) using animal tracheal mucosa which was irrigated with a similar buffered hypertonic solution.

The aim of this study was to determine if MCC in vivo was improved significantly by the use of a buffered hypertonic saline (3%, pH 7.6) vs. buffered normal saline irrigations.

MATERIALS AND METHODS

Twenty-one volunteers aged 25 to 45 years were selected to participate in the study. None of the 21 had any history of upper respiratory tract infection symptoms within the 3 weeks prior to the study. In addition, there could be no history of significant allergies, smoking, or recurrent exposure to smoke-filled environments. Patients taking systemic or topical sympathomimetics, parasympathomimetic agents, or antihistamines were excluded, as were those who had undergone sinus surgery in the past. No volunteer had engaged in any strenuous exercise within 30 minutes prior to testing.

Mucociliary clearance was assessed by using the saccharin clearance test method.[3,4] Testing was performed in an area of constant humidity with a room temperature of 68 to 72°F (20° to 22°C). The subject was asked to sit head upright and several saccharin grains were placed on the medial aspect of the inferior turbinate 1 to 1.5 cm behind its anterior border using a moistened cotton swab. After placement of the saccharin grains, the subject was to refrain from sniffing, bending, or sneezing. The individual was then instructed to swallow at 30-second intervals and

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TABLE I.
Directions for Preparation and Use of the Solution.

Preparation

1. Clean a 1-quart glass jar carefully, then fill it with bottled water. You need not boil the water.
2. Add 2 to 3 heaping teaspoons of pickling or canning salt. DO NOT use table salt, because it contains additives.
3. Add 1 rounded teaspoon of baking soda (pure bicarbonate).
4. Store at room temperature and shake or stir before each use.
5. Mix a new batch weekly.

Use

1. Pour some of the mixture into a clean bowl. Warming it to body temperature may help, but make sure it is NOT HOT.
2. Fill the syringe or bulb irrigator. To avoid contamination, DO NOT place bulb or syringe into jar.
3. Stand over the sink or in shower and squirt the mixture into each side of the nose several times.
4. Rinse the nose two to three times daily.

to record the time of the saccharin taste to the nearest half minute.

Each volunteer was initially assessed for a control saccharin transit time. Subjects were then given 10 sprays with a handheld atomizer of either a 0.9% saline solution or a 3% saline solution (both buffered to pH 7.6) to one side of the nose. Ten additional sprays were then given to the same side after an interval of 1 minute. A second saccharin transit time was performed 10 to 20 minutes after irrigation to assess any change. This same procedure was then repeated on a different day with the opposite concentration used on the initial trial. Again, a control time was obtained prior to testing with the alternate saline solution, followed by a second transit time.

To allow dispersal of excess irrigation fluid and time for an optimal ciliary response to the altered physiologic environment, a period of 10 to 20 minutes separated the nasal irrigation and the placement of the saccharin. Each subject acted as his/her own control for the purposes of analysis. For each subject, transit times following irrigation are compared only with the subject's own control time for that day to compensate for physiological variances such as the nasal cycle or other daily variations in nasal physiology.[4]

The Wilcoxon's signed rank test was used to analyze the data to determine any differences in changes in times, both in minutes and percent of baseline.

RESULTS

Results are shown as saccharin transit times in Tables II and III. This compares times both before and after buffered hypertonic saline nasal irrigation as compared to buffered normal saline nasal irrigation. There was no significant difference in control values between the solutions ($P = 0.27$), thus ruling out any bias due to differing baseline times prior to testing with the buffered hypertonic or normal saline solutions. Transit time decreased from baseline in the buffered hypertonic trials by 17% ($P = 0.007$) compared with a 2% decrease ($P = 0.71$) for buffered normal saline. The difference between the percent changes was statistically significant, with a P value of 0.013.

TABLE II.
Results After Treatment With Hypertonic Saline.

Subject	Control (min)	After BHTS (min)	Change (min)	Change (%)
1	5.5	5.5	0	0
2	7.5	6.5	−1.0	−13
3	9.0	6.0	−3.0	−33
4	10.0	6.5	−3.5	−35
5	8.0	6.5	−1.5	−19
6	18.0	8.5	−9.5	−53
7	28.0	15.5	−12.5	−45
8	17.0	13.0	−4.0	−24
9	15.0	12.5	−2.5	−17
10	11.5	9.5	−2.0	−17
11	23.0	9.0	−14.0	−61
12	6.5	7.0	+.5	+8
13	12.0	8.5	−3.5	−29
14	14.0	11.0	−3.0	−21
15	15.0	10.0	−5.0	−33
16	8.0	10.0	+2.0	−25
17	16.5	11.0	−5.5	−33
18	14.0	17.0	+3.0	+21
19	8.0	10.5	+2.5	+31
20	6.0	6.0	0	0
21	30.5	28.0	−2.5	−8
Mean:	13.5	10.5	−3.0	−17

BHTS = buffered hypertonic saline treatment.

The changes in minutes were also significant. The hypertonic saline produced a mean improvement of 3.1 minutes ($SD = 4.4$; $P = 0.002$) vs. 0.14 minutes in the buffered normal saline group ($SD = 7.0$; $P = 0.69$). Again, the difference of changes was statistically significant to a P value of 0.02. This shows a marked improvement of saccharin transit time with use of buffered hypertonic saline irrigations as compared to buffered normal saline, both in percent change and in change in minutes. Because of intersubject baseline variability, the clinical importance of time changes in minutes is questionable.

