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TECHNIQUES FOR CEREBRAL BYPASS

Practical Laboratory for Microvascular Anastomosis

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Microvascular surgery has advanced significantly over the latter half of the twentieth century and has become an integral part of the neurosurgical repertoire. Two major developments allowed for successful anastomosis of small vessels: the introduction of the operating microscope and the manufacture of small suture material. In spite of advances in technology, the technique remains a difficult one to learn and is best perfected in a laboratory setting. The mastery of surgical technique on vessels 1 mm in diameter allows for a smooth transition to the operating room.

MICROVASCULAR LABORATORY

To perform microsurgery in an atraumatic fashion requires appropriate instruments, an adequate operating microscope that provides illumination and magnification, and an operating seat for the surgeon that allows maintenance of good posture and provides an area that may function as an armrest.

The operating microscope typically has a 200-mm objective with a range of magnification from ×4 to ×25. Sutures are usually placed at about ×16 power, and this power is usually lowered to approximately ×10 while tying the knot. The higher powers may be used for closer inspection of the vessel wall and to check suture placement.

The microsurgical instruments that are necessary for vascular anastomosis include the following:

1. A nonlocking round-handled needle driver with straight or curved microtips
2. Round-handled double-sharp microscissors
3. A pair of 13-cm forceps with round handles and sharp tips used for handling tissue
4. A second pair of 13-cm round-handled forceps with curved blunt tips and a tying platform to use for suture tying
5. A third pair of forceps with small rat tooth tips for handling tissue
6. A 30-gauge needle with a blunt tip turned at a 45° angle and attached to a small syringe, which can then be used for irrigating the vessel
7. A microvascular clamp, preferably a double clamp mounted on a frame. Suture-holding cleats may be mounted on the frame (Fig. 1).

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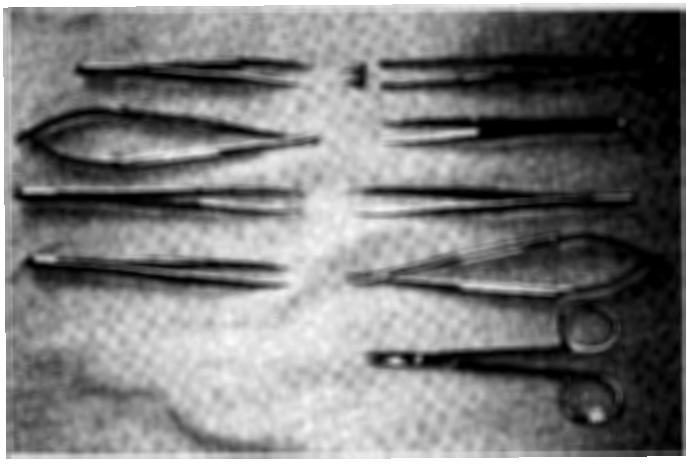

Figure 1. Surgical instruments for microvascular anastomosis. Clockwise from top right: (1) large forceps with groove for vascular clamp; (2) blunt forceps for handling tissue; (3) rat-tooth forceps for handling subcutaneous tissue; (4) curved micro needle driver; (5) scissors; (6) microforceps for vessel handling; (7) platform forceps for tying suture; (8) microscissors; (9) sharp-tipped microforceps for vessel dilatation; and (10) double vessel clamp.

Either an 8-0 or 10-0 monofilament nylon suture on 50- to 70-μm needles may be used for the anastomosis. A rubber dam, preferably of a bright color, may be cut and used under the vessel to isolate the vessel from the surrounding tissue. The operating field may be bathed in a small amount of lactated Ringer's solution; this is essential for venous anastomoses. The vessels are irrigated with a solution of 1% lidocaine, which is used to vasodilate the vessel, and heparin solution at 1000 U/mL of lactated Ringer's solution, which is used to irrigate the ends of the clamped vessels and to prevent thrombus formation.

Most hand movements in microsurgery are performed in small increments of pronation and supination of the fingers and forearm. It is important to practice this technique so as to prevent injury to the vessels and to allow the work to be performed in a small field.

