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Intracranial vascular anastomosis using the microanastomotic system

Technical note

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The authors describe the use of a microanastomotic device to perform intracranial end-to-end vascular anastomoses. Direct end-to-end anastomosis was performed between the superficial temporal artery and branches of the middle cerebral artery (MCA) in three patients. Two patients had moyamoya disease, with severe proximal MCA disease, and one suffered an internal carotid artery occlusion with poor collateral flow. All patients reported a history of recent ischemic symptoms. Each anastomosis was accomplished in less than 15 minutes with technically satisfactory results. Postoperative angiographic studies demonstrated patency of the bypasses in all patients.

KEY WORDS • microanastomotic system • intracranial anastomosis • superficial temporal–middle cerebral artery bypass • moyamoya disease • carotid occlusion

INTRACRANIAL vascular anastomosis performed by means of microsurgical techniques has been well described and has been used to accomplish extracranial–intracranial (EC–IC) bypasses with the superficial temporal artery (STA) or occipital artery as a donor vessel as well as to anastomose vein grafts from the EC–IC circulation.[15,21] More recently, IC–IC vascular anastomosis in which interposition grafts featuring microsuture anastomoses were used has been described in the treatment of intracranial vascular lesions, most commonly large aneurysms.[10]

A microanastomotic system initially described by Östrup and Berggren[16] has been used in plastic and reconstructive surgery to accomplish anastomosis of small arteries and veins by using a coupling device without sutures. Advantages of the system include very high-quality anastomoses with lumen-to-lumen contact of the vessels and high patency rates. Another distinct advantage is the shorter time needed for the anastomotic procedure compared with microsurgical techniques in which sutures are used, which may reduce the risk of ischemic neuronal damage during anastomosis of cerebral vessels.

Description of the Technique

The microvascular anastomotic system (Futuretech, Bessemer, AL) is composed of two polyethylene rings that each have six sharp pins embedded in them. To perform an end-to-end anastomosis (Fig. 1), the end of each vessel is brought through the center of the appropriately sized ring, everted, and then impaled on the pins. The vessel is thereby perforated from the outer to inner surface. Closing the microanastomotic device brings the two rings into opposition. Further closure allows each set of pins to become seated in perforations on the opposite ring, and in this way the vessels are coupled with lumen-to-lumen contact. The two halves of the device are then pinched with forceps to assure proper seating of the pins. Final tightening of the device forces a drive pin to release the anastomosed vessels and the polyethylene rings from the holder. The temporary vessel clips are then released, and flow is reestablished.

Illustrative Cases

Case 1

The first patient in whom the device was used was a 56-year-old man who had developed moyamoya disease 2 years after receiving a bone marrow transplant for acute lymphocytic leukemia. His initial symptoms were transient ischemic attacks (TIAs) referable to both cerebral hemispheres, characterized by numbness and weakness of his left arm, followed by the development of similar