DISCUSSION

Otolaryngologists and rhinologists commonly recommend nasal irrigations in the treatment of patients with acute and chronic sinusitis. Nasal irrigations have also been utilized in the postoperative care of functional endoscopic sinus (FES) surgical patients. The irrigations help to clear static secretions, rinse infective debris, and minimize crusting, which may obstruct normal sinonasal drainage or lead to adhesions. The senior author uses a 3%

TABLE III.
Results After Treatment Wtih Normal Saline.

Subject	Control (min)	After NS (min)	Change (min)	Change (%)
1	13.0	13.5	+.5	+4
2	12.0	10.0	−2.0	−17
3	10.0	11.5	+1.5	+15
4	11.5	11.5	0	0
5	11.5	13.5	+2.0	+17
6	13.5	13.5	0	0
7	45.0	20.0	−25.0	−56
8	17.0	23.0	+6.0	+35
9	18.5	15.0	−3.5	−19
10	15.0	15.0	0	0
11	29.0	43.0	+14.0	+48
12	7.0	6.5	−.5	−7
13	7.0	6.0	−1.0	−14
14	9.0	7.5	−1.5	−17
15	9.5	11.0	+1.5	+16
16	14.0	8.0	−6.0	−43
17	13.5	13.0	−.5	−4
18	23.0	28.0	+5.0	+22
19	9.0	14.0	+5.0	+56
20	8.0	6.5	−1.5	−19
21	14.0	17.0	+3.0	+21
Mean:	15.0	14.5	−.14	−2

saline irrigation formula buffered to approximately pH 7.6 in the treatment of patients with acute and chronic sinusitis and as an adjunct in the management of patients with significant rhinitis secondary to other disorders.

It has been suggested that saccharin dissolution in this test method provides a less accurate assessment of MCC than tagged insoluble particles, as the saccharin mixes between sol and gel layers of the mucociliary blanket and is not carried solely in the superficial gel layer. This layer is usually propelled at a more uniform rate by the tips of the cilia, whereas fluid motion in the sol layer may oscillate back and forth.[4] However, it is likely that any such limitation, if present in vivo, would tend to *underestimate* the effect of changes in MCC and the improved clearance rates with the buffered hypertonic saline nasal irrigations. In fact, Proctor has found close correlation, for each individual, between clearance rates with saccharin and tagged insoluble particles.[5]

The results of transit times with the buffered hypertonic saline from this study demonstrate decreased mucous clearance times in the majority of subjects (15/21, 71%) (Table II). The average improvement in these times was 4.87 minutes. Two subjects had no change in MCC rates after 10 to 20 minutes and four subjects actually recorded slower times. Interestingly, the number of patients with improved transit times after the buffered 0.9% saline was less than might be expected (10/21, 48%).

Mucociliary clearance may be modified by changes in ciliary beat frequency (CBF), and rheologic changes in the mucous blanket such as viscosity and shearing forces. Other factors, including cilial loss, outflow obstruction, and mucosal apposition, may also play a role, especially in chronic sinusitis.

Rheologic alterations in this study may be the most important factor. Saline improves MCC in healthy and cystic fibrosis (CF) patients.[6] A change with normal saline irrigations in healthy patients was not seen by Majima et al., but they did see a significant change in those with sinusitis. This may be a result of the saline increasing the depth and thinning of the sol layer of mucous.[7] NaCl also decreases the viscosity of mucus in vitro.[8] Pavia et al.[9] have noted increased mucous clearance from the lung (no change in cough pattern) with the use of small volumes of 7.1% nebulized saline; clearance rates were almost twice as fast as the control group for 50 minutes.

These changes may be more pronounced in pathologic processes such as sinusitis. Some authors have cited increased nasal mucociliary times on saccharin testing of sinus patients vs. normal controls.[7]

Increasing viscosity, as frequently is seen in chronic sinusitis, is believed to gradually decrease CBF.[10] In addition, outflow obstruction, crusting, mucosal apposition, and altered ventilation are all factors which may lead to worsening MCC. All subjects in this study had no symptoms of infective rhinitis or sinusitis. Saline irrigations, and especially buffered hypertonic saline, may have resulted in even greater changes in symptomatic patients.

Buffered hypertonic saline is a mildly alkaline solution. It is believed that an acidic milieu may cause mucus to be present in a "gel" or viscous state. Alkaline environments cause the mucus to be in a "sol" state.[11] This is similar to the gel and sol phases of mucous mentioned previously. The thickened mucous may be more effective in isolating particulate matter, however, it may lead to an increase in the amount of tether between the gel and sol layers[12] and thus interfere with normal mucociliary function.

Other factors in vivo may also be related to nasal MCC. This study did not objectively address the effect of buffered hypertonic saline on nasal patency. It has been frequently noted that there is at least a subjective improvement in nasal patency in patients with congestive rhinitis. The exact role of nasal patency in MCC will require further study.

CONCLUSION

Buffered hypertonic saline nasal irrigation is an important addition to the care of sinus disease, both chronic and postsurgical. Improvement in mucociliary transit times was seen with buffered hypertonic saline solutions vs. buffered normal saline (3.1 minute improvement compared to 0.14 minutes, P = 0.02, and 17% improvement compared to 2%, P = 0.013). Buffered hypertonic saline irrigations should be used in chronic and postoperative sinus patients. Those with other causes of rhinitis, including acute sinusitis, may also benefit from regular nasal irrigation with this solution.

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