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Superficial temporal artery to middle cerebral artery anastomosis

Intraoperative evaluation by fluorescein angiography and xenon-133 clearance

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✔ Fluorescein angiography and xenon-133 (^{133}Xe) clearance studies were performed during surgery on 15 patients who were undergoing superficial temporal artery (STA) to middle cerebral artery (MCA) anastomosis. Fourteen patients had occlusive disease of the internal carotid artery (ICA), and one patient had severe stenosis of the MCA. Before anastomosis, fluorescein angiography showed slow filling of the MCA branches through collateral channels. Focal areas of impaired microcirculatory filling and washout were seen in the territory of severely sclerotic cortical arteries. The findings of preanastomotic ^{133}Xe clearance studies were variable and a uniform pattern of regional cerebral blood flow (rCBF) changes was not defined. In 55% of the patients, rCBF was reduced to 25 ml/100 gm/min or less at one or more detector sites. Fluorescein angiography provided an immediate assessment of anastomotic patency and clearly displayed the distribution of blood entering the epicerebral circulation through the STA. In 67% of patients, multiple MCA cortical branches filled with fluorescein, whereas in 33% filling was restricted to the receptor artery territory. An immediate, substantial ($\geq$ 15 ml/100 gm/min) increase in rCBF was demonstrated in 73% of patients after anastomosis. The rCBF changes were consistently better in patients with donor and receptor arteries greater than 1 mm in diameter. Redistribution of collateral input acted to increase rCBF in areas distant from the anastomotic site. Some improvement in fluorescein circulation and rCBF also was seen in cortex supplied by sclerotic MCA branches.

KEY WORDS · cerebral ischemia · cerebral revascularization · cerebral blood flow · fluorescein angiography

CEREBRAL blood flow (CBF) in patients undergoing superficial temporal artery (STA) to middle cerebral artery (MCA) anastomosis has been studied before and after surgery by Schmiedek, *et al.*,[18] Yamamoto, *et al.*,[12,23,24] and others.[1,14] These investigations demonstrated reduced regional cerebral blood flow (rCBF), usually multifocal, in the cerebral hemisphere ipsilateral to the occluded internal carotid artery (ICA) or MCA. The revascularization

Information about the changes in the epicerebral circulation and rCBF during surgery is limited. Experimental studies have been performed on dogs,[15,16] but the results, although interesting, are difficult to relate to the human situation. The object of this investigation was to study the epicerebral circulation and rCBF during surgery in patients undergoing STA-MCA anastomosis for occlusive disease of the ICA or MCA. This was accomplished using fluorescein

TABLE 1

*Clinical presentation and diagnostic findings in 15 patients undergoing STA-MCA anastomosis**

Case No.	Sex, Age (yrs)	Clinical Diagnosis	Clinical Localization of Cerebral Ischemia	Angiographic Findings	CT Scan Findings
1	M, 44	recent small stroke, TIA'S	rt fronto-parietal	rt ICA stenosis (diffuse)	no abnormality
2	M, 59	recent small stroke, TIA's	lt frontal, lt parieto-occipital	lt ICA occlusion, lt ECA stenosis (95%), rt CCA occlusion	no abnormality
3	M, 68	recent small stroke	lt frontal	lt ICA occlusion	small lt cerebral infarction
4	M, 60	recent small stroke, lt amaurosis fugax	lt parietal	lt ICA occlusion, lt ECA stenosis (50%)	small lt cerebral infarction
5	M, 50	recent small stroke, TIA'S	rt frontal	rt ICA occlusion	small rt cerebral infarction
6	M, 63	recent small stroke	lt parietal, rt frontal	lt & rt ICA occlusion, lt ECA stenosis (95%)	bilateral cerebral infarction
7	F, 60	recent small stroke, TIA's	lt frontal	lt ICA stenosis (supraclinoid)	no abnormality
8	M, 51	old lt cerebral stroke, TIA's	rt fronto-parietal	rt & lt ICA occlusion, rt ECA stenosis (70%)	large lt cerebral infarction (old)
9	F, 61	recent small stroke, TIA's	rt fronto-parietal	rt ICA occlusion, rt ECA stenosis (95%)	small rt cerebral infarction
10	M, 16	recent small stroke	rt frontal	rt ICA stenosis (supraclinoid)	small rt cerebral infarction
11	M, 55	recent small stroke, TIA'S	rt frontal	rt ICA occlusion	no abnormality
12	F, 47	recent small stroke, TIA's	lt fronto-parietal	lt ICA occlusion, lt ECA stenosis (90%)	no abnormality
13	M, 53	TIA's	lt frontal	lt ICA occlusion	no abnormality
14	F, 47	old lt cerebral stroke, TIA's	lt fronto-parietal	lt ICA occlusion	lt cerebral infarction
15	M, 39	recent small stroke TIA's	lt frontal	lt MCA stenosis	no abnormality