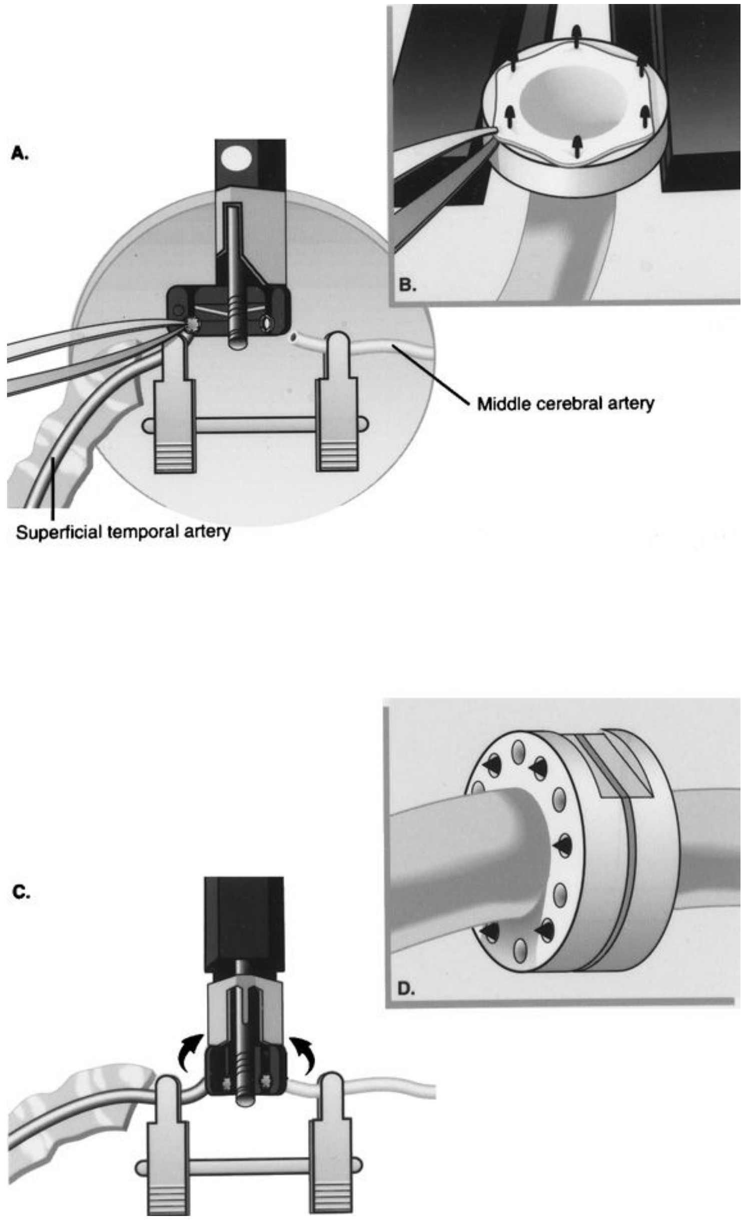

FIG. 1. Illustrations showing the technique for anastomosing microvessels by using the microanastomotic device. A and B: The vessels are loaded onto the ring by pulling the cut end through the ring and everting the edges of the vessel onto the pins, using specially designed forceps. C and D: The leaves of the ring-holding device are then opposed by turning a knob on the applicator, completing the anastomosis.

symptoms referable to the right side. Evidence of multiple small infarctions in the border zone areas between the anterior cerebral artery (ACA) and middle cerebral artery (MCA) perfusion distribution of the right hemisphere was present on computerized tomography (CT) and magnetic resonance studies of the brain. A single-photon emission CT (SPECT) scan was obtained and revealed decreased resting perfusion in the right frontal and temporal as well as in the left insular regions. The patient subsequently suffered a stroke involving the left brain and manifesting as aphasia and hemiparesis on the right side. A cerebral angiogram revealed a right MCA occlusion and severe supraclinoid carotid stenosis on the right side and also a severe stenosis of the left supraclinoid carotid artery and MCA. The patient began to recover slowly and a right STA–MCA bypass was performed using a microvascular suture technique to improve the perfusion to the right hemisphere. Approximately 3 weeks after the right bypass, a left STA–MCA bypass was performed using the microanastomotic system.

Operative Procedure

The STA was traced by means of Doppler ultrasonography and dissected using standard techniques. The cra-

