Mechanical suture in vascular surgery

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MECHANICAL SUTURE IN VASCULAR SURGERY

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THE HISTORY AND NEW TECHNIQUE OF THE VASCULAR SUTURE

The first attempts to place a vascular suture were made in the 18th century. In 1759, the British physician Hallowell, following the advice of Lambert, a well-known surgeon, sutured the brachial artery which he had accidentally injured during bloodletting.

For over a century such operations amounted to just a few cases. Assman's and Nikass's experiments made without asepsis in the mid-19th century frequently caused thrombosis and only discredited the vascular suture. It was not until 1877 that healing of a small vascular wound without subsequent thrombus formation was proved possible by N. Schultz's experiments. In the same year N. V. Eck succeeded in placing a portacaval anastomosis to eliminate experimental ascites; this stimulated further research in restorative surgery on vessels. The introduction of asepsis went alongside a successful use of lateral sutures in clinical practice.

In 1881, Schede sutured a parietal defect in the femoral vein, injured at operation, and in 1888 Matas placed a lateral vascular suture in an operation for aneurysm of the brachial artery. In 1896, Glück made the first experiment in the transplantation of vessels.

Having analysed failures in vascular suturing, A. A. Yasinovsky (1889) came to the conclusion that the cause of thrombosis was, above all, discontinuity of the vascular intima injured with rough instruments, also subsequent invasion of the vascular lumen by exposed periadventitial tissue and comparatively coarse ligature, etc.

P. I. Tikhov (1894) studied the venous suture experimentally. Passing a knotted and continuous suture through all the layers of the vessel wall, he established that the threads facing the vessel lumen were separated from the blood flow by a small parietal thrombus, and the wound in the vessel walls healed to leave a connective tissue scar. His histological studies furnished a theoretical substantiation of the vascular suture. He established that thrombosis did not necessarily lead to a complete closure of the sutured vessel lumen. The risk of extensive thrombogenesis at the vascular suture is warded off by the formation of an initial parietal thrombus which, by isolating the vascular suture from the blood flow, smoothes its rough surface and promotes regeneration of the vascular endothelium. Later on, this thrombus partially resolves and subsequently, the incipient endothelial regeneration is accompanied by the incapsulation of sutures, as well as their protrusion beyond the vessel wall and penetration into the surrounding cellular tissue.

N. I. Napalkov gave the same explanation of the vessel wall wound healing. He considered that it involved the formation of a parietal thrombus, proliferation of vascular endothelium, and formation of scar tissue in the medial and external membranes. V. R. Braitsev, in his paper "The Suture and Vascular Grafts", published in 1916, gives a different interpretation of the vascular wound healing. In his opinion, "the healing of the wound lips following suturing depends on intensive proliferation of the intima rather than on preliminary blood deposition, which is no more than a complication and disturbance in the healing of vascular wounds".

At the turn of the 20th century such experiments were taken up by clinics, and reports on vascular sutures became more frequent.

G. F. Tseidler (1894) successfully placed a parietal suture on the popliteal vein; the artery, sutured by I. F. Sabaneyev, was occluded by a thrombus following embolectomy (1895).

V. G. Tsege-Manteifel (1895) sutured a defect on the femoral artery after the excision of an aneurysm, and four years later he placed a suture on the inferior vena cava.

In 1886, M. V. Orlov reported a successful application of a lateral suture on the popliteal artery injured at operation.

At the end of the 19th century the technique of the parietal vascular suture was well developed and used in experiments and the clinical treatment of vascular lesions and aneurysms.

In 1895, Murphy was the first to suture the severed ends of the femoral artery in surgery of arteriovenous aneurysm.

Murphy's success was made possible by his elaborate technique of connecting a cut artery by invagination of its central end into the peripheral one by means of three or four mattress silk sutures. First, these sutures were applied to the central end of the vessel, stitching the tunica externa and tunica media alone; the ends of the threads were led through the entire thickness of the arterial wall at the peripheral end from inside outwards, where they were tied up (Fig. 1).

The main shortcoming of this method is a considerable stricture of the arterial lumen at the suture, not to mention its complicated technique. Moreover, all the layers of the central end of the vessel and part of the suture get into the vessel lumen. The infiltrating blood accumulated both on the clots of the occluded capillaries of the incised vessel wall and on the stitches which had got inside the vessel, and, as a rule, produced thrombosis at the site of the communication. In view of this, Murphy's method, however progressive, did not take on, though it induced surgeons to elaborate the technique of a circular juncture.