*STA = superficial temporal artery; MCA = middle cerebral artery; TIA = transient ischemic attacks; ICA = internal carotid artery; ECA = external carotid artery; CCA = common carotid artery; CT = computerized tomography.

Clinical Material and Methods

Patient Population

Fluorescein angiography and ^{133}Xe clearance studies were performed during surgery on 15 patients (Table 1) undergoing STA to MCA anastomosis. The 11 men and 4 women ranged in age from 16 to 68 years (mean: 51 years). Atherosclerosis was the primary pathological process in the 14 adults. The arteriopathy in the 16-year-old male patient (Case 10) was thought to be the result of homocystinuria.

Clinical Presentation

Eleven patients presented with cerebral transient ischemic attacks (TIA's) in the MCA distribution. Nine of them had also suffered a recent (< 3 months ago) small cerebral infarct. One patient (Case 4) had small, ipsilateral infarct. The three remaining patients had experienced recent cerebral infarction only.

Cerebral Angiography

Preoperative angiography with visualization of the aortic arch, vertebral arteries, and carotid arteries (both intracranially and extracranially) was carried out in each case. Ipsilateral occlusion of the ICA was demonstrated in 11 patients. Inaccessible ICA stenosis was seen in three patients, including the 16-year-old boy (Case 10) who was shown to have progressive, severe stenosis of the supraclinoid segment. Four patients with ICA occlusive disease also had focal, high-grade (≥ 90%) stenosis at the origin of the ipsilateral external carotid artery (ECA). They underwent external carotid endarterectomy with insertion of a vein-patch graft 2 weeks before craniotomy.

tomy performed 2 weeks after craniotomy. Severe, focal stenosis of the MCA trunk was demonstrated in Case 15.

Operative Procedure

A No. 18 polyethylene catheter was inserted percutaneously into the ipsilateral common carotid artery (CCA) immediately before surgery. The catheter was intermittently irrigated with small amounts of heparinized saline (1000 units/500 ml isotonic saline) throughout the operation to prevent thrombus formation and to maintain catheter patency.

An inverted U-shaped scalp flap was turned. The larger STA branch, together with a generous cuff of connective tissue, was mobilized carefully. A relatively large temporoparietal craniotomy was performed. The largest exposed cortical artery, usually the angular branch of the MCA, was selected as the receptor vessel. Mean STA diameter was 1.3 mm (range: 0.9 to 1.6 mm) and mean receptor artery diameter was 1.2 mm (range: 0.9 to 1.6 mm). Continuous suturing[11] was performed for the anastomosis in all but the initial three patients, in whom the standard interrupted suture technique was used. The operations were carried out by one surgeon (J.R.L.).

The arterial blood pressure was maintained at preoperative levels during the intraoperative studies. Arterial pCO_2 was kept in the 40 $\pm$ 3 torr range.

Intraoperative Studies

Fluorescein Angiography. The technique of fluorescein angiography has been described in detail elsewhere.[5,6,9] Studies were performed before and after anastomosis. Sodium fluorescein (5 ml of a 1% solution) was injected rapidly into the ipsilateral CCA through the indwelling catheter. Illumination for photography was provided by a strobe light equipped with a Kodak-Wratten 47A filter.* Barrier filters (Kodak-Wratten 2B and 21) were used to keep unwanted exciting radiation from reaching the film. Rapid, serial photographs of the cortex were taken with a motorized Nikon camera fitted with a 200-mm Medical Nikkor lens.† A data-back digital timer‡ automatically printed the time in one-hundredths of a second in the corner of each frame. The surgeon viewed the operative field through a presterilized Kodak-Wratten 21 filter.