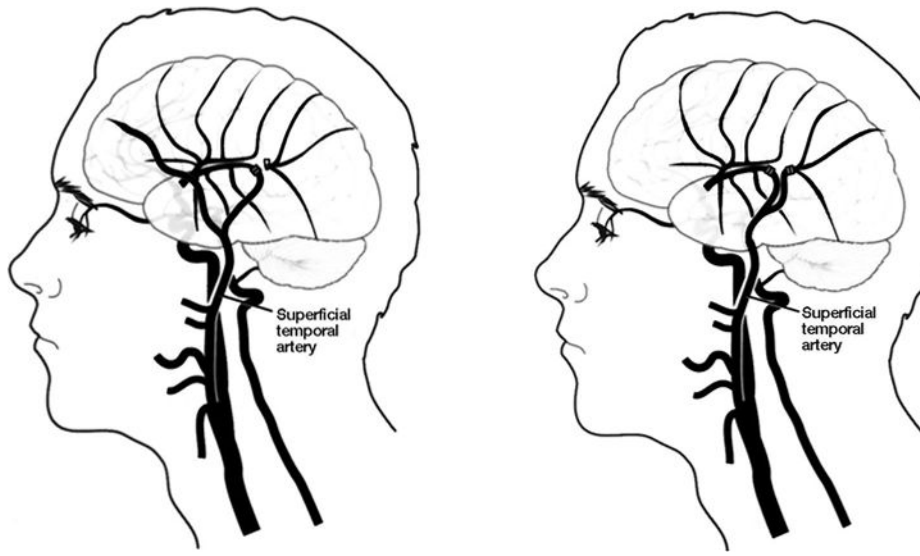

FIG. 2. Illustrations showing the configuration of the bypass grafts used in the three cases described. *Left:* Case 1 involved a patient with moyamoya disease in whom the flow was retrograde in the MCA branches. An end-to-end anastomosis was performed between the STA and a sylvian branch of the MCA. The distal branches of the MCA were ligated. *Right:* In Cases 2 and 3, two branches of the STA were mobilized, and end-to-end anastomoses were joined to the divided ends of the MCA branch.

niotomy was performed over the left sylvian fissure, and the arachnoid over the fissure was opened. Following identification of a branch of the MCA in the sylvian fissure, a directional Doppler ultrasound device was used to record the blood-flow velocity as well as the direction of flow in the vessel. It was determined on Doppler ultrasonography that the blood was flowing retrograde in the MCA branch. An MCA branch that measured 1.5 mm in diameter was chosen and was then further dissected, and small perforating branches were divided. The STA was prepared by stripping the surrounding tissue from the distal part of the vessel for approximately 2 to 3 cm and dividing it distally. The vessel was then irrigated with heparinized saline solution and clamped with a temporary vascular clip. A set of 1.5-mm collars was chosen and placed in the microanastomotic device. The STA was placed in one of the collars with the aid of microscopy (Fig. 1) as previously described. Acklund Beamer temporary clips were placed on the MCA branch and the vessel was then divided in half. The microanastomotic device was then brought into the sylvian fissure and the MCA branch was brought through the opposing collar and impaled on the pins by using jeweler's forceps, and Pierse ring-end forceps (MI 1517-3; Micrins Corp., Lake Forest, IL). The two vessel ends were then opposed by tightening the knob on the end of the device. A small hemostat was used to ensure good closure of the device and it was then expelled from the holder. Following inspection, the clips were removed and brisk flow was established from the superficial temporal into the middle cerebral branch on removal of the STA temporary clip. The MCA branch had been cross-clamped for approximately 10 minutes before flow was reestablished. The Doppler ultrasound recording obtained intraoperatively revealed excellent flow through the anastomosis. There was no leaking at the site of the anastomosis at any time after vessel coupling. A small amount of cotton and surgicel were then placed around the vessel and it was irrigated with a dilute solution of papaverine. A permanent aneurysm clip was then placed on the distal MCA branch (Fig. 2 *left*). Postoperative angiograms obtained 1 day after surgery revealed good flow through the STA, which subsequently filled the periinsular middle cerebral branches. The anastomosis has remained patent on color-flow Doppler studies for 1.5 years after the operation. The patient suffered no complications from the procedure.

Case 2

This previously healthy 30-year-old woman initially presented to medical attention after a mild left hemisphere stroke. She subsequently experienced repeated TIAs and further strokes manifested by episodes of aphasia, right hand weakness, and sensory symptoms. Diagnostic tests were performed, including CT and MR studies of the brain, which revealed small infarctions in the left frontal and parietal regions. On cerebral angiography severe stenosis was revealed in the left MCA, proximal ACA, and distal internal carotid artery. Small collateral vessels were also found in the region of the carotid termination. Mild stenosis of the right proximal MCA and ACA was also present, consistent with the diagnosis of moyamoya disease. Regional cerebral perfusion was evaluated on ^{99m}Tc-SPECT scans, which revealed a mild decrease in perfusion at rest and a marked decrease in the left hemisphere following the administration of Diamox.

