A HISTOLOGICAL STUDY OF THE CIRCULAR SUTURE OF THE BLOOD-VESSELS

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The purpose of this study is to obtain some light on the repair of sutured blood-vessels, and to determine upon a simplified technic which would render the circular suture of blood-vessels practicable in general surgery.

The first recognized successful suture of a blood-vessel was performed by Jassinowski, in 1889. He made use of interrupted sutures. Burci, in 1890, and Silberberg, in 1897, report similar results. The same year Murphy reported his method of invagination. Doerfler in 1889 first used the method now employed, the essential features of which were the use of fine round needles and fine silk, and the continuous sutures embracing all the coats of the vessel. Hirsch, Brian and Jaboulay were followed in 1900 by Payr, Bougle, Clermont, Tomaselli and Salvia. Berard and Carrel began to study end-to-end arteriovenous anastomosis in 1902. During the next years Jensen and Hoepfner and Floresco pursued the same studies. In 1905 Carrel and Guthrie had favorable results from their method of continuous sutures penetrating the media and intima. Other workers in blood-vessel suture were Ullman and von Decastello, Stich, Jeger, Borst and Enderlen, Lespinasse, Villard and Tavernier, Yamanoüchi, Horsley and Bernheim.

The results of arterial circular suture in animals by Borst and Enderlen, Yamanoüchi, Ward, Stich and Carrel by Carrel's method show 74.2 per cent. successes in a total of 148 cases. Sofotereff says that in 352 cases operated upon by the Carrel method, there were 49.8 relative percentage of successes, 15.5 per cent. by the Murphy method, and 17.6 per cent. by the Payr method of invagination with magnesium rings.

Of the methods described, Jeger considered Carrel's technic the best for the surgeon who has made a specialty of blood-vessel suture, but was inclined to believe that the Payr method, on account of its simplicity, would find a field of usefulness in war surgery.

Carrel's technic is as follows: "The round straight needles, Kirby No. 16, threaded with fine silk and sterilized in vaseline, are used. The

operative field is circumscribed by a black Japanese silk towel on which the fine threads can be easily seen. The temporary hæmostasis is secured by elastic clamps, forceps or rubber bands. The vessels are severed and the adventitia removed from the end of the vessels. The blood is washed out not only from the vessels but also from the operating field. The vessels and the surrounding parts are then covered with warm vaseline.

"The vessels to be sutured must be approximated without much tension. They are brought together by three retaining stitches, introduced at three equidistant points of their circumference. By traction on these threads, the circumference of the vessel can be transformed

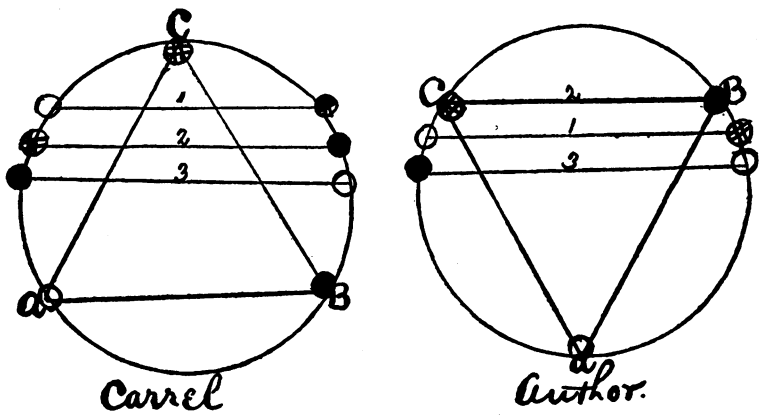


FIG. 1.—AO, first retaining and traction suture, also starting point of circular suture; B● second retaining and traction suture; C●, third retaining and traction suture. Lines 1, 2 and 3 (left figure) indicate the relative position of the corresponding sides of the triangle during the suture by Carrel's method. Lines 2, 1 and 3 (right figure) indicate the relative position of the corresponding sides of the triangle during the suture by author's modification.

into a triangle. The first retaining thread is used as a continuous suture, uniting the three sides of the triangle. During the suture great care is taken to approximate accurately the cut surfaces of section of the walls.

