The technic of end-to-end arterial anastomosis : with report of a case / by Albert Ehrenfried ... and Walter M. Boothby.

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STEPHEN PILCHER, M.D., LL.D., of New York.

SIR WILLIAM MACEWEN, M.D., LL.D., OF GLASGOW.

W. H. A. JACOBSON, M.Ch., OF LONDON.

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WITH REPORT OF A CASE.

BY ALBERT EHRENFRIED, M.D.,

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WALTER M. BOOTHBY, M.D.,

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THE TECHNIC OF END-TO-END ARTERIAL ANASTOMOSIS.*

WITH REPORT OF A CASE.

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WALTER M. BOOTHBY, M.D.,

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VASCULAR anastomosis has developed chiefly within our own day. Its history begins, however, with the first arterial suture on June 15, 1759, when Hallowell, at the suggestion of Lambert, closed a wound of the brachial artery by passing a small steel pin, rather more than a quarter of an inch in length, through the two lips of the wound and then twisting a thread around it, as in the hare-lip operation. The closure was successful, and the pulse remained thereafter nearly as strong as in the other wrist. Asman, after fourteen years (1773), on the basis of four unsuccessful experiments on dogs, concluded that a vessel could not be sutured by this method with preservation of its lumen. Wattmann seventy years later (1843), reported that he had performed lateral ligation of a vein with success by holding up the edges of the wound with forceps and surrounding it with a ligature. Nicaise in 1872 maintained that lateral suture was practicable, and stated that Ollier and Gensoul had both performed it. Hirsch (1881) and Braun (1882) did important work on lateral suture, while Gluck (1882) devised a small ivory clamp for closing arterial wounds. Jassinowsky, in 1889, reviewed the general literature of the subject of lateral suture, published an extensive series of personal experiments, and established the procedure on a sound basis.

* The experimental work upon which this paper is based was performed in the Laboratory of Comparative Physiology at the Harvard Medical School, through the kindness of Dr. W. T. Porter.

Eck, investigating the physiology of the liver, performed in 1877 successful lateral anastomoses between the vena cava and the portal vein of dogs. His technic resembled that of lateral intestinal anastomosis, except that the anastomotic openings were not made until all the stitches had been placed. He used for this purpose a pair of fine scissors, to each tip of which was soldered a length of silver wire terminating in a curved needle. After the posterior line of sutures had been made, these needles were passed through the vessels (one the vena cava and the other the portal vein) at points determining the length of the incision. The anterior line of sutures was then placed, the scissor-blades were pulled into the vessels by means of the wires, and the veins cut between the two lines of sutures. This technic was improved by Stolnikow (1882), Hahn, Massen, Nenchi, and Pawlow (1893), and others, and the subject of Eck fistula forms an important chapter in blood-vessel surgery.

Von Horoch in 1888 tried to sew together the ends of an artery which had been cut across; he was unable to accomplish this without interfering with its patency. Robert Abbe, 1894, of New York, was the first to successfully perform end-to-end anastomosis; he divided the abdominal aorta of a cat and "tied each end over a glass bobbin by a fine silk thread, and tied the ends together." Queirolo and Masini, working on the Eck fistula, introduced in 1895 an appliance consisting of a tube of glass through which one cut end of the artery was threaded and cuffed back and then invaginated into the other end and held in place by a ligature. Nitze in 1897, demonstrated a similar anastomotic aid made of ivory, and Von Karltrew working also on the Eck fistula, improved the technic of its use in 1899. Payr in 1900, apparently without knowledge of the above methods, described in detail two appliances made of an absorbable material (magnesium); for a short time Payr's protheses were quite popular, and from one form, similar to that of Queirolo, the Crile cannula has developed.

While these men were perfecting anastomotic aids Murphy,

of Chicago, was attempting to develop a technic of suture without aids, and in 1897 he described a successful method of anastomosis by invagination. When dealing with moderately sized vessels, this method proved to be superior to that of Payr. Several men made attempts to improve the technic, especially Bouglé in 1901. Coincidently with Murphy, Jaboulay and Briau developed a method of end-to-end anastomosis by means of interrupted mattress sutures with evagination of the intima, and in 1898 they presented a specimen to the Medical Society of Lyons, in which there was a perfect union of the endothelium without any thrombus formation. Salomoni in 1900 independently devised a technic similar to that of Jaboulay and Briau. The method of Jaboulay and Briau was improved by the former's pupil, Carrel, into the method which is now generally used.

It was in 1902 that Carrel first described his now famous method of circular suture, converting the circumference of the vessel into a triangle by means of three stay sutures; he also pointed out the necessity of the use of the finest needles and silk and the maintenance of absolute asepsis. Carrel's method has become the method of choice wherever permanent union is desired and has been extensively used by both experimenters and clinicians; among others, Hubbard, Jensen, Floresco, Watts, Stich, Makkas, Dowman and Lund have used it and reported excellent results.

