End-to-side anastomosis of small vessels using an Nd:YAG laser with a hemispherical contact probe

Technical note

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A new technique is described which enables the surgeon to perform an end-to-side anastomosis between arteries with little (< 2 minutes) or no occlusion of the recipient artery. The technique was developed in rabbits, but has recently been successfully used in a patient in whom an anastomosis between the superficial temporal artery and a proximal branch of the middle cerebral artery was created.

KEY WORDS • vascular anastomosis • extracranial-intracranial bypass • laser

For some years, we have been trying to develop a technique that would enable us to create an anastomosis between arteries without occlusion or with a very short occlusion time of the recipient artery. When such a technique is developed, a high-flow bypass procedure will be feasible with the proximal portion of the middle cerebral artery (MCA) as the recipient artery. In a recent article, we described a technique in which the donor artery was sutured for three-fourths of its circumference to the exterior of the recipient artery before the recipient artery was occluded. After occlusion, a hole was cut in the arterial wall and the anastomosis was completed with a running suture. In this way, the occlusion period was reduced to about 5 to 10 minutes, and in a large series of rats an anastomosis was created with a patency rate of about 95%.

In an addendum to that article we alluded to an improvement of that technique which completely obviated occlusion of the recipient artery. In this communication we describe this technique in detail and present our experimental and initial clinical results.

Surgical Procedure

The experiments were performed in Flemish Giant rabbits under general anesthesia (halothane). Figure 1 illustrates the procedure used. The recipient artery (the left common carotid artery (CCA)) was exposed. The area of the recipient artery for which the anastomosis was planned had an external diameter of about 2.5 mm. The adventitial layer was removed with the aid of the operating microscope, and the external portion of the tunica media was removed. The diameter of this area was slightly larger than that of the hemispherical contact probe on the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser (1.8 or 2.2 mm). Two centimeters proximal to the distal end of the prepared donor artery, a conventional end-to-side anastomosis was made with a small auxiliary piece of vessel (for example, a vein) and the donor artery; this created an artificial side branch.

Next, the donor vessel was connected with its distal end to the external wall of the recipient artery by means of 10 to 12 interrupted sutures (Ethicon 10-0) that passed through and through the wall of the donor artery, but only through the adventitial layer of the recipient artery just outside the area where the adventitial layer was removed.

The Nd:YAG laser catheter with a coated hemispherical contact probe on top (diameter 1.8 or 2.2 mm) was introduced in the donor artery via the artificial side branch and pushed up until the tip touched and impressed slightly upon the wall of the recipient artery at the spot where the adventitia had been removed. Using an 18-W, 0.5-second laser pulse, a hole was created in the recipient artery and the catheter was withdrawn.

* Hemispherical contact probe manufactured by SLT, Malvern, Pennsylvania.
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Fig. 1. Drawing depicting the different steps of the end-to-side anastomosis. **Left Rear:** After removal of the adventitial and muscular layers at the spot where the anastomosis is planned, the distal end of the donor artery is connected with the exterior of the recipient artery, just outside the prepared area. About 2 cm proximally from the anastomosis site an artificial side branch is made in the recipient artery, utilizing a conventional end-to-side technique. **Left Front:** The Nd:YAG laser catheter with the hemispherical contact probe on top is introduced via the artificial side branch. **Right Rear:** The hemispherical probe makes contact with the wall of the recipient artery at the site where adventitial and medial layers are removed. The recipient artery is temporarily occluded with vessel clips on both sides of the anastomosis. A hole with a diameter of 1.8 or 2.2 mm is created in the recipient artery with a laser pulse of 0.5 sec at 18 W. **Right Front:** After withdrawal of the laser catheter, the anastomosis side is flushed with a heparin-salt solution, the temporary clips are removed, and the artificial side branch is occluded with a hemoclip. The proximal temporary clip on the donor artery is also removed.

The artificial side branch of the donor artery was occluded with a hemoclip. The anastomosis was now completed.

The possibility existed that, at the moment when the laser created the hole in the wall of the recipient artery, air bubbles and debris could form in the recipient artery. Thus, we occluded the recipient artery during the laser pulse with two temporary aneurysm clips and flushed the anastomosis with a heparin-salt solution via the artificial side branch. This occlusion time was extremely short (1 to 2 minutes). After removal of the temporary clips from the recipient artery, a hemoclip was applied to the artificial side branch.

**Results**

**Rabbit CCA Anastomosis**

In the last 3 years we have performed this operation in 65 rabbits. The left CCA was used as the recipient vessel and the right CCA as the donor vessel. In the first 35 rabbits we made the anastomosis without removal of the adventitial layer of the recipient artery. In the majority of cases (about 65%) a patent anastomosis was obtained. However, we discovered that the hole burned by the laser tip was sometimes too small using a pulse of 18 to 20 W and 0.5 second.

When the laser energy was increased, a bigger hole was created. However, this was associated with the risk of a laser-induced lesion of the opposite vessel wall.

In the last 30 experiments we removed the adventitial layer and the muscular layer of the recipient artery in the way described above. We have now been able to create a very consistent hole with a laser pulse of 18 W and 0.5 second, and a patent anastomosis has been obtained in a large majority of cases (90%). Furthermore, no single laser-induced lesion of the vessel wall or the anastomosis itself was observed. In most cases, the hole burned by the laser tip was of the same diameter or slightly larger than the diameter of the laser tip used (2.2 or 1.8 mm).

The patency of the anastomosis was examined by direct exploration and inspection of the anastomosis site at the moment when the animal was killed (1 hour to 3 months after creation of the anastomosis).