Xenon-133 Clearance Studies. Clearance studies were performed immediately following fluorescein angiography, that is, before and after anastomosis. The cortex was covered with a thin plastic film. Four small, lithium-drifted semiconductor detectors were placed gently on the plastic film overlying the inferior frontal, supramarginal, angular, and superior temporal gyri. Xenon-133 (10 to 12 mCi) dissolved in 3 ml of isotonic saline was rapidly injected into the ipsilateral CCA through the indwelling catheter. The detecting system was remotely connected through a scalar interface to a PDP-12 computer. The mean rCBF from each cortical area was calculated by a modification of the stochastic analysis.[5,10]

Results

Intraoperative Findings

Gross Observations. Evidence of previous infarction, consisting of gyral atrophy and pallor, was seen in 10 patients. It involved a single gyrus in two patients, two or three gyri in six patients, and more than three gyri in two patients. In eight of these 10 patients, cortical infarction was found to lie in the territory of a severely sclerotic cortical artery. Neovascularization, consisting of numerous irregular, thin-walled vessels, was seen adjacent to the infarcted areas in 5 patients.

Fluorescein Angiography. Studies performed before anastomosis showed delayed filling of the cortical branches of the MCA. The mean duration between injection of fluorescein into the ipsilateral CCA and its initial appearance in the epicerebral circulation was 2.4 $\pm$ 0.4 seconds, compared with 0.7 $\pm$ 0.3 seconds following anastomosis. In patients with occlusive disease of the ICA, filling of the MCA branches occurred in an anterograde direction. In the patient with high-grade stenosis of the MCA trunk (Case 15), filling of the MCA branches occurred in a retrograde direction through epicerebral collateral channels from the anterior and posterior cerebral arteries.

Patency of the anastomosis was demonstrated in 13 patients. In one of these patients (Case 13), partial obstruction of the STA was seen at the site where the temporary occluding clip had been applied. This was corrected by gentle manipulation and the application of a small amount ($\leq$ 2 ml) of 1% Xylocaine (lidocaine). The anastomosis was found to be occluded in two patients. A thrombus was successfully removed and patency restored in one of these patients (Case 6). In the other (Case 3), patency was re-established in the proximal segment only of the receptor artery. The cortical receptor artery in both patients was narrow (< 1 mm) and diffusely atherosclerotic.

Fluorescein transit time through the STA was slow (> 1.5 seconds) in two patients. One (Case 8) had a 70% stenosis at the origin of the ECA. The other patient (Case 9) had a diffusely narrow (< 1 mm), atherosclerotic STA.

Circulation time, that is, time between maximum arterial and venous filling, was improved in all

*Kodak-Wratten 47A filters manufactured by Eastman Kodak Co., 3483 State Street, Rochester, New York.

†Nikon camera and Nikkor lens manufactured by Nikon, Inc., 623 Stewart Avenue, Garden City, New York.

‡Data-back digital timer designed and made in the Department of Neurosurgery, Montreal Neurological Institute, Montreal, Quebec, Canada.