About two years ago we undertook to perform the operation on the abdominal aorta of cats, with the purpose of acquiring facility in the technic. Of our first series of fifteen animals no statistics were kept. Ether was administered with a cone, and the mortality from ether and from bronchopneumonia following operation was high; thrombosis was frequent.

On the basis of this preliminary experience, we perfected the technic of operation after the manner in which we shall describe it, and as we have used it since. We then undertook a second series of thirty cats, which we operated upon between the dates of January 23, and July 29, 1910. The animals were

anæsthetized by the intratracheal insufflation method. The mortality statistics are as follows:

2 died of thrombosis within 24 hours.
1 died of secondary hemorrhage on 5th day.
1 died of complete rupture on 8th day.
1 died of false aneurism on 33d day.

5 operative deaths.

1 died of general peritonitis on 6th day.
1 died of general peritonitis on 8th day.
1 died of general peritonitis on 23d day.
1 died of gastro-intestinal on 28th day.
1 died of gastro-intestinal on 31st day.

5 deaths from infection and intercurrent disease.

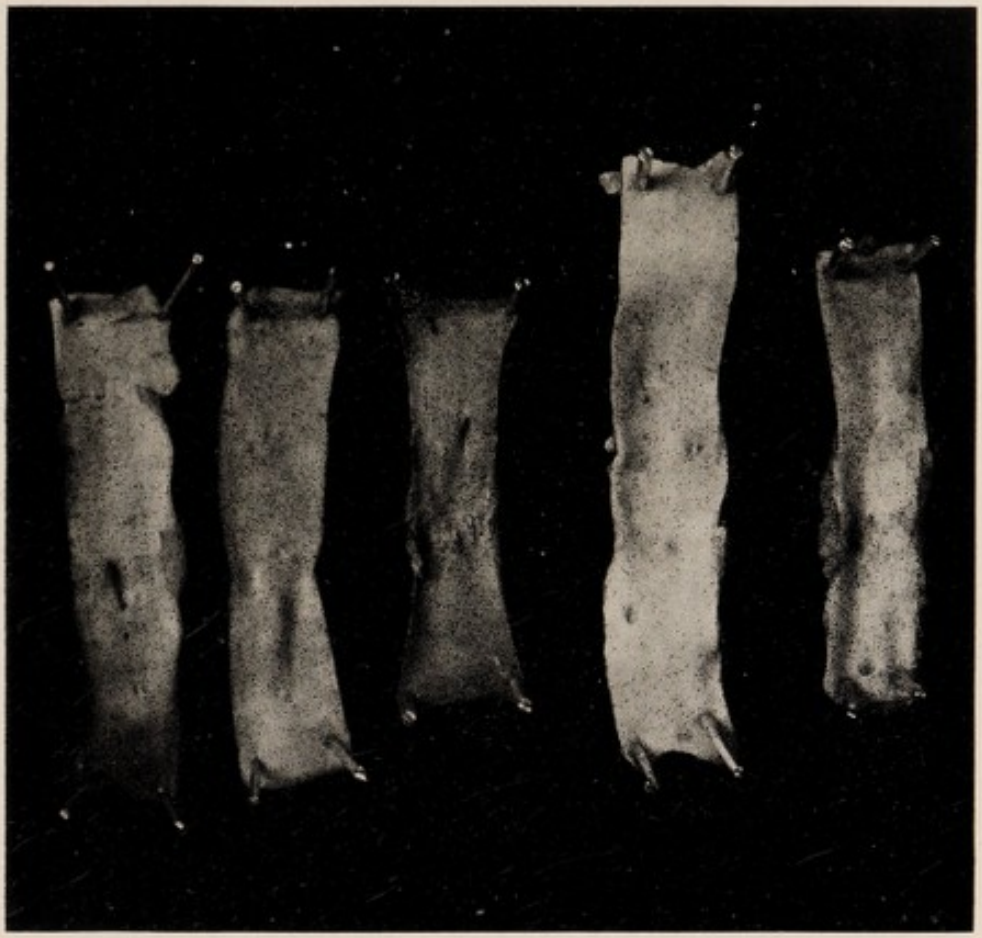
The segments of sutured aorta were saved in the five cases that died of intercurrent disease, preserved in alcohol, and photographed (see Fig. 1). It is worthy of note that in this series there were no ether deaths and no cases of post-operative bronchopneumonia.[1]

The deaths from infection and intercurrent disease were the result of the operating conditions and the housing of the cats.