**Human MCA to Rabbit CCA Anastomosis**

In a recent series of three experiments, we interposed a 2-cm long piece of the proximal portion of a human MCA (obtained the same day or the day before from an autopsy specimen and kept in a tissue-culture solution) in the left CCA of the rabbit. The right CCA was now connected with the interposed piece of MCA in the left CCA, using the same anastomosis technique as described above. The adventitial layer and the muscular layer of the MCA were as easily and safely removed from the human MCA as from the rabbit CCA. A nicely patent anastomosis was created.

Ten of the anastomoses from the chronic experiments (survival time 2 months) were studied with the aid of the scanning electron microscope. The same endothelialization was noted where the hole in the artery was cut as was seen in our previous experiments (Fig. 2).

**Illustrative Case**

This 69-year-old man had transient ischemic attacks in the right cerebral hemisphere despite aspirin therapy. Both internal carotid arteries were occluded at the bifurcation of the CCA, and collateral flow was by way of both posterior communicating arteries. The contribution of reversed flow via the ophthalmic arteries on both sides was poor.

**Operation.** The frontal branch of the right superficial temporal artery was anastomosed with one of the M2 branches of the MCA deep in the sylvian fissure, utilizing the same technique as described above. We used the M2 branch as the recipient artery for safety reasons.

**Postoperative Course.** The patient had no neurological deficit postoperatively. After 1 week, during a hypotensive period, he developed temporary ischemia of the left cerebral hemisphere, but no ischemic symptoms in the right hemisphere, which was probably protected by the bypass. The postoperative angiogram (Fig. 3) revealed a marked enlargement of the frontal branch...
FIG. 2. Scanning electron microscopic images of the anastomosis site 6 weeks after anastomosis. a: Overview of the anastomosis side viewed from the inside of the recipient artery. The arrow points to the spot where the donor artery is stitched to the exterior of the recipient artery. × 16. b: Higher magnification of the opening of the recipient artery. The rim is re-endothelialized. × 475. c: Complete re-endothelialization of the rim is visible in this 75° tilted view. × 158. d: Further magnification of the image in c. × 475.

of the superficial temporal artery that was used for the bypass (preoperatively, both branches of the superficial temporal artery had the same diameter). The MCA territory was now filled with contrast medium via the bypass.

Discussion

Theoretically, a so-called "high-flow bypass," where a donor vessel with a diameter of at least 2 mm is connected with a relatively large, more proximal recipient artery (for example, the M1 segment of the MCA or the intracranial carotid artery), may be more effective in revascularizing the brain in patients with hemodynamically caused ischemia. 

Occlusion of the proximal brain artery for a period of 20 to 40 minutes, the time necessary to create a conventional end-to-side anastomosis, may itself induce ischemia and is therefore a risky affair. Utilizing the end-to-side anastomosis technique described above, occlusion of the recipient artery during the making of the anastomosis is obviated.

For safety reasons, we advise flushing the anastomosis site with a heparin-salt solution for the removal of possible debris produced by the laser pulse. For this maneuver, it is necessary to occlude the recipient artery for a period of only ½ to 1 minute. The Nd:YAG laser with the hemispherical contact probe proved to be very
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FIG. 3. Postoperative angiograms, lateral views, of the patient with an extracranial-intracranial bypass between the frontal branch of the superficial temporal artery (STA) and one of the branches of the middle cerebral artery (MCA). a: Both branches of the STA had the same diameter. The frontal branch, which is connected with one of the M1 branches of the MCA, is markedly enlarged and supplies the MCA territory. b: The two hemoclips occlude the artificial side branch used for the introduction of the laser catheter. The MCA territory is filled with contrast material via the bypass.

effective in the creation of a consistent hole with a predictable diameter in the recipient artery.

However, to achieve a patency rate of 95% in our experimental animals, we had to remove the adventitial layer and a part of the medial layer of the recipient artery at the site of anastomosis. This is a delicate microneurosurgical procedure and is not without risk. Theoretically, a pulsed laser with a multifiber catheter and with a very restricted vaporizing effect on the tissue would be the ideal laser for use in the end-to-side anastomosis described. Such a laser renders removal of adventitial and medial layers superfluous, making this new type of end-to-side anastomosis a safe procedure.

Addendum

In January, 1991, an Excimer laser† became available at our institute. This is a xenon-chloride gas-based laser with a wavelength of 308 nm. The energy is delivered in pulses (120 nsec and 10 or 20 Hz) with a power of around 25 mJ per pulse. At our request, a special catheter was made with a diameter of 2.2 mm at the tip, consisting of 140 laser fibers. The fibers are glued together at the tip and polished, making a completely flat smooth surface. With a pulse rate of 20 Hz and a power of 25 mJ per pulse, the tip creates a perfectly round hole with a smooth surface in the wall of the recipient artery.

For the rabbit carotid artery it takes 1 second to create the hole and for the rabbit aorta 2.2 seconds. The hole diameter is exactly the same as that of the laser catheter tip. With the operating microscope on maximum magnification, no thermal effect can be observed at the surface of the hole or the surrounding tissues. The laser tip penetrates the vessel wall with a nice surgical feel and when the tip enters the lumen of the recipient artery the surgeon stops pressing the foot-switch. The big advantage of the Excimer laser compared with the Nd:YAG laser is that removal of the adventitial and medial layers is not necessary. Since no noticeable heat is produced, no damage can be caused to the surrounding tissue.

The technique described in this communication was used in 10 rabbits to create an anastomosis between the carotid arteries using the Excimer laser. An excellent patency rate was obtained and no adverse reactions caused by the laser were noticed.

References


† Excimer laser and fiber catheter manufactured by Technolas, Munich, Germany.

Manuscript received February 26, 1991. Accepted in final form August 12, 1991. Address reprint requests to: Cornelis A. F. Tulleken, M.D., Ph.D., Department of Neurosurgery, University Hospital, P.O. Box 85500, NL-3508 GA Utrecht, The Netherlands.