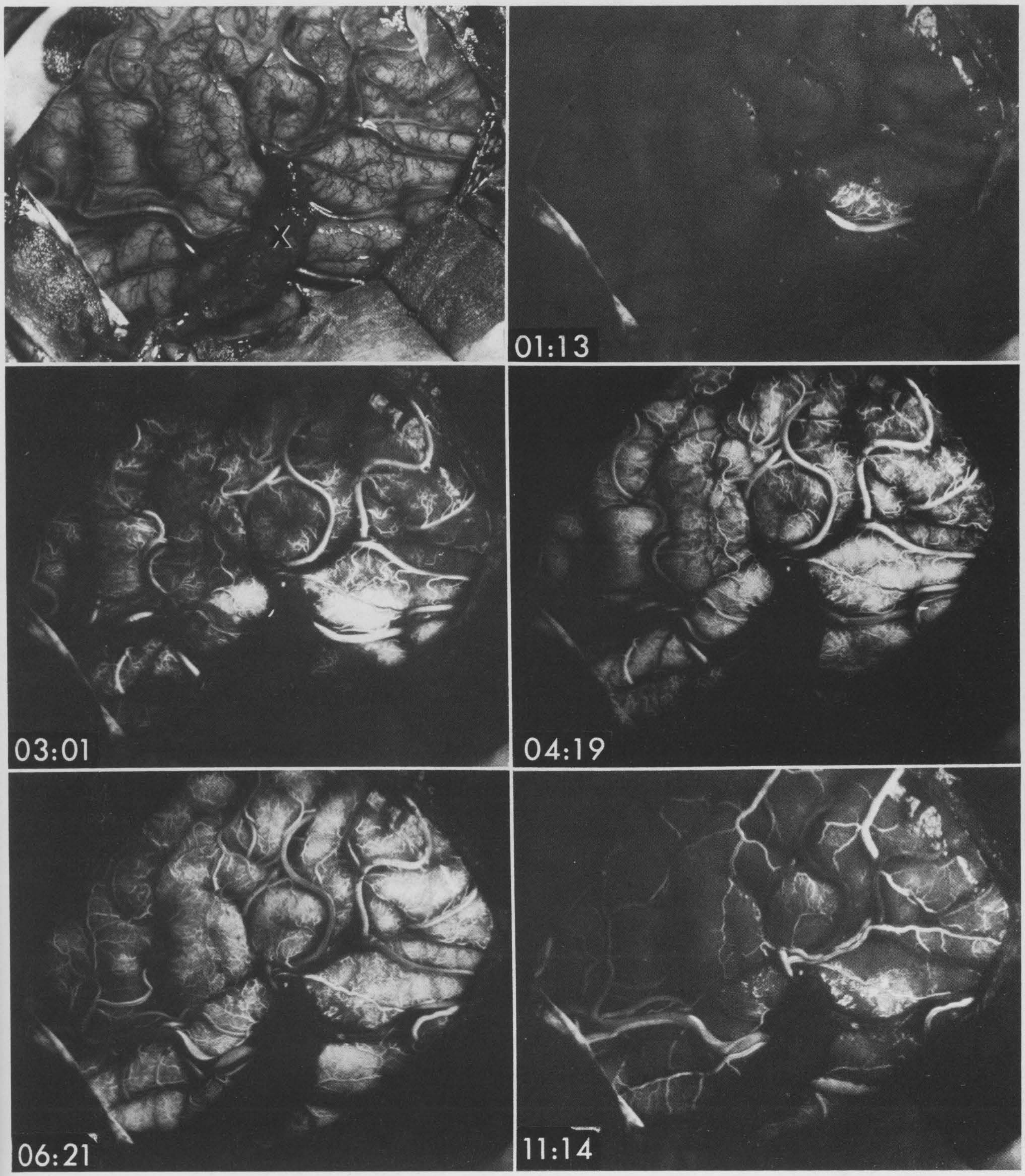

FIG. 1. Fluorescein angiography after anastomosis in Case 4. *Upper Left:* Left temporoparietal craniotomy before fluorescein angiography. The superficial temporal artery was covered by a generous cuff of connective tissue and fat (X). *Upper Right:* At 01:13 seconds following injection of fluorescein, filling of the cortical receptor artery was observed. *Center Left:* The cortical branches of the middle cerebral artery filled in an anterograde direction. The microcirculation supplied by the receptor artery also has filled. *Center Right:* Microcirculatory filling was widespread. *Lower Left:* Filling of cortical veins has begun. *Lower Right:* At 11:14 seconds, the veins were well filled and microcirculatory washout was essentially complete. Leakage of fluorescein into the extravascular compartment was seen adjacent to the cortical