Shortly thereafter Payr suggested a method of circular connection of the severed vessel ends without suturing them, but using absorbable tube prostheses.

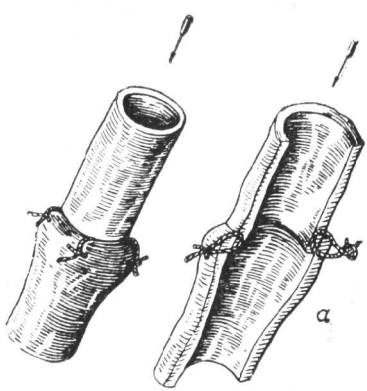

Fig. 1. Vascular suture according to Murphy

a—mattress silk suture

The vessel is introduced into this tube, 0.75 cm to 1 cm long, its inner diameter precisely corresponding to the outer diameter of the central end of the artery to be stitched, in such a way as to make its free end project 1-2 cm (Fig. 2,*a*). The projecting central end of the vessel is bent under the tube in a reverse direction with its endothelium outside, and is fixed to the prosthesis with an external circular ligature (Fig. 2,*b*).

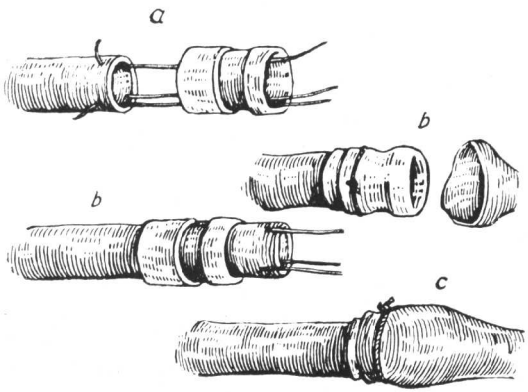

Fig. 2. Vascular suture according to Payr (model 1)
a, *b*—separate stages of vascular suturing; *c*—sutured vessel

Then the arterial lumen at the peripheral end is dilated by means of three threads, stitched on its very edge through the entire thickness of its wall at an equal distance from each other in order to introduce the central end of the artery fixed on the prosthesis (Fig. 2, *c*). The free end of the peripheral portion of the artery is fixed to the central portion, endothelium-to-endothelium, by means of an outer circular ligature.

This method of joining vessels, however, also has a number of disadvantages. The most substantial of them are: necrosis, which may develop as a result of disturbed blood supply attending compression of the vessel walls with the circular ligature; the ligature slipping off may entail a secondary hemorrhage. It has also been established that the

change of the vessel diameter and loss of elasticity at the communication site due to the presence of the prosthesis cause an abnormal blood flow liable to produce thrombosis.

Therefore Payr suggested another version of the vessel joining technique, which requires the use of two cylinders (Fig. 3). The cylinders are fitted on the vessel ends, the latter's free edges being drawn on the widened parts of the

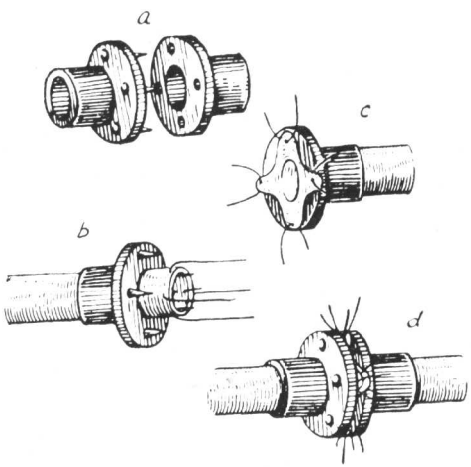

Fig. 3. Vascular suture according to Payr (model 2)
a —cylinders; *b, c*—separate stages of vascular suturing; *d*—sutured vessel

prostheses. Then the cylinders are tightly joined by means of hooks on one of them and openings on the other, their intimas being in close contact and fixed to the cylinder wall.

This method has all the drawbacks of the first version.

In the past few years there has been growing interest in prosthetic technique, especially among American surgeons. In 1903, Carrel suggested a new method of circular stitching of blood vessels with a continuous suture, which won him a Nobel Prize in 1912.

His technique is as follows: after gripping the vessel with clamps temporarily, its circular lumen is transformed

into an equilateral triangle (Fig. 4, *b*) by means of three main sutures placed at an equal distance from each other (Fig. 4, *a*), and then all the three sides are stitched with a thin continuous suture (Fig. 4, *c*).