Of the other twenty animals, twelve were killed August 15, 1910, at the request of Prof. E. H. Nichols of the Department of Surgical Pathology, to supply material for the demonstration of the healing of arteries. Four of the remain-

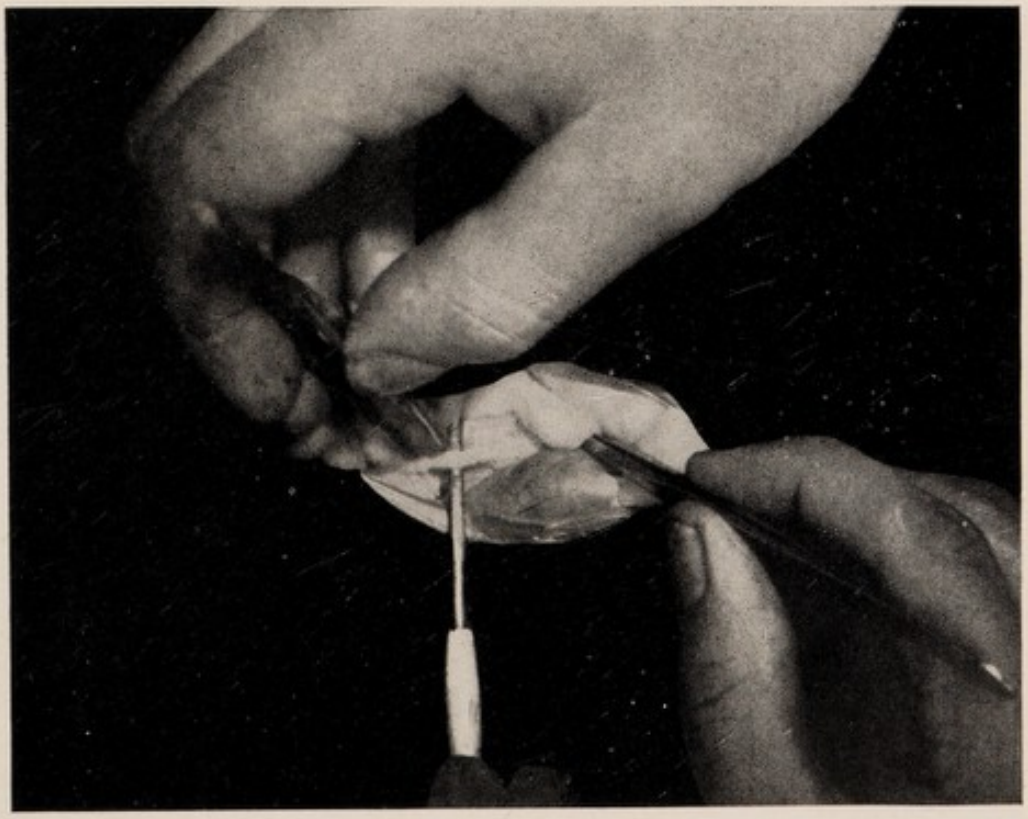
[1] The apparatus which we used consists of a Wolffe bottle half full of ether; through one stopper passes a glass tube which dips below the surface of the ether and is connected by rubber tubing with the air-pressure tap of the laboratory, and the other connects with a straight metal intratracheal tube. Another piece of tubing is connected with the tubing to and from the bottle so as to pass the air current around it, without taking up any ether vapor. This is long enough to lie in a loop upon the floor. When ether is required, from time to time, the assistant presses upon this loop for a second or two with his foot, forcing the air to bubble through the ether. A mercury bottle is connected on to serve as a safety valve, as described by Ehrenfried: Intrathoracic Insufflation Anæsthesia, Apparatus and Cases, Boston Medical and Surgical Journal, 1911, clxiv, p. 532.

FIG. 1.



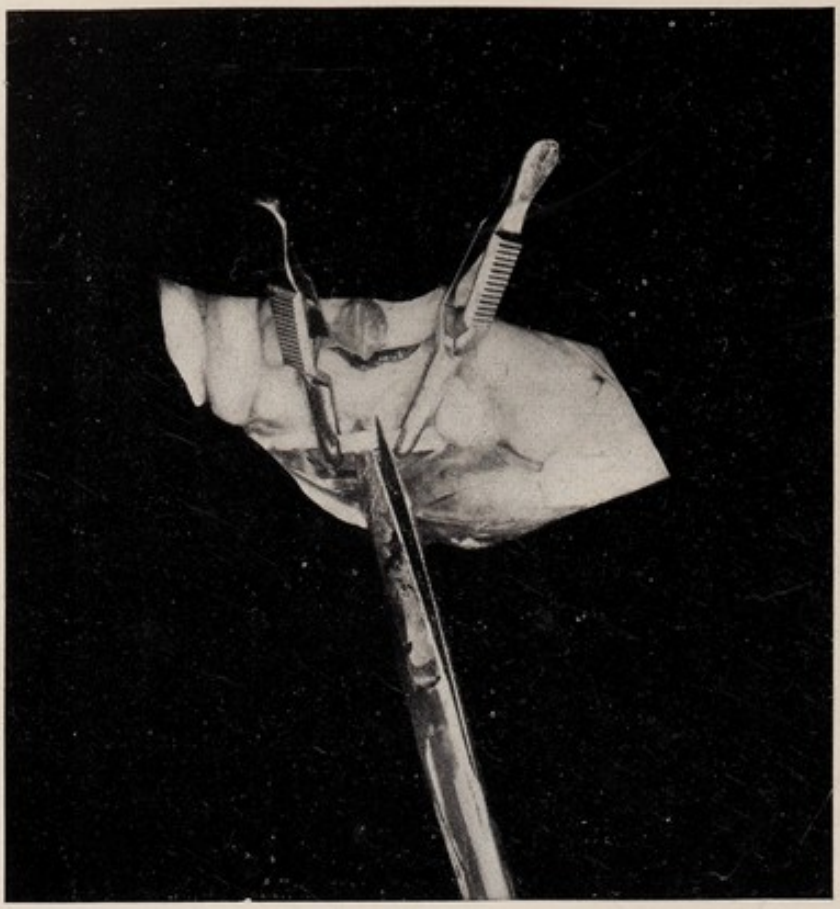
Section of healed aortæ taken from cats which died of intercurrent disease (considerably enlarged).