Operative Procedure

Two equal-sized frontal and parietal branches of the STA branching approximately 2 cm above the zygoma were identified on angiography. Both branches of the STA

FIG. 3. Case 2. Intraoperative photograph of the anastomoses between two branches of the STA *(arrows)* and the divided MCA branch *(arrowheads)*.

were dissected and mobilized. A craniotomy was performed over the posterior aspect of the sylvian fissure, and a posterior temporal surface branch of the MCA, which measured approximately 1.5 mm, was identified, dissected, and mobilized. Acklund Beamer temporary clips were placed across the vessel, and it was divided in half. The microanastomotic device was then used to perform an end-to-end anastomosis from each branch of the STA to each end of the divided MCA branch, using 1.5-mm collars (Figs. 2 *right* and 3). There was no leakage of blood from either anastomosis following release of the temporary clips, and excellent flow was confirmed in each branch by means of Doppler ultrasonography. The total cross-clamp time required to perform both anastomoses was 30 to 35 minutes.

An angiogram was obtained 1 day postsurgery and showed patency of both anastomoses. Subsequent follow-up angiography performed 3 months later showed continued patency of both branches of the STA and both bypass grafts, with enlargement of the proximal branch and a slight decrease in the size of the distal branch.

Case 3

This 71-year-old woman presented with repeated TIAs, characterized by episodes of aphasia and right upper-extremity clumsiness and weakness. Evaluation of her admission CT scans revealed that she had a small parietal infarction and a left internal carotid occlusion. There was no crossover via the anterior communicating artery and no forward fill through the posterior communicating artery. The patient was initially placed on aspirin therapy, which was then discontinued because of continued ischemic symptoms, and Coumadin was instituted. She continued to experience transient ischemic symptoms while taking Coumadin and also suffered gastrointestinal bleeding, which required that the medication be discontinued.

Physiological testing including transcranial Doppler ultrasonography with autoregulation and CO_2 reactivity testing, as well as SPECT scanning before and after Diamox administration revealed evidence of exhausted vasomotor reserve. The patient underwent an STA–MCA bypass.

Operative Procedure

The STA bifurcated into two equal-sized frontal and parietal branches, which were both dissected. After a craniotomy was performed to expose the perisylvian region, a posterior temporal branch of the MCA, which measured approximately 1.5 mm in diameter, was isolated and dissected free from its small perforating branches. Temporary clips were placed and the MCA branch was divided. A lacrimal dilator was used to enlarge the branches of the MCA and STA before anastomosis. The microanastomot-