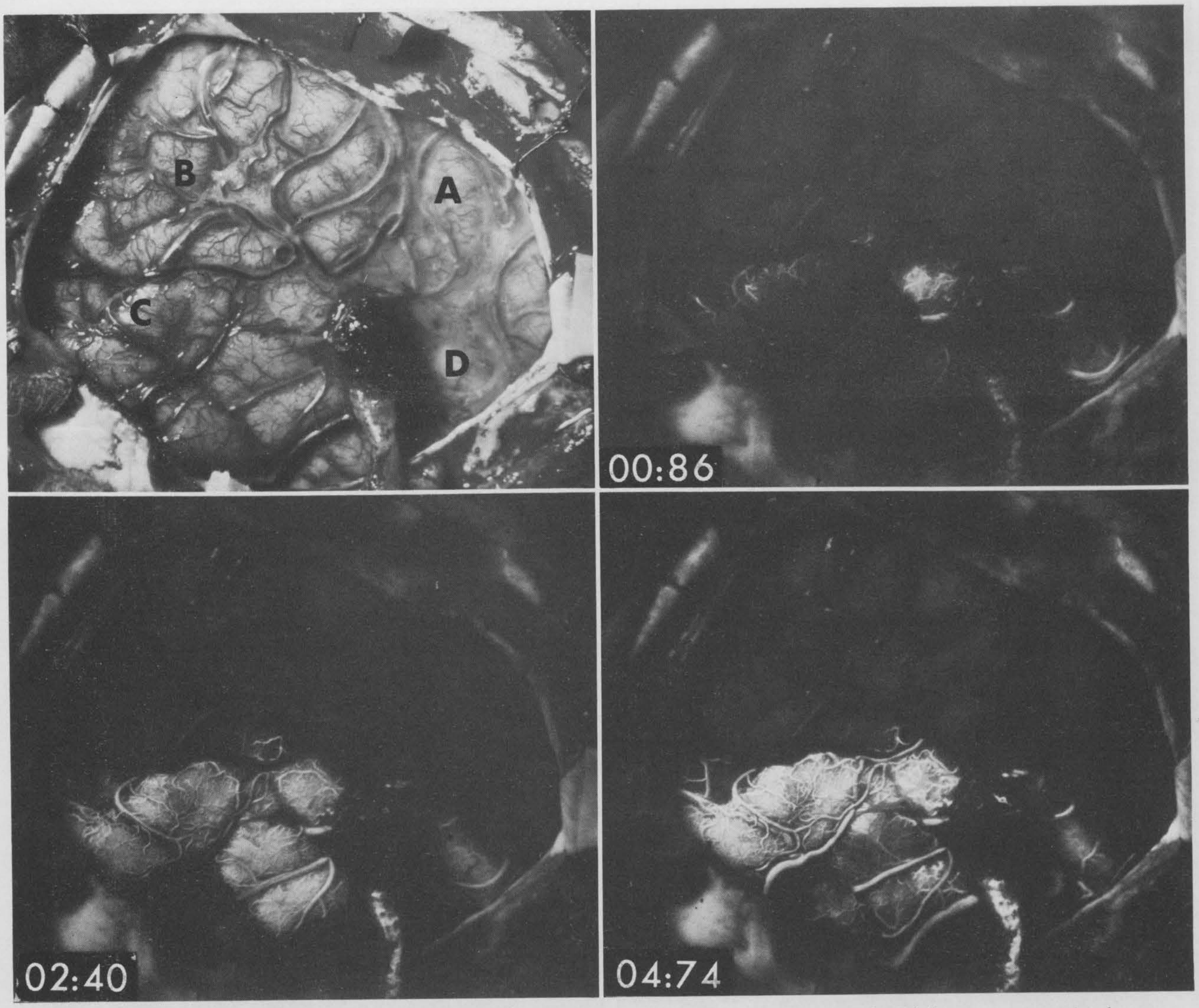

FIG. 2. Fluorescein angiography after anastomosis in Case 5. *Upper Left:* Right temporoparietal craniotomy before fluorescein angiography. The letters indicate the sites of the ^{133}Xe detectors. *Upper Right:* At 00:86 seconds following injection of fluorescein, filling of the cortical receptor artery was observed. *Lower Left:* Fluorescein filling was limited predominantly to the receptor artery territory. *Lower Right:* At 04:74 seconds, the veins draining this area filled with fluorescein. Washout in the lower gyri was more rapid. Preanastomotic regional blood flow (rCBF), in ml/100 gm/min, at the four detector sites was: A, 15; B, 15; C, 17; and D, 20. Postanastomotic rCBF was: A, 56; B, 33; C, 60; and D, 40.

patients following anastomosis. Comparison of the preanastomotic and postanastomotic circulation times revealed a mean improvement of 44% (range: 10% to 80%).

Fluorescein angiography showed the distribution of blood supplied by the STA through the anastomosis. Of the 14 patients who underwent surgery for occlusive disease of the ICA, nine had filling of multiple MCA cortical branches (Fig. 1) and five had filling predominantly in the receptor artery territory (Fig. 2). Essentially all of the MCA cortical branches filled in an anterograde direction in the patient (Case 15) with MCA occlusive disease (Fig. 3).

Many of the severely sclerotic cortical arteries were occluded and consequently did not fill with fluorescein. The cortical microcirculation in their territory occasionally filled slowly through multiple irregular, thin-walled channels (that is, by neovascularity) coming from adjacent cortical arteries. Impaired microcirculatory filling and washout were often seen in areas supplied by patent, sclerotic MCA branches (Fig. 4). Although these regional flow abnormalities persisted after anastomosis, some improvement was noted.

Extravasation of fluorescein out of the microvasculature was occasionally observed adjacent to the

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