FIG. 2.



End-to-end anastomosis of divided abdominal aorta in a cat; the retroperitoneal space has been opened up, the artery exposed and lifted up on the blunt dissector.

FIG. 3.

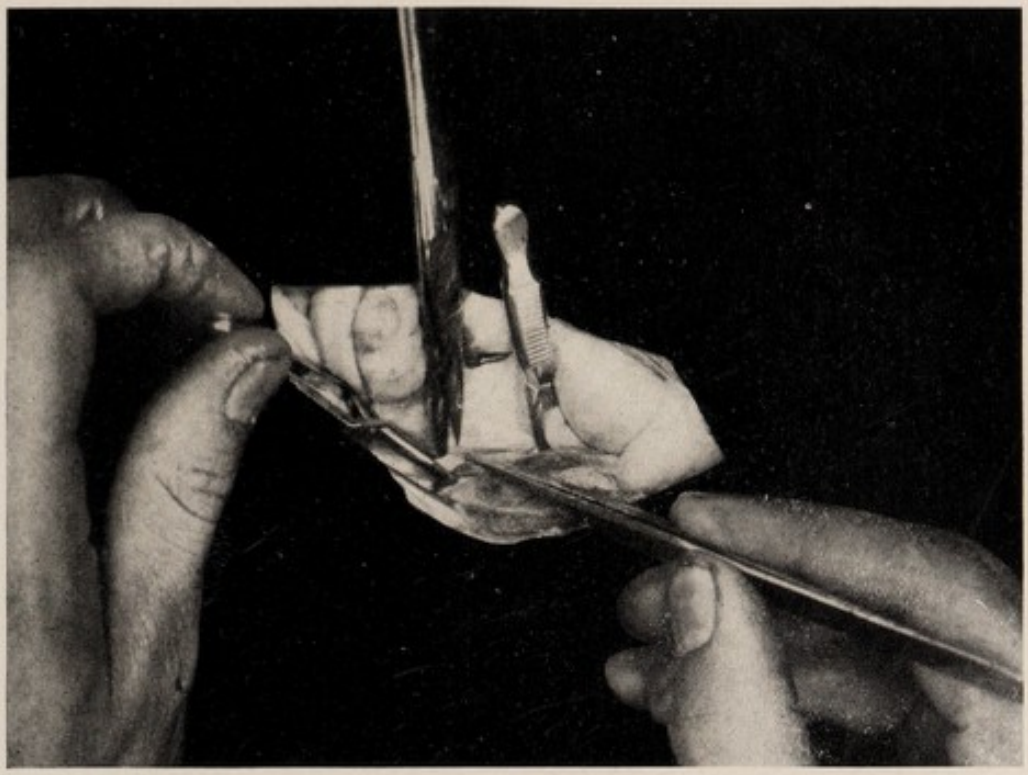


The clamps have been applied, and the artery is being divided.

FIG. 4.

The segments are being washed free of blood and clot with sterile salt solution.

FIG. 5.