"In arteriovenous anastomosis the vein is generally larger than the artery. After the ends of both vessels have been approximated by the three retaining sutures with some of the stitches of the continuous suture, a relatively larger portion of the vein is taken up than of the artery, thus the caliber of the vein is progressively reduced and a good union takes place. In side-to-side anastomosis, both vessels are brought near one another, and an ellipse resected from the contiguous walls. A temporary provisional suture is introduced into the posterior margin of both vessels, but is not tied. Two retaining sutures unite either end of the openings. The ends of the retaining stitches are on the external

surface of the vessels. The union is completed by a continuous suture. Leakage during the first minutes after the circulation is restored is controlled by gentle pressure with gauze. After two or three minutes the sponges are removed, and, if some hemorrhage persists, one or two complementary stitches are added."

I believe that it is important to avoid the use of instruments in handling the severed ends of the vessels. The adventitia is drawn over the end of the vessel with fingers well oiled with paraffin, and severed with scissors.

The third side of the triangle with Carrel's method is made accessible for suture only by twisting the vessels for a distance of 180 degrees. By introducing the first retaining stitch on the posterior side so that the triangle formed by the three retaining stitches will have its apex downward, it was found that the vessels were twisted only for an arc of a quarter of a circle or 90 degrees. The importance of this feature of the technic is particularly emphasized in an attempt to anastomose the shorter vessels, such as the renal and splenic. I find that liquid paraffin is more easily handled than vaseline, especially during cold weather.

While the eversion of the vessel ends emphasized by most of the experimenters is quite essential, this detail should not be exaggerated, particularly in the anastomosis of arteries where the histological reconstruction of the continuity of the vessel should be sought for in order to assure a perfect functional result.

The results obtained seem to prove that coaptation of the respective layers of the vessel wall can be accomplished with a simple running suture. This is illustrated in a number of the specimens which attains the object with a minimum amount of cicatrix and with an almost perfect restoration of the normal integrity of the vessels. A restoration of the intima is most essential in order to eliminate as far as possible the dangers of an occluding thrombus. It cannot be denied, however, that this can be accomplished without the practice of the mattress or double mattress suture advocated by Horsley. This is shown in the histological study of the specimens. The objection to the mattress suture on theoretical grounds would be that it has a tendency to evert the severed ends of the layers of elastic tissue and muscularis. This tendency even goes so far as to eliminate the possibility of their re-entering into the continuity of the vessel wall. I have found in side-to-side anastomosis that the use of the three-bladed clamp of Jeger very much simplifies the procedure. After the vessels have been fenestrated, the introduction of an additional temporary traction suture in the anterior margins

of the openings facilitates the use of the straight needle without inflicting injury upon the exposed intima. These temporary sutures should not be tied and are readily removed after the continuous suture has been completed. The traction is produced with the weight of the serrefines.

The histological studies of the process of healing of the circular suture of vessels have been as follows:

Carrel in 1907 reported findings after autotransplantation of jugular vein to carotid. He stated that the walls were thickened and, *vice versa,* in the transplantation of artery into vein the walls become attenuated so that it might be said that the transplant eventually shows changes in its structure in accordance with the blood-pressure to which it has been subjected. Stich, Makkas and Dowmann show the thickening of the intima and proliferation of the endothelium.

Fischer and Schmieden report histological findings in transplantation of vein to carotid removed from a dog after eighty-six days. They found a marked thickening of the media due to a hypertrophy of the muscularis and connective tissue invasion. The intima was somewhat thickened over the line of suture. They also found among the spindle-cell proliferation of the intima, some cells that resembled smooth muscle cells. They note the absence of elastic fibres in all of their specimens.

Capelle states that he found proliferation of the intima with very little changes in the media or adventitia. W. Ward found that homotransplantations, similar to heterotransplantations, eventually become absorbed. The elastic fibres, however, remain intact.

Borst and Enderlen in an autotransplantation of carotid artery after 132 days report that the elastic fibres were replaced by connective tissue. There were small areas of necrosis in the media. The sutures were surrounded by granulation tissue, containing phagocytes and giant-cells. The vasa vasorum were increased in number and somewhat thickened. The elastic fibres end at the scar and show a tendency to divide into bundles. A few very delicate newly formed elastic fibres were present in the scar itself. The muscularis showed marked atrophy.

Ribbert is quoted by Borst and Enderlen as saying that a homotransplant seems to be able for a short time at least to withstand the biological differences in body juices between the donor and host. He believes that the transplant will begin to show evidences of absorption as soon as its own tissue fluids are exhausted.