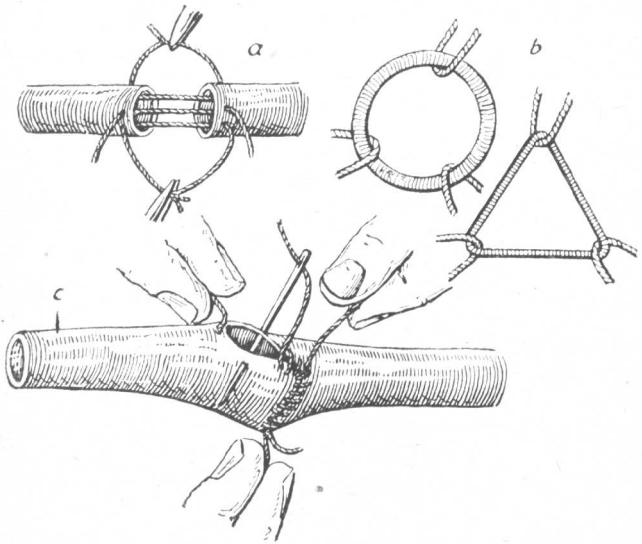

Fig. 4. Vascular suture according to Carrel
a, b, c—separate stages of vascular suturing

The technique of the circular vascular suture is based on general rules, such as thorough asepsis, extreme caution in manipulations with the vessel ends, careful hemostasis in the surrounding tissues. The main prerequisite of this method is joining the endothelial surfaces of both vessel ends by placing through everting sutures along the entire thickness of the vessel wall.

During suturing the edges of the two vessel lumina are constantly stretched by preliminary stitches and the round cross-section of the vessel changes to triangular.

Carrel's method found a wide application, though joining of vessels with a manual circular suture has essential shortcomings, which sometimes frustrate the entire work of

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the surgeon. Small-diameter vessels can hardly be sutured by hand at all whereas suturing large-diameter vessels requires utmost skill and self-control.

The complexity of manual suturing and frequent failures have largely discredited this method.

N. I. Bereznigovsky (1924) stated that the vascular suture had not opened up new prospects either for surgery or for the treatment of aneurysms.

Even Delbet, with his wide experience in surgery, was apparently satisfied with the vascular ligature; he considered vascular suturing to be an exercise in surgical manipulation. In 1948, L. M. Ratner, a noted vascular surgeon, wrote: "The role of the vascular suture in surgery has so far been uncertain, despite numerous works on this subject and hundreds of operations."

Thrombosis usually developing at the suture is a major disadvantage of Carrel's method, as well as the other manual methods. This is inevitable, since in continuous close stitches the silk thread injures the vessel intima and causes thrombus formation. Besides, part of the stitches often get into the vessel lumen and entail blood collection and clotting. The stricture of the vessel lumen, which is usual for manual suturing, is another cause of thrombus formation. The irregularity of stitches may cause secondary hemorrhage. These shortcomings became apparent in clinical practice. Thus, out of the 44 operations performed by S. K. Safoterov (1910) by the circular suture technique, only three were successful.

N. A. Bogoraz staged a number of experiments on dogs using circular suturing of vessels. None were successful. This prompted new and better suturing techniques.

In 1912, Danis suggested that cuff-like eversions of the vessel end should be made by means of three velum sutures and thus fixed with its endothelium outside, the central end of the vessel being invaginated into the peripheral one (Fig. 5). With this method, a free space forms in the lumen of the sutured vessel, where blood stagnates and clots. That is why this method is out of use.

In 1913, N. A. Dobrovolskaya developed a method of circular end-to-end suturing of minute vessels (less than 2 mm in diameter). This method is based on an artificial dila-

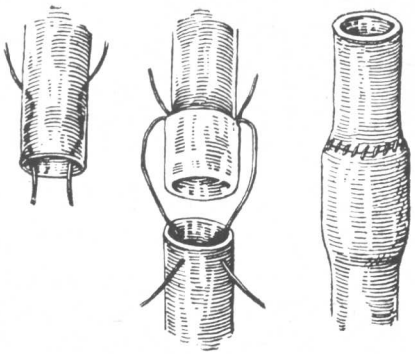

Fig. 5. Vascular suture according to Danis

tation of the vessel lumen (perimeter). N. A. Dobrovolskaya recommends to cut out two corresponding flaps on both vessel ends, using a very convenient incision technique; when stitched together, these flaps form a vascular side-to-side anastomosis, the shape of the flaps being variable depending upon the operative technique (Fig. 6).