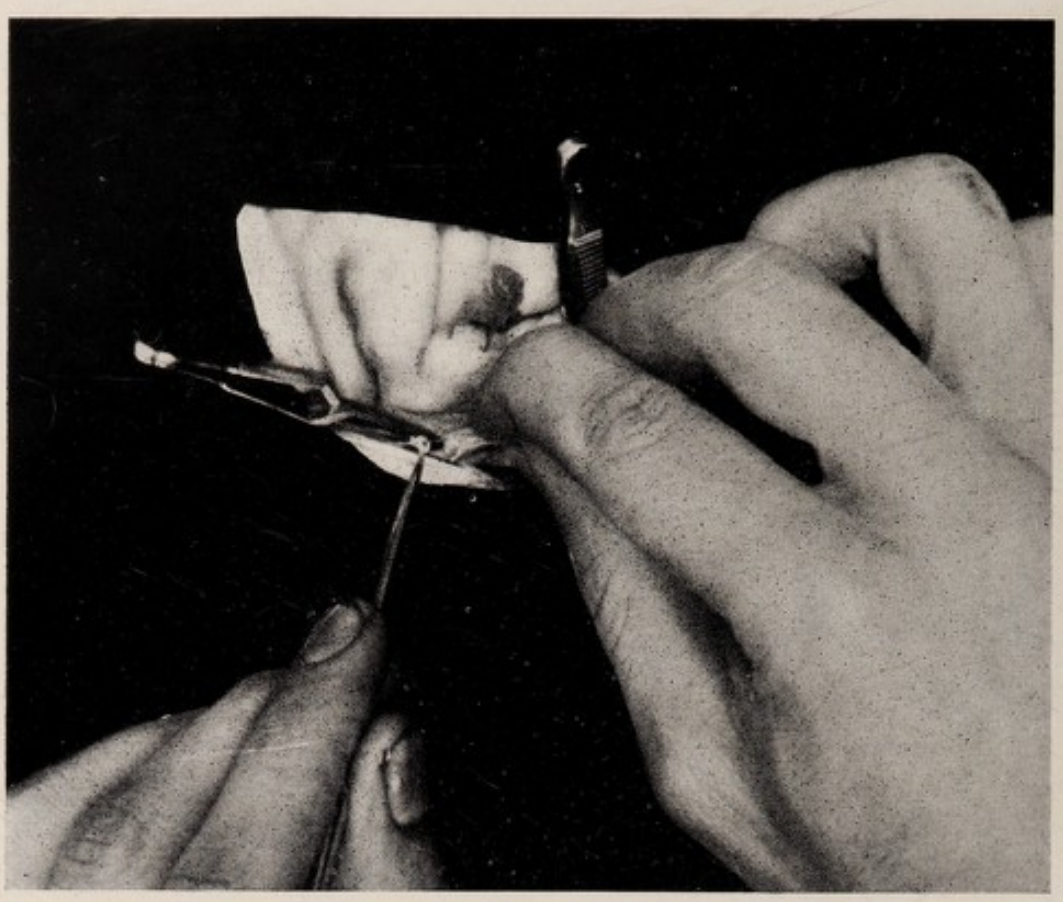


Trimming off the adventitia.

FIG. 6.

Starting the first stay suture.

FIG. 7.