BASIC SURGICAL TECHNIQUE

Placement of the suture must be done in a precise and controlled manner. The transected vessel should not be held with the microinstruments, because this can damage the vessel intima. Instead, the tips of the forceps are inserted into the vessel and support the vessel wall. The needle is passed perpendicular to the vessel wall approximately two needle widths from the edge. The needle tip is then passed into the opposite lumen with a gentle transverse motion to ensure that it is free of the vessel wall. The tying forceps are held on the outside of the vessel wall to apply counterpressure while the needle is pushed through the vessel wall at the same distance from the edge as in the first vessel. The needle and most of the suture are pulled through until only a short segment of suture remains.

At this point, the forceps in the left hand may be replaced with the tying forceps. All knots must be square and tied with three to four flat throws. The first knot may be a surgeon's knot. Because of the delicate nature of the suture, it is important not to attempt to tie the knot too tightly. In general, when the light within the closing loop of the throw disappears, the tension is sufficient.

The strands of the suture are cut individually, and a tail of approximately four to five times the width of the needle is left. Sutures along the vessel wall should be evenly spaced.

PREPARATION OF LABORATORY ANIMALS

The rats are anesthestized initially with a small amount of chloroform anesthetic

followed by an intraperitoneal injection of 0.5 mL of pentobarbital (at a concentration of 50 mg/mL). The intraperitoneal pentobarbital may be repeated as necessary if the rat begins to move.

Regions that may be used for microvascular anastomosis in the rat include (1) the femoral artery and vein located in the inguinal area; (2) the carotid artery and jugular vein located in the neck; and (3) the vena cava and aorta, which may be localized through a midline laparotomy. The carotid artery is approximately 1 mm in diameter, and the femoral artery is approximately 0.5 to 0.8 mm in diameter.

ARTERIAL END-TO-END ANASTOMOSIS

The vessel is isolated and cut. The adventitia of the vessel is dissected free of the ends, and the vessel ends are placed in the double clamps. The clamp bars can then be pulled together to approximate the vessel ends. A small rubber dam is placed underneath the clamp to isolate the vessel from the surrounding tissues. The cut vessel is irrigated with dilute heparin solution. There are several suturing methods that may be used to perform the anastomosis.

Triangular Anastomotic Technique of Carrell

This technique allows placement of six sutures for small vessels, nine sutures for intermediate vessels, and 12 sutures for larger vessels (Fig. 2). The open end of the vessel may be described in terms of the face of a clock, with the top being 12:00. The first two sutures are placed at 10:00 and 2:00 and tied. One end of each suture is then attached to the cleat to hold the vessel in position. The next suture is placed at 12:00 and tied. For a small vessel, this would complete the front third of the