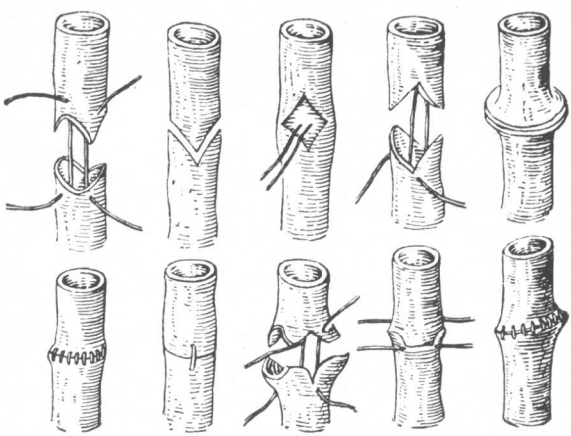

Fig. 6. Circular suture according to N. A. Dobrovolskaya

When joining one vessel to the side of the other, flaps of a larger size are cut out to increase the sections to be stitched together (Fig. 7).

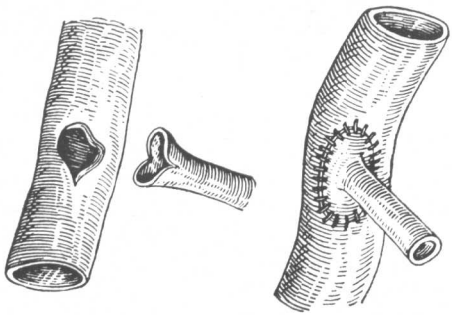

Fig. 7. Lateral suture according to N. A. Dobrovolskaya

N. A. Dobrovolskaya's method is also not free from the above-mentioned shortcomings of the manual vascular suture, mainly, the danger of thrombosis.

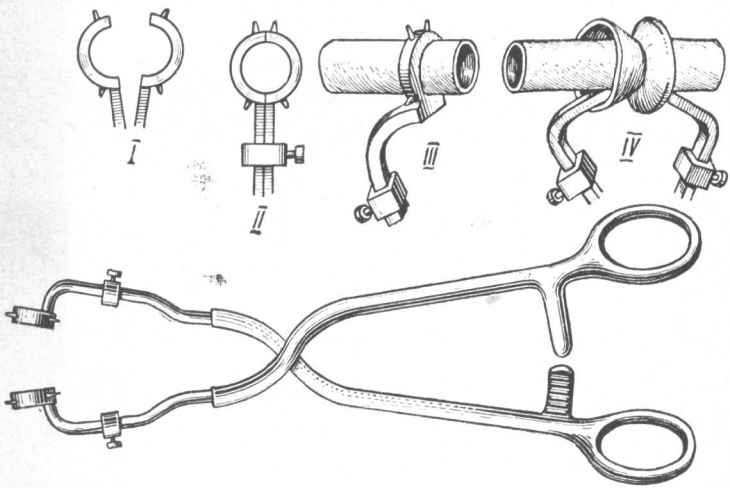

Fig. 8. Shpuga's forceps

To simplify the technique of vascular suture G. M. Shpuga (1934) suggested a new design of forceps, convenient for pulling up the vessel ends in case of a considerable defect. The forceps (Fig. 8) have connecting detachable forks (*I*) consisting of two half-rings provided with pins on their external surface (*II*). The vessels are gripped with a fork of a size corresponding to their diameter and severed after

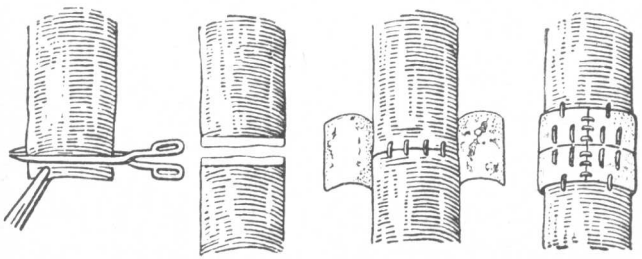

Fig. 9. Vascular suture according to V. L. Khenkin

the clamps have been placed. The vessel ends are quickly everted, intima outwards, and placed on the pin tips (*III*) by means of pincers. The same is done to the other end of the vessel; then the two halves of the forceps are joined and locked with a spur rack (*IV*). The vessel ends, fixed and approximated, are stitched together manually.