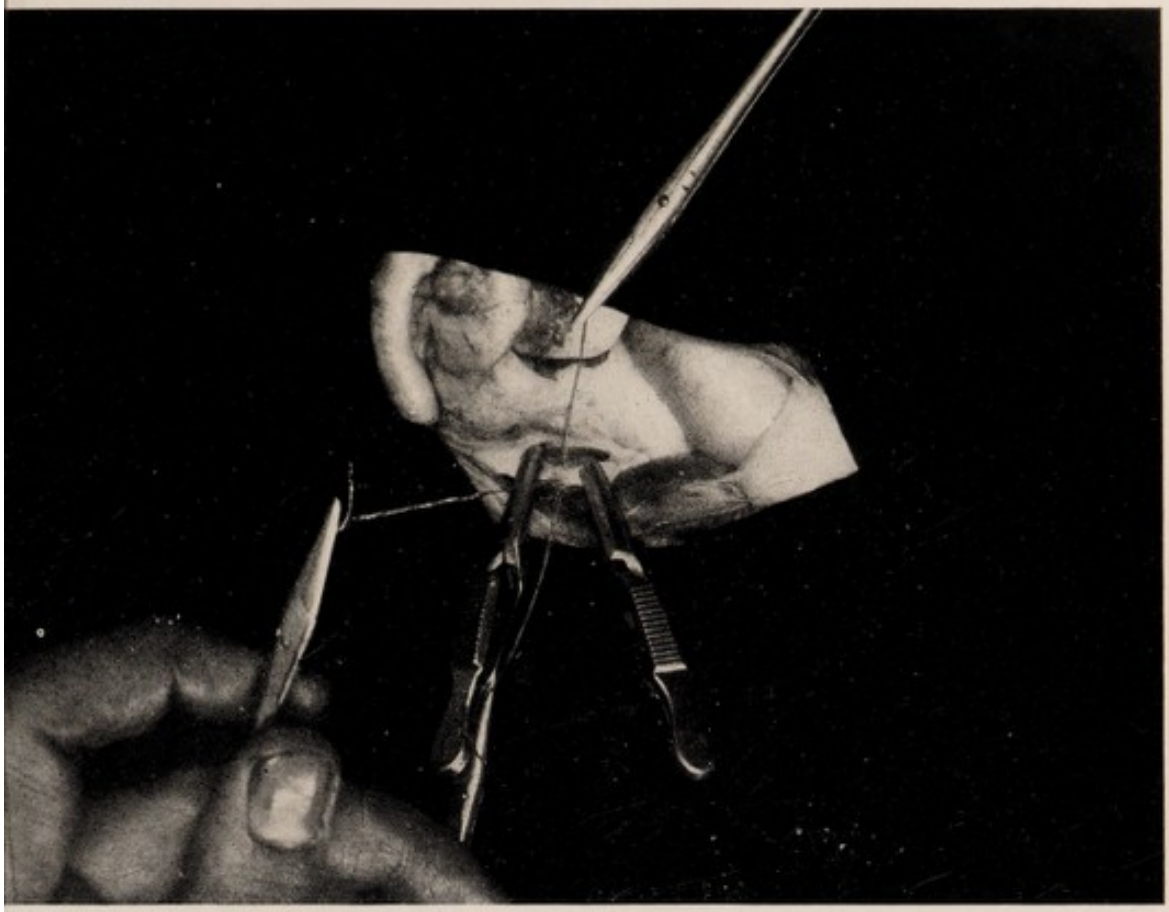


Completing the first stay suture.

FIG. 8.

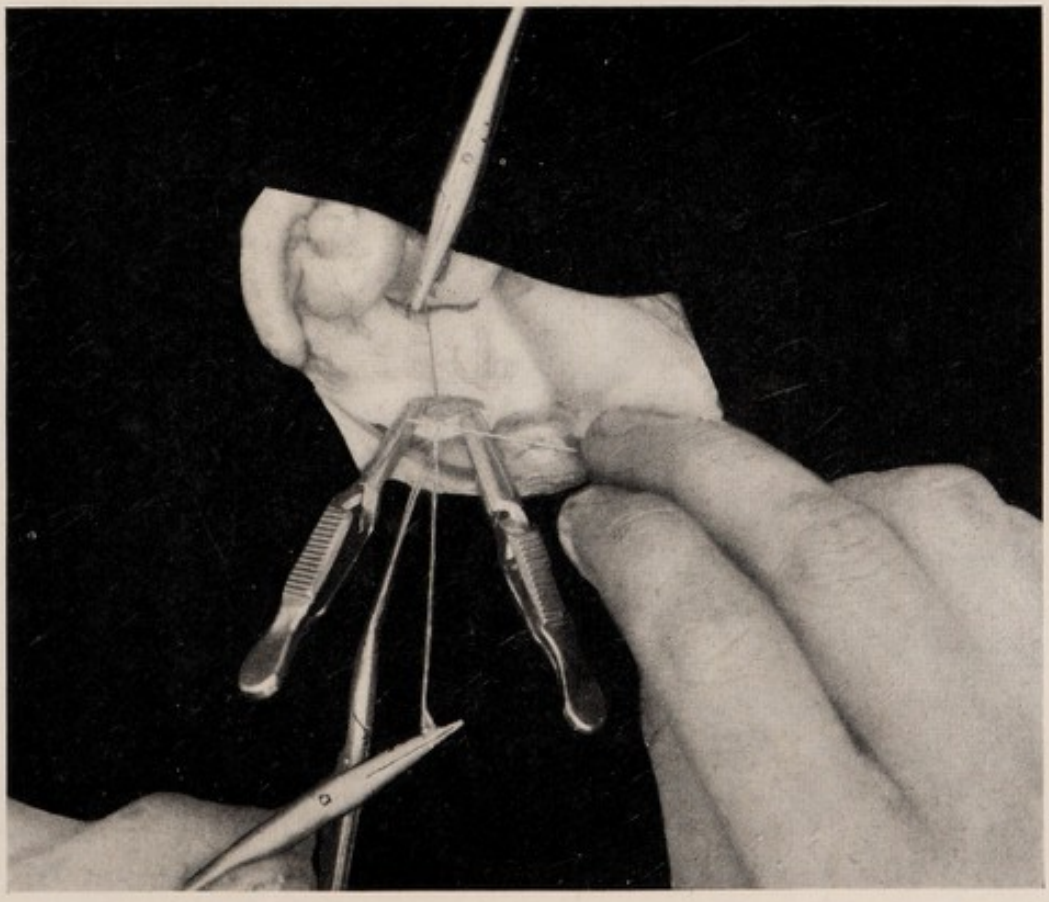
All the stay sutures in place.

FIG. 9.



The stay sutures have been drawn up and tied.

FIG. 10.



Starting the continuous circular stitch. (The needle and silk used for this series of photographs are coarser than those regularly employed.)

ing cats have died since that date, two have been used for other purposes, and two are now living (Aug. 1, 1911).

The kit which we use in operating contains the following instruments:

Six light mosquito hæmostats for use in tying off collaterals, to snap on the ends of the three stay sutures, and on the end of the running suture after it is tied, in starting. Heavy snaps will tear the vessel wall by their weight.