Jacobsthal claims that he saw new elastic fibres appear as early as 12 days, Borst and Enderlen, 14 days, and Faykiss in 3 weeks.

Borst and Enderlen believe that the union of the vessels evidently

takes place by scar tissue. Minute small areas of necrosis have been observed in the media. Archibald Smith has also reported such a finding. "There is some danger of aneurismal formation following the cutting out of the silk sutures when drawn too tightly or when introduced under too great tension. The triangular-shaped groove formed by the eversion of the two vessel ends becomes covered with endothelium. The endothelium showed proliferation of a spindle-cell variety and can be observed within twenty-four hours. The sutures were surrounded by polymorphonuclear leucocytes and buried in the new tissue formation. Elastic fibres and muscle fibres disappear in the everted portion of the vessels while the elastic fibre of the media near the scar undergoes degeneration. A few delicate elastic fibres make their appearance later in the scar itself. We cannot therefore say that all the elements of the vessel wall are absolutely restored, but that scar tissue enters into the process of healing."

According to Aschoff, the vascular wounds are closed immediately by fibrin and platelets. "The degree of thrombosis depends upon the amount of traumatism inflicted, secondly upon the nature of the wall of the vessel (arteriosclerosis), and thirdly, the state of the circulation. The process is followed by a cellular proliferation which infiltrates and covers the thrombus. This is followed by invasion of the adventitia and media. The media is the seat of marked connective tissue and very slight muscle cell proliferation. New elastic fibres permeate the scar, especially the outer layers. An absolute restoration of the elastic and muscular tissue of the vessels seems improbable."

According to Yamanoüchi, union takes place by the formation of scar tissue with a partial preservation of the muscle cells, the elastic fibres being somewhat increased in number. He found that homotransplantations of vessels were followed by gradual degeneration and destruction of the transplant which is eventually replaced by connective tissue. The findings in No. 3529 and No. 2753 agree with those of this author.

Borst and Enderlen claim that the muscularis disappears almost entirely from the vicinity of the suture line.

The specimens No. 3846 and No. 3258 in this series show the muscularis well preserved and extending into the line of suture.

The presence of valves in a vein transplant does not necessarily favor coagulation or thrombus formation, as is demonstrated in several of these specimens (see Fig. 10, No. 2477).

The consensus of opinion is that the restoration of the intima is brought about by proliferation of the endothelium.

My specimens in which histological examinations were made include examples of end-to-end or circular sutures, side-to-side anastomosis between artery and vein, the end-to-end arteriovenous anastomosis and the transplantation of segments of vessels:

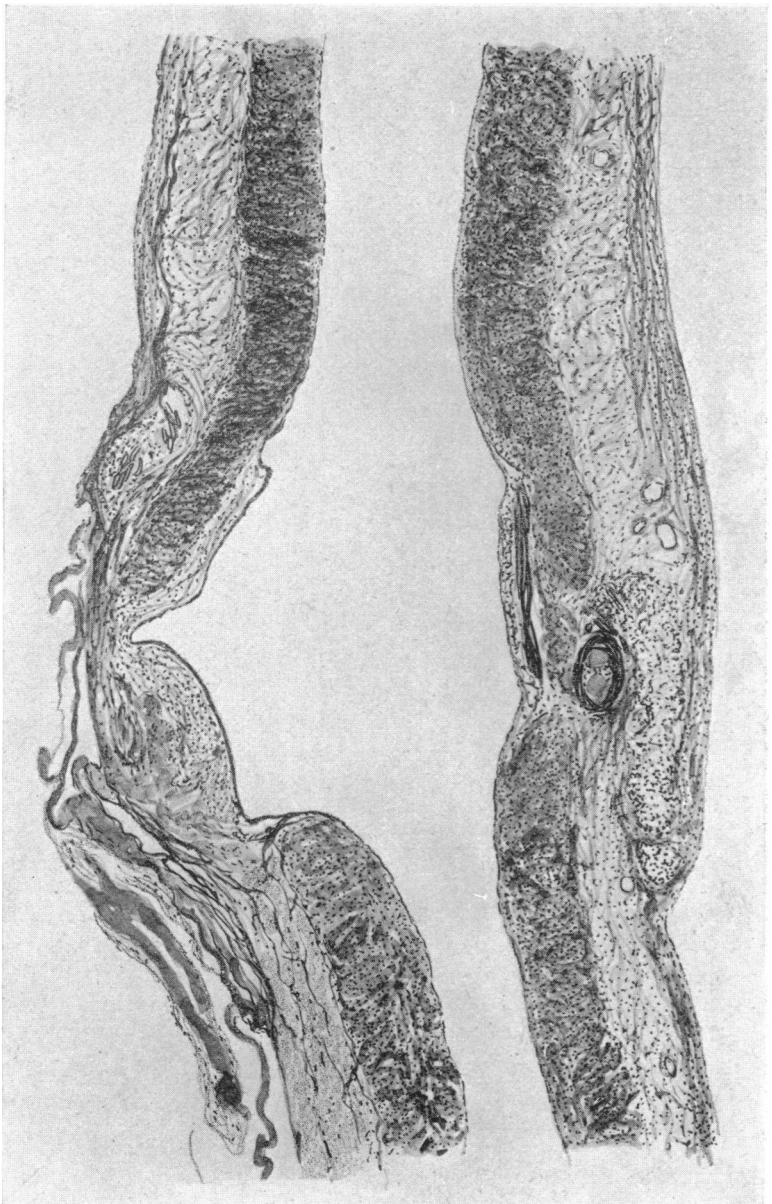
Experiment No. 40.—Fig. 2. Drawing. Low power. End-to-end suture of carotid. Dog No. 27. Surg. Path. No. 3729. Operation, November 13, 1915. Specimen removed November 22, 1915. Sutured ends separated by ½ mm. of connective tissue on one side; on the other side by 2 mm. This connective tissue at some points is dense; at other points it is loosely constructed. The intima regenerates everywhere. At one point one of the sutures lies within the vessel lumen, and is completely covered by connective tissue, with an endothelial surface. Where there was wide separation of the vessel ends, there is a considerable mass of relatively loose connective tissue on the surface which is covered with intima. In the depths the repaired vessel wall is dense and suggests osteoid structures. In the depths of the suture line at another point, very definite osteoid structure exists. There is a distinct dilatation of the lumen present at the site of the suture line.

Fig. 3. Drawing. End-to-end suture of carotid. Dog No. 27. Surg. Path. No. 3729. Operation November 13, 1915. Specimen removed November 22, 1915. Sutured ends separated by ½ mm. of connective tissue on one side; on the other side by 2 mm. This connective tissue at some points is dense; at other points it is loosely constructed. The intima regenerates everywhere. At one point, one of the sutures lies within the vessel lumen, and is completely covered by connective tissue, with an endothelial surface. Where there was wide separation of the vessel ends, there is a considerable mass of relatively loose connective tissue on the surface which is covered with intima. In the depths, the repaired vessel wall is dense and suggests osteoid structures. In the depth of the suture line at another point, very definite osteoid structure exists. There is a distinct dilatation of the lumen present at the site of the suture line.

Experiment No. 47.—Fig. 4. Drawing. End-to-end suture of carotids. Dog No. 108. Surg. Path. No. 3846. Operation January 20, 1916. Specimen removed February 9, 1916. Cicatricial tissue firmly unites one vessel end to that of the other. One extremity is slightly everted and the other is implanted upon it. The recess is so obliterated by connective tissue that the intimal lining is completely regenerated. The suture line is hardly discernible on account of the merging of the cicatrix with the sutured ends. Smooth muscle cells as demonstrated in a Van Gieson stain infiltrate the cicatrix.

Experiment No. 1.—Surg. Path. No. 2053. End-to-end suture of carotids. Dog. No. 313. Operation April 30. Specimen removed May 27. Strong dense cicatrix joins both ends. The lining membrane completely regenerated. Some bulging of vessel wall at site of cicatrix.

Experiment No. 43.—End-to-end anastomosis of carotids. Eleven days. Dog No. 56. Surg. Path. No. 3765. Operation December 9, 1915. Specimen removed December 20, 1915. Vessel wall on one side shows the ends are in perfect alignment. There is a minimum amount of scar tissue forming the suture line. On the other wall there is an eversion. The recess is filled in with fibrin and leucocytes. Cicatricial tissue firmly unites end of vessel wall to end of vessel wall.



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