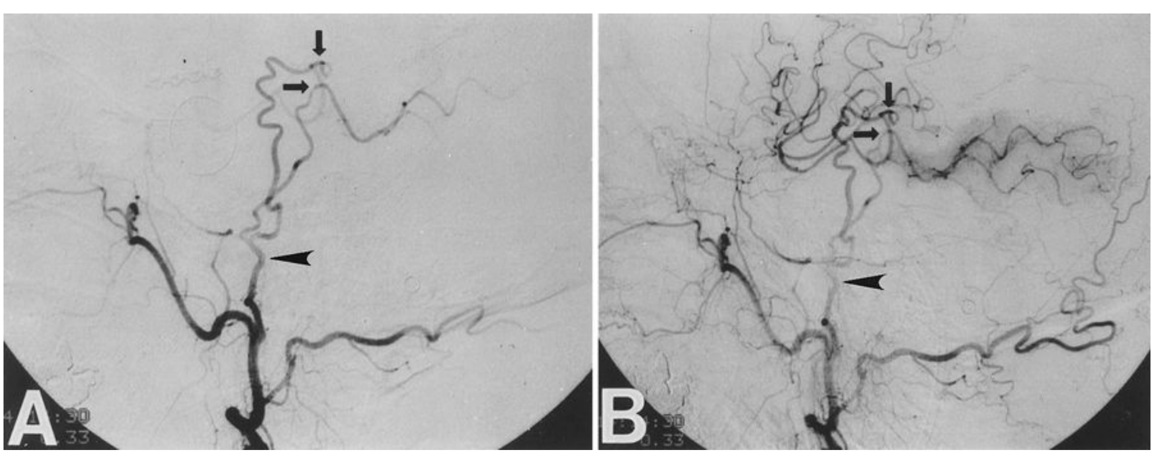

FIG. 4. Case 3. Postoperative angiograms obtained 1 day after surgery, illustrating early (A) and late (B) filling of the STA–MCA bypass made by using the microanastomotic device. *Arrows* illustrate the site of anastomosis, and the STA is marked by the *arrowhead.*

ic device was used to perform two end-to-end anastomoses between the two branches of the STA and each end of the MCA branch as described in the previous case (Fig. 2 *right*). The total time taken to perform both anastomoses, from clamping of the MCA branch to restoring flow in both branches, was 25 minutes. Postoperative angiographic studies revealed excellent flow into both branches of the recipient vessel (Fig. 4). Repeated angiographic studies obtained 6 months postsurgery revealed patency of both branches of the bypass without significant enlargement of the vessels.

Discussion

Intracranial vascular anastomosis accomplished with microsutures is an established technique in a variety of procedures used in cerebrovascular neurosurgery. An alternative to the standard suture technique for connecting vessel ends intracranially, a microanastomotic device, is described in this report.

The EC–IC bypass procedure continues to be a useful adjunct in the treatment of giant aneurysms and may be useful in selected patients with refractory cerebral ischemia caused by proximal intracranial vessel occlusions or stenosis.[1,4,9,13,15,19,20] In patients with moyamoya disease, revascularization surgery in which either direct STA–MCA bypass or synangiosis procedures are used has been described and is effective in improving cerebral perfusion in these patients.[6,7,12] Although EC–IC bypass has not been demonstrated to be effective in reducing stroke in unselected patients with occlusive disease of the MCA, carotid siphon, or carotid occlusion,[5] recent reports have described the use of the STA–MCA bypass to alleviate symptoms and improve cerebral perfusion in patients who have occlusive disease and decreased vasomotor reserve that produce continued ischemic symptoms.[13,19] Although the operation remains controversial, it is possible that a subgroup of patients with occlusive cerebrovascular disease and poor hemodynamic reserve may benefit from procedures designed to augment cerebral blood flow.[1,3]

The microanastomotic device has been introduced as an alternative to the microsuture technique and has been used with excellent results for anastomosis of small arteries and veins in reconstructive surgery.[2,14,18] The stated advantages are an excellent technical anastomosis with high patency rates and a shorter time for performing the procedure. It has been noted that in peripheral vessels the device is particularly suited for venous anastomosis, because the vessel walls are thinner and can be more difficult than arteries to suture. The cerebral arteries are also thin walled compared with peripheral vessels and therefore are also well suited for anastomosis with this device.

The potential advantages of using the device in the cases described in this report are twofold. First, a shorter cross-clamp time than for the standard suture anastomosis was achieved in all three cases. Each end-to-end anastomosis in the cases reported here required approximately 10 minutes to perform. The total cross-clamp time for the MCA branch with the two-limb bypass was approximately 25 minutes in both cases. With additional experience this time may be further shortened. In our experience a standard suture end-to-side STA–MCA anastomosis requires approximately 40 to 45 minutes of cross-clamp time for the MCA branch. In most cases, the duration of cross-clamping needed to perform a standard suture STA–MCA bypass is not sufficient to cause ischemia. However, if patients who are now being selected for the procedure have compromised cerebrovascular reserve, long temporary occlusion times, particularly in proximal vessels, may lead to ischemic brain damage in some cases and may potentially be avoided using this technique.