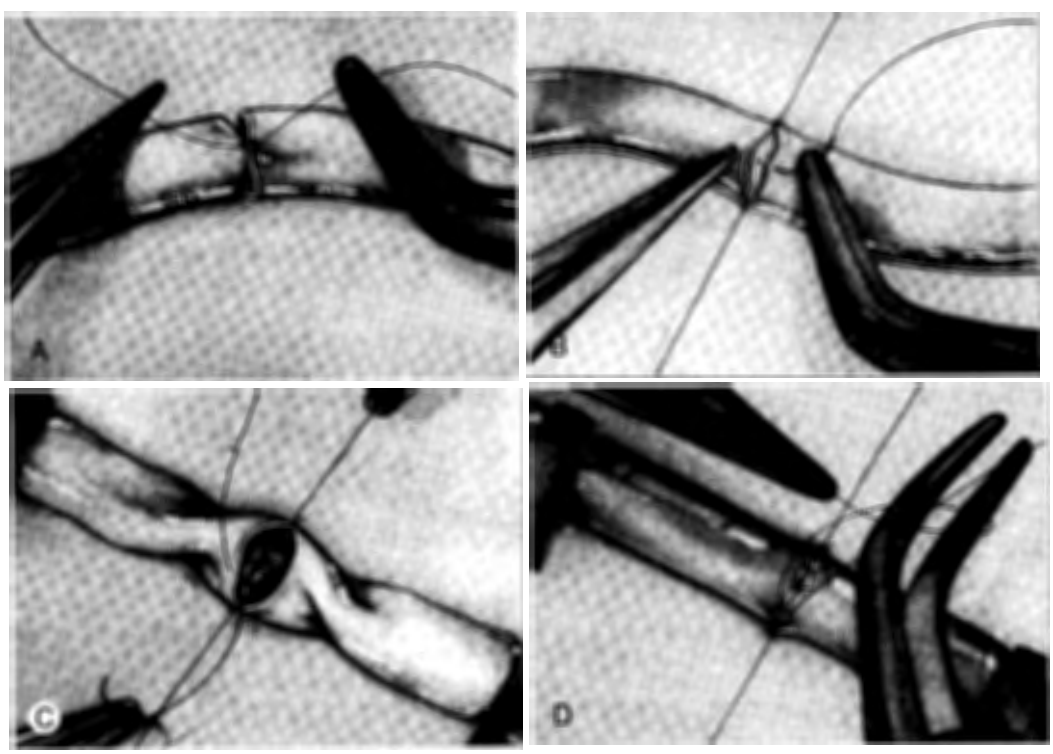

Figure 2. Triangular technique of Carrell. *A*, The first suture is placed on the front wall at 10 o'clock. *B*, After the second suture at 2 o'clock and the third suture at 12 o'clock are placed, the front wall is complete. *C*, The vessel is rotated to expose the back wall, where three additional sutures are placed. *D*, The completed anastomosis.

anastomosis; for a large vessel, one additional suture is placed between 10:00 and 12:00, and then another one is placed between 12:00 and 2:00. The clamp is rotated 180° to expose back wall of the vessel. Because this represents two thirds of the vessel wall, more sutures are required for this wall. A suture is initially placed at 6:00, and one or three sutures are placed between the 6:00 suture and each stay suture. The clamp is then reversed back to the original position, and the distal clamp is released. Subsequently, the proximal clamp is released. A small amount of fat over the anastomotic site usually stops any mild bleeding. If there is significant bleeding, further sutures may need to be placed.

Buncke Technique

This technique is essentially a teaching technique, and allows placement of eight sutures each spaced 45° apart (Fig. 3). Because the technique requires that the clamp be turned over four times, it is not a practical technique to use in the operating room.

The Buncke technique begins with the first suture at 12:00 on the front wall. After the suture is placed, the clamp is turned over with the cleats facing down, and the second stitch is placed at 6:00. The clamp is then turned right side up once again; the 12:00 suture is tied to the far cleat and the 6:00 suture is tied to the nearest cleat. This essentially converts the two sutures to 3:00 and 9:00, respectively. The next stitch is placed between the two sutures at the new 12:00 position. A stitch is then placed between the central suture and each of the stay sutures such that each suture is 45° apart. The clamp is flipped over, and this procedure is repeated on the back wall. The clamp is returned to the front position, and the stay sutures are removed from the cleats and cut.

Cobbett Technique

Unlike the Buncke technique, the Cobbett technique does not involve any rotation of the clamp. Using this technique, six equally spaced sutures may be placed in the vessel wall (Fig. 4). This is accomplished by suturing the back wall first using a suture technique in which the needle is passed from the outside to the inside on the near vessel edge and subsequently from the inside to the outside on the far vessel edge. The suture is then tied, ensuring that the knot is left on the outside of the vessel. The first suture is placed on the back wall in this fashion at the 4:00 position and is secured to the far cleat. The next suture is placed at the 6:00 position, and both ends are cut. The last back wall suture is placed at the 8:00 position and is secured to the near cleat. In this manner, an arc of 240° remains; this constitutes the front wall of the vessel. A suture is placed in the center at 12:00 to bisect the front wall, and this suture may be used as a lift stitch. A suture is then placed between the 12:00 position and each of the two stay sutures such that a total of six sutures are used to complete the anastomosis. The stay sutures are then cut.

END-TO-END VENOUS ANASTOMOSIS

The same techniques described for arterial anastomosis may be used for end-to-end venous anastomosis. Because of the weak structural integrity of the vein wall, there are several problems that may be encountered. The vein wall is much weaker, thinner, and more redundant than the wall of the artery. Once the vessel has been sectioned, the anastomotic procedure should be carried out using a small amount of normal saline. This normal saline puddle facilitates the demonstration of the lumen. The adventitia of the vein must be removed; however, it is thin, and removal may result in destruction of the vessel wall itself. Because the vessel wall is floppy, the lumen may be more difficult to open. A smaller number of sutures may be used in the venous anastomosis such that a vessel 1.2 mm in diameter only requires six sutures.

When removing the clamp, it is important to remove the proximal clamp first, because the flow here is retrograde compared with that in the artery. In addition, no flicker test is possible, and only the strip test may be used to test the anastomosis. Venous anastomosis is often patent initially but may subsequently thrombose.

END-TO-SIDE ANASTOMOSIS

The end-to-side anastomosis is best carried out by joining the carotid artery to the jugular

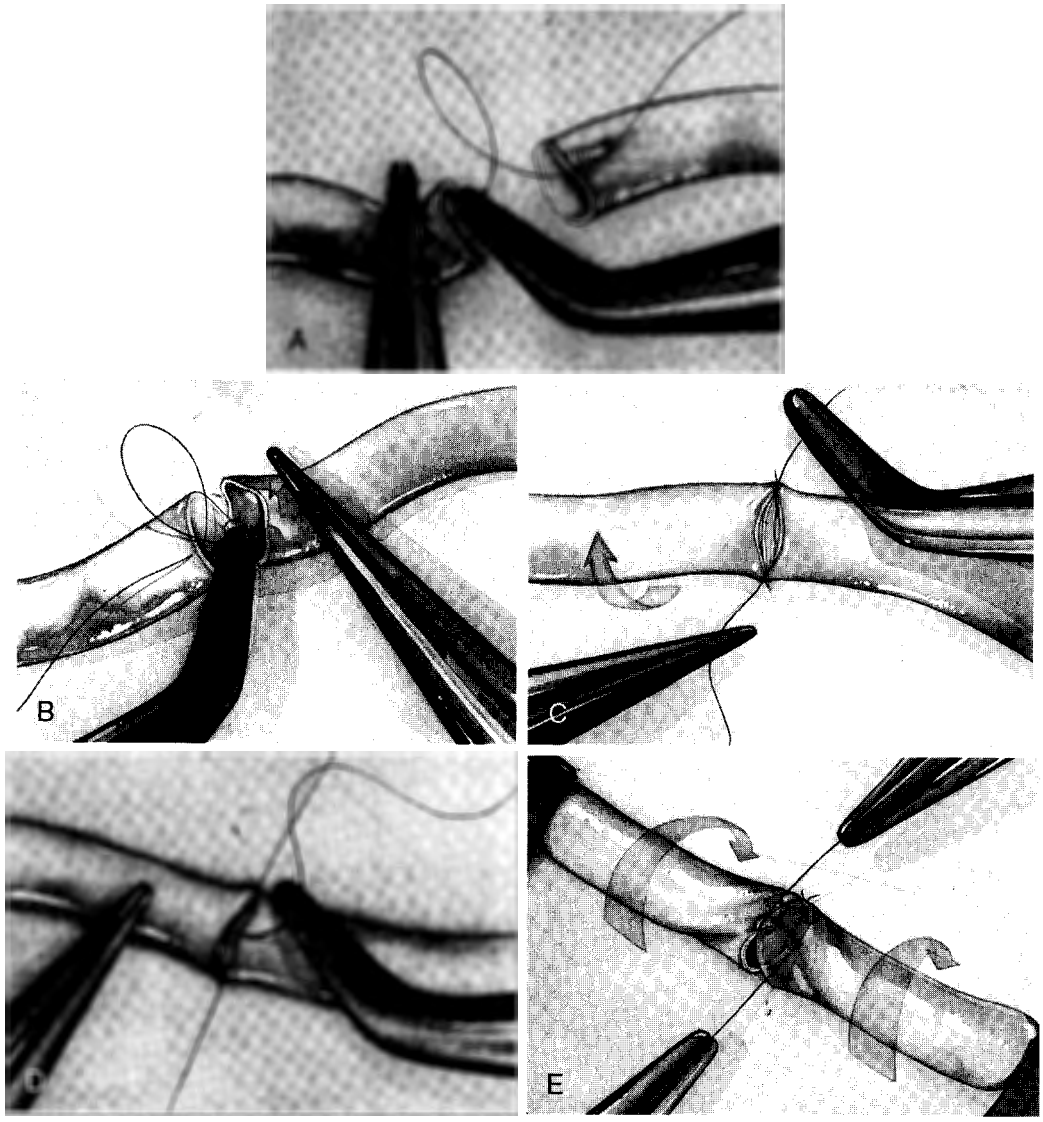

Figure 3. The Buncke technique. *A*, The first of eight sutures is placed on the front wall at 12 o'clock. *B*, The vessel is turned over and the second suture is placed at 6 o'clock. *C*, The vessel is rotated 90°. *D*, Three sutures are placed on the new front wall. *E*, The vessel is again flipped over and three sutures are placed on the back wall to complete the anastomosis.

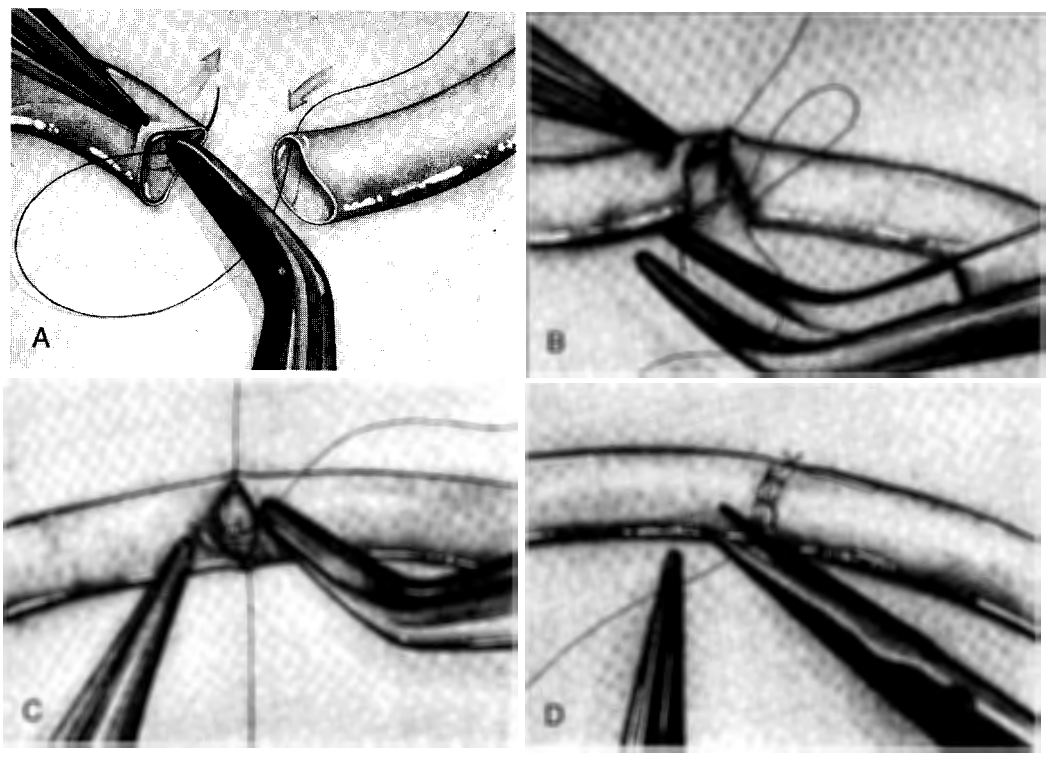

Figure 4. The Cobbett technique. *A*, The first suture is placed on the back wall at 4 o'clock with the vessel in neutral position. *B*, The second suture is placed at 6 o'clock and the third at 8 o'clock. This completes 120° of the back wall. *C*, Three sutures are placed on the front wall. The vessel is never turned. *D*, The anastomosis is complete.

vein. The carotid artery should be dissected, and the distal end should be ligated. The cut end is cut obliquely to allow for a fish-mouthed shape for the anastomosis. A longitudinal incision is made in the wall of the jugular vein. Alternatively, an elliptically shaped incision may be used. The lumens of both vessels are irrigated. Sutures number one and number two are placed at each end of the incision in the jugular vein and at the corresponding ends of the open carotid artery. Once the first two sutures are placed, the front wall is sewn with four evenly spaced sutures as shown in Figure 5. The clamp is then reversed, and the back wall is sewn in the same fashion. The clips are opened in the following order: first, the distal jugular vein clamp is released; second, the proximal jugular vein clip is released; and third, the clip on the carotid artery is released.

ANASTOMOSIS WITH A MICROVASCULAR DEVICE

A microvascular anastomotic device may be used for end-to-end anastomosis of arterial vessels. This device is available in a size ranging from 1 to 3 mm. This anastomotic system is composed of two polyethylene rings, with six sharp pins embedded in the rings. The arterial ends are prepared in the same manner as for suture anastomosis, although mobilization of at least 1 cm of vessel is required. One vessel end is brought through the center of the ring, everted, and impaled on the pins. The same is done for the opposite vessel. The rings are then brought together and closed into position. The vessels are coupled by lumen-to-lumen contact. In this way, anastomosis can be accomplished quickly and with minimal trauma to

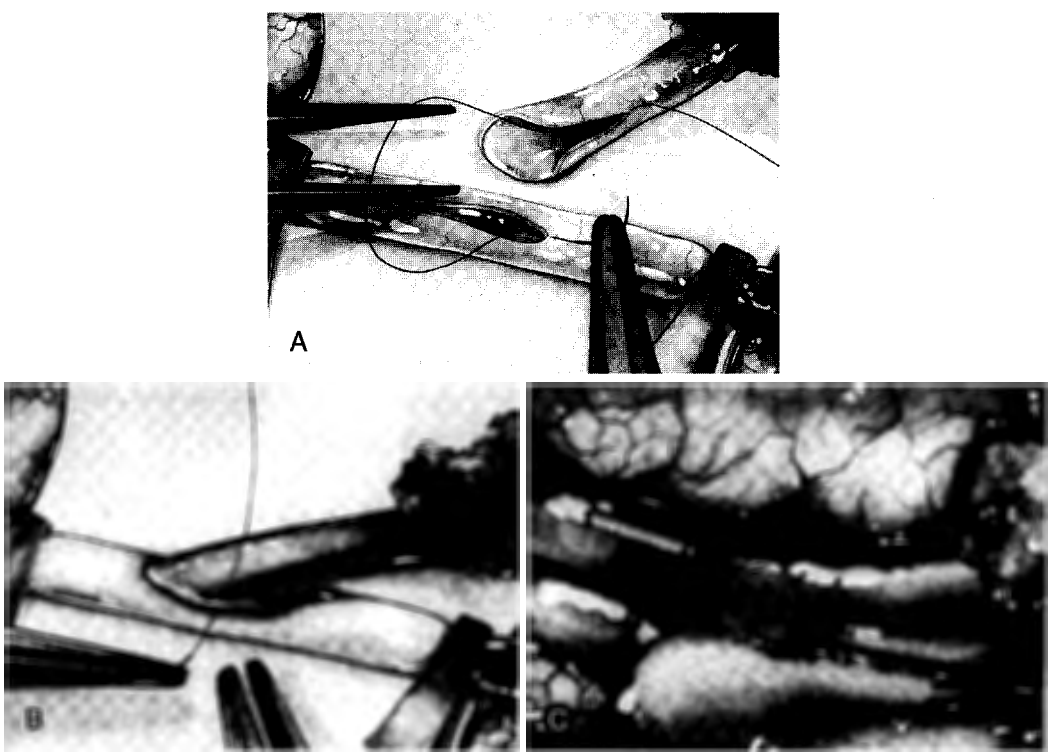

Figure 5. End-to-side anastomosis. *A*, After an elliptical incision is made in the vessel, the first suture is placed at the end of the incision and through the cut end of the recipient artery. *B*, After the two end sutures are placed, the front and back walls are sutured. *C*, The finished product of an end-to side anastomosis.

the vessel. The disadvantages of such a system are that it may not allow for significant enlargement of the bypass. In addition, it may be difficult to use in deep locations within the cranium. Nevertheless, because of the efficiency of this technique and the shorter duration of cross-clamp time, it is useful in certain settings. This technique is illustrated in Figure 6.

TESTS OF PATENCY

Once the anastomosis has been completed, it is important to test the patency of the vessel. This is done initially by releasing the distal clamp to allow retrograde flow and subsequently by releasing the proximal clamp. There may be a small amount of oozing from the suture line, but this may be controlled with application of a small amount of fat. The downstream stripping test may be used to demonstrate patency. In this test, forceps are used to clear a small segment of vessel of any blood distal to the anastomosis. Subsequently, the proximal clamp is released, and when the empty segment fills with blood, this confirms anterograde patency. In the flicker test, forceps are placed underneath the vessel and used to elevate the vessel. This results in a

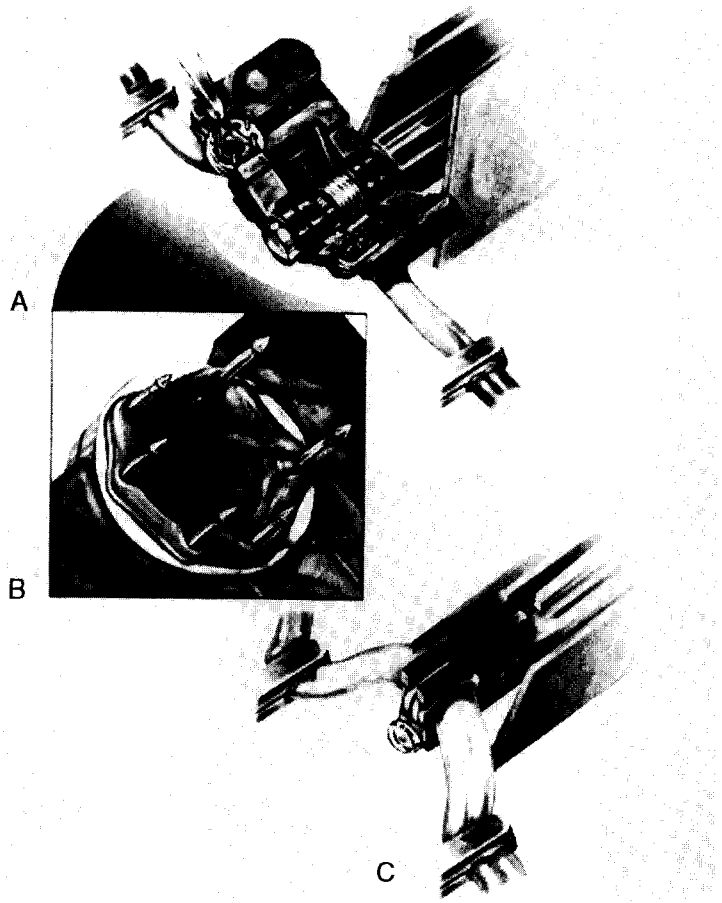

Figure 6. The microvascular anastomotic device. *A*, The ends of the arteries are brought through the device rings. *B*, The ends of the vessels are everted over the prongs, such that all layers of the vessels wall are perforated by the prong. *C*, The coupler is closed, bringing the two rings into apposition, and released. (Courtesy of David W. Newell, MD, Seattle, WA.)

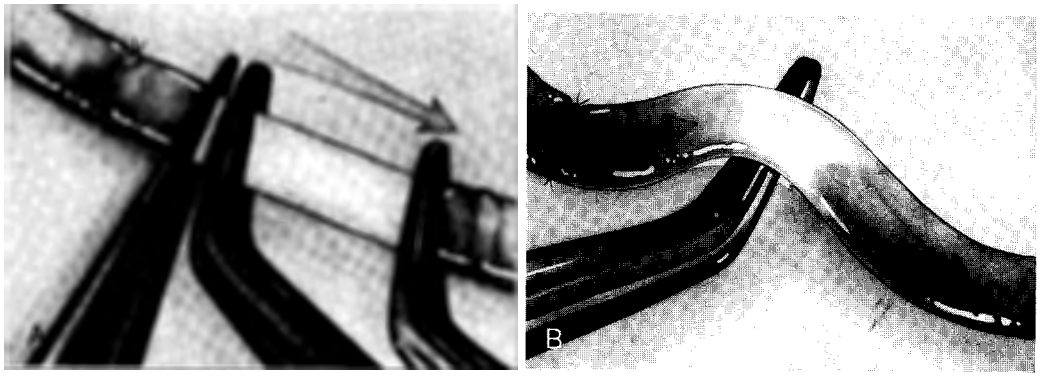

Figure 7. Tests of patency. *A*, The downstream stripping test. Release of the proximal clamp results in filling of the isolated segment. *B*, The flicker test. Elevation of the vessel distal to the anastomosis results in a partial obstruction and filling only during systole. This is seen as a red and white flicker.

partial compression distal to the anastomosis, which results in only systolic filling of the vessel and alternating red and white flicker (Fig. 7).

SUMMARY

Microvascular and anastomotic training in the laboratory is essential before application in the clinical setting. Mastery of the different techniques of end-to-end and end-to-side anastomoses allows the surgeon to use the appropriate tool for each setting.

Suggested Readings

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