Two vessel clamps. At Carrel's suggestion we use the small old-fashioned "serrefine," with the blades filed smooth, and the tension of the springs weakened until the blades come together flat with the least possible pressure. On large vessels in the human, Crile clamps may become necessary, but the serrefine is preferable because it is lighter and more easily handled. It is a wise precaution in human surgery to apply a Crile clamp some distance proximal to the cut, to provide against the possibility of slipping of the serrefine.

One blunt dissector, to assist in freeing up a sufficient length of vessel for operative purposes. We make use of a straight blunt aneurism needle.

One fine blunt scissors, curved on the side, to trim off adventitia.

Two pair of smooth jeweler's forceps (Boley, MM, filed blunt). These we have found to be the best adapted of any forceps for handling the fine needle.

One medicine dropper and sterile saline solution, for flushing out the segments of artery before sewing.

One bottle of vaseline, in which to sterilize the silk sutures.

Fine Pagenstecher, for tying off small branches cut in freeing the artery. Catgut swells up and interferes with the operation.

Needles, No. 16 Kirby sharps.

Suture material, No. 0000 Chinese silk, untwisted into the three strands of which it is composed. About 18 inches is threaded on the needle, the needle is stuck through a square of card, and the silk is wound about this. Two such cards are enough for an operation; one length will make the three stay sutures, and another will suffice for the continuous suture. On account of the difficulty of threading, it is wise to economize in the suture material. If the needles are allowed to remain for long in the vaseline, they are likely to become brittle.

The ability to perform end-to-end arterial anastomosis comes only as the result of practice, gained upon the living animal. The best subject of experimentation is the cat; it is inexpensive and not hard to care for. The abdominal aorta is easy to get at; it is approximately the size that would be met with in human surgery, slightly larger than the brachial

and slightly smaller than the femoral artery. If the artery thromboses, or if the lumen is sewed up (the commonest mishaps in the beginner), the cat dies.

The animal selected is given no food the night before. For operation it is strapped upon the board, etherized, and the hair clipped from its belly which is washed with soap and water and rinsed with alcohol. Operative asepsis in all its details is essential; gloves, however, are not worn. The operator stands upon the cat's right. An incision is made from one inch below the ensiform to one inch above pubes. A snap is applied to peritoneum and fascia on either side and thrown back. The intestines are taken out and wrapped in a hot towel on the cat's left. (A black silk laparotomy sheet, with one side long for covering the intestines, is a distinct advantage; against it the needle and silk can be readily seen.) The laparotomy sheet is pinned to the edges of the wound by Bachaus towel clamps to prevent exposure of the skin, and to avoid getting hairs into the operative field.

The retroperitoneal space is opened up by blunt dissection, and the aorta is freed for a distance of about three-quarters of an inch between the superior and inferior mesenteric arteries. Occasionally one or two posterior-lateral branches will have to be tied off; double snap with mosquitoes and tie short with very fine Pagenstecher or silk. Tie off as few branches as possible, because the ties get in the way, and because if the branches which supply the cord are cut the cat dies within twenty-four hours with paralysis of the hind legs. Lift up the vessel on the blunt dissector, apply the clamps, perpendicularly, about one-half inch apart, and cut between. Gently wash out the segments of vessel with salt solution in the medicine dropper, and then apply a little warm vaseline to the cut edges with the blunt dissector. Trim off any redundant adventitia or any connective tissue that might get in the way when suturing.

The three stay sutures are now placed at points equidistant about the circumference of the artery, one stitch being exactly posterior, corresponding to the tips of the clamps. The needle

is passed directly through the vessel wall of the proximal segment, including the intima, and is passed back (from within outward) through the distal segment at the corresponding point. If there is any difficulty, the vessel wall may be grasped by the forceps, which have been dipped in vaseline. The stay is not tied, but its ends are left long, and grasped by a mosquito snap. When the last one has been placed, they are all gently drawn up so as to approximate the cut edges of the artery. While the assistant holds two taut, the operator ties the third, snugly, using a surgeon's knot to prevent slipping. The other two are tied in turn; the tied ends of all are left long and snapped with mosquitoes. The ends of the posterior stay should come out on the cat's left.

Everything is now ready for the application of the continuous suture. The clamp handles are directed to the operator, and the first stitch is applied just anterior to the posterior stay suture. A tie is made to start from; its end is left long, and is snapped by the mosquito on the posterior stay. The operator holds the stay suture toward which he is sewing in his left hand, while his assistant holds the stay from which he is sewing, applying enough pull so as to keep the section which is being sewed on the stretch. The third stay, which lies beneath, is slackened up and relieved of the weight of its snap, otherwise the under wall of the artery might be pulled up against the anterior, and the two sewn together. The assistant pulls up with his right hand the slack of the running suture, after each stitch is passed, so as to evert the edges and bring intima to intima. (If the operator prefers to sew away from, rather than toward himself, he ties the posterior stay so that the ends come out on his side, and starts the running suture just anterior to it. In this case the assistant, with his right hand across the table, will hold the two stays, and the surgeon will pull up his own slack.) About six stitches usually suffice for each of the three sections.

The first section being completed, the assistant takes the stay which the operator was holding, the operator picks up the next one, the handles of the clamps are directed to the

side of the assistant, so as to expose the next section, and the suture is continued. When this section is completed, the operator cuts close the stay which the assistant is holding, which is no longer needed. The assistant then passes the long end and the posterior stay, which are snapped together, under the artery. The clamp handles are directed back to the side of the assistant, so as to bring the third section into view. The suture is continued, the operator taking the stay which was passed under, and the assistant the other. This section being completed, the ends of the running suture are tied to each other and cut. The stays are cut and the clamps removed, the distal one first.

There is practically always leakage of blood in some amount, usually through the stay holes, which have been stretched by the pull upon the stay sutures. If the anastomosis is otherwise competent, this ooze will stop in a half minute, some loose gauze being applied over the site of operation. If more than gentle pressure is applied on the gauze, a thrombus is apt to form within the artery. Where there is no leakage, there is probably thrombosis, and the pulsation of the vessel will have disappeared below the anastomosis. In this case the thrombus may sometimes be broken up and sent along by massaging and "milking" the artery. If the artery "spurts" through one hole, where a stitch has cut through, for instance, the clamps may be reapplied and the hole sewed over, with some show of success. In case there is more than one tear, the anastomosis had better be cut out and performed over again.

The intestines are replaced, and the peritoneum and fascia of the abdominal wall are sewed up together with a running buttonhole stitch of Pagenstecher, and the skin likewise. No dressing is applied. The entire operation should take thirty-five minutes or less; the clamps should not be on longer than fifteen minutes.

The advantage of being prepared to apply this technic to human traumatic surgery is suggested by the following case, which we report through the courtesy of Dr. L. R. G. Crandon,

Assistant Visiting Surgeon, Boston City Hospital, who invited one of us to assist him in the treatment thereof. [2]

T. G., Syrian, was brought to the Relief Station of the Boston City Hospital at 4.30 P.M., April 23, 1911, by a police ambulance, with the story that he had been stabbed in the left groin. He was conscious, restless and pale, pulse 80, of small volume and low tension.

Just below Poupart's ligament on the left was a narrow, somewhat pouting, clean-cut slit in the skin about three-quarters inch long, running nearly transversely. There was considerable blood on the thigh and the clothes covering the thigh. About the wound was some swelling. No pulsation in the femoral artery or its branches below this point was made out.

The thigh was cleaned and shaved. On the passing of a director into the wound, to ascertain where to introduce a wick, active arterial hemorrhage ensued. The wound was packed, and a sterile dressing was applied with pressure. Heaters and blankets were ordered, and salt solution administered by rectum.

Patient was cold, restless, and weak for two or three hours, but then became more quiet, stronger, and warmer. There was no return of pulsation in the branches of the femoral artery. Operation was advised and accepted.

Operation, Drs. Crandon and Ehrenfried: Under ether an incision was made above and parallel to Poupart's ligament. The external iliac artery was found and a Crile clamp applied. An incision five inches long was made over and parallel to the femoral artery, the region of the punctured wound was laid open, and the dissection carried down to the femoral artery. This was found completely severed, though the ends were held together beneath by some strands of uncut adventitia. The surrounding tissues were infiltrated with blood-clot. The vein and nerve were intact.

Crile clamps were applied to the artery, the adventitia trimmed away, and the ends sewed together by the technic just described. The clamps were taken off, and then the clamp on the iliac artery was removed. There was some oozing of blood from the anastomosis, which ceased in two minutes under light pressure. Pulsation was readily felt beyond the suture.

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[2] We are indebted to Dr. Paul Thorndike, Surgeon-in-Chief, Boston City Hospital, for permission to publish the following record.

The abdominal wound was sewed up in layers, the thigh wound by mass sutures. Sterile dressing was applied. Stimulation, heaters and blankets.

The recovery was rapid and uneventful, despite the weakness of the patient from loss of blood. When seen the next day the left foot was warm, and on the day following pulsation of the dorsalis pedis could be readily made out, and heaters and blankets were discontinued. The temperature and pulse were normal on the fourth day, and remained so. On May 3 the stitches were removed, and on May 7 the patient went home, well except for a small granulating area at the site of the original wound.

We have applied this technic also in one case of transfusion, but without satisfaction. We consider the ordinary methods of transfusion, of which that of Elsberg is undoubtedly the best, more rapid and certain. The chief difficulties to suture in transfusion are the inequality in size of the vessels, their difference in texture, and the possibilities of tension under which the operation is performed. There is no question, however, but that the Carrel method of end-to-end anastomosis has already made for itself an important place in operative surgery.

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