Another possible advantage is that a bypass with an immediately higher flow than a standard single-vessel end-to-side STA–MCA bypass may be constructed with a short cross-clamp time. In Cases 2 and 3, the construct involved the use of two branches of the STA for anastomosis to each end of an MCA branch, with the potential for higher flow than a standard single-limb end-to-side STA–MCA bypass.

In all three cases the anastomotic device provided an immediate high-caliber anastomosis that had excellent flow characteristics as assessed by intraoperative Doppler ultrasonography and postoperative angiography. Patients such as the one presented in Case 1, who had a proximal MCA occlusion, have a somewhat unique circulation in that the initial flow was retrograde in the branches of the MCA. It was judged that the distal artery could be clipped without compromising flow, thereby allowing an end-to-end anastomosis between the STA and a more proximal MCA branch than is normally used. Under circumstances that include a patent MCA and antegrade flow, STA–MCA bypass procedures are usually done in an end-to-side fashion. In this situation, the construct described in Case 1 may not be advisable. As illustrated in Cases 2 and 3, an alternative construct in which two branches of the STA are used is more appropriate in cases in which flow is normally directed in the MCA branches. However, this configuration may not be possible in all patients because of the variations in the branching pattern of the STA. The microanastomotic device can be used to perform an end-to-side anastomosis,[11,17] but this may not be advisable with vessels of small caliber such as the distal MCA branches.

Another potential use of the microanastomotic device is IC–IC interposition grafting in which either small arterial or vein grafts are used to bypass intracranial lesions such as large aneurysms. Several recent reports have described the use of microvascular suture techniques to perform intracranial interposition grafts.[9,10] The faster anastomosis time and reduced cross-clamp time afforded by the microanastomotic device may be more advantageous for this purpose, for which more proximal vessels are cross-clamped. The current design of the applicator may limit its use in deeper and more restricted brain regions; however, redesign for this purpose appears to be feasible.

A potential disadvantage in using the microanastomotic system described is that the ring needed to connect the vessels may not allow as much expansion of the anastomosis as would the suture technique. A continuous suture may similarly restrict expansion of the anastomosis more than an interrupted suture technique. Latchaw, et al.,[8] have demonstrated maturation of STA–MCA bypasses by documenting increased bypass vessel caliber, as well as increased perfusion territory on serial angiographic studies in some cases. We have also obtained short-term follow-up angiographic studies at 3 months postoperatively in

Case 2 and at 6 months postoperatively in Case 3 and only observed evidence of enlargement in one of the feeding vessels; all of the bypasses have remained patent. Enlargement of feeding vessels is likely dependent on flow demand and other factors, in addition to local factors at the site of anastomosis. Other potential disadvantages of using the device exist. As with microvascular sutures, effective use requires experience with microvascular techniques. If the vessels are mishandled they can tear, resulting in the need to trim back the end, thereby shortening the vessel. The use of specially designed Pierse ring-end forceps can minimize vessel damage. Another requirement for use of the device is that the vessel size be relatively close to the size of the ring used. If a vessel is too small for a given ring size it can tear during loading. If a vessel is too large, it can lead to redundancy and narrowing within the ring. We attempted to use the device to treat a patient with moyamoya disease, whose case is not outlined in this report, in whom a saphenous vein graft was anastomosed end-to-end to an MCA branch. The vein was too large for the 1.5-mm ring selected and created redundancy and narrowing within the ring. The procedure was therefore converted to a suture anastomosis.

Conclusions

Based on our initial experience, it appears that the microanastomotic device is feasible for intracranial vascular anastomosis and may offer advantages over suture techniques, including reduced cross-clamp time and the construcion of higher flow bypasses. Reduction in cross-clamp time for more proximally located anastomoses may allow safer vascular reconstruction for large or calcified aneurysms that cannot be directly clipped.

Disclosure

None of the authors has any financial interest in the device described in this report.

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