The essential point in G. M. Shpuga's suggestion is an element of "mechanisation" in the technique of vascular suturing. However, his experiments failed, since in order to fit their edges on the pins the vessels had to be pulled so as to make the everted end touch their tips. The pin is so high that this tension gets the intima torn and causes thrombus formation. A shorter pin may cause the vessel edges to slip off easily. All this complicates the suturing technique and leads up to thrombosis.

V. L. Khenkin (1944) suggested the following method of vascular suturing (Fig. 9). After severing the vessel the excessive adventitia is trimmed off. Then widely spaced intermediary sutures are placed to join the ends of the vessel which are embraced along the line of contact with a

collar prepared from a nearby vein and fixed with six stitches to the adventitia. This collar lessens the danger of secondary hemorrhage at the anastomosis.

This method, however, does not ensure complete approximation of the intimae of the vessel ends either. The incised vessel wall is pushed into the vascular lumen by tightening the widely spaced stitches, and this results in throm-

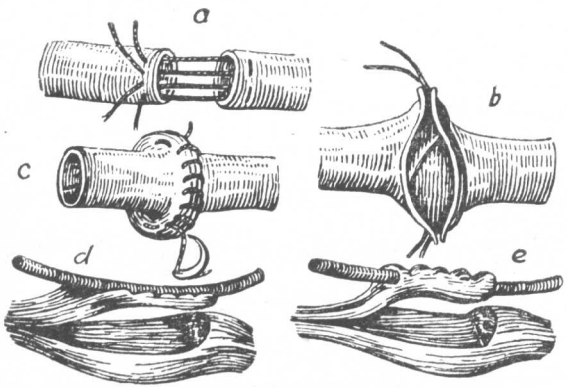

Fig. 10. Vascular suture according to A. A. Polyantsev

a, b, c—placing of sutures on the vessel walls; *d, e*—tubulisation of the vessel with a muscle

bosis; secondary hemorrhage between the stitches is also likely. Therefore, this method has not become popular either.

A. A. Polyantsev suggested a muscle tubulisation of the suture (Fig. 10) to strengthen it and lessen the risk of secondary hemorrhage. Yet the danger of thrombosis and vascular stricture persists.

M. G. Akhalaya made a great number of amputations of dogs' extremities with their subsequent reattachment. The vessels of the extremities were united with a continuous circular suture. Out of the 28 dogs operated upon only one had blood circulation in the joined extremity restored and maintained. On the 15th day after the operation, however, a thrombus occluded the vascular suture and the extremity

was lost. In the other animals the limbs did not accrete due to thrombosis, secondary hemorrhages, and full imperforation of the anastomosis caused by stenosis.

The method suggested by G. M. Solovyov (1955) is somewhat better and close to Danis'. The author uses it with good results, the suturing taking only eight to ten minutes;

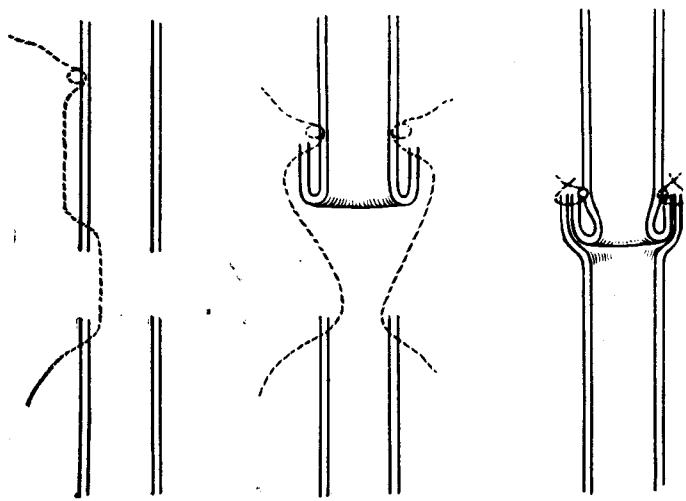

Fig. 11. Vascular suture according to G. M. Solovyov

nevertheless, this method is cumbersome and inferior to the mechanical one (Fig. 11).

Among the afore-mentioned methods of uniting blood vessels none found wide application by reason of nearly identical shortcomings, namely:

a) the risk of thrombosis;

b) no guarantee against secondary hemorrhage;

c) stricture of the vessel at the junction;

d) the suturing is, as a rule, time-consuming;

e) impossibility of suturing small vessels.

Thus, the vascular suture should meet the following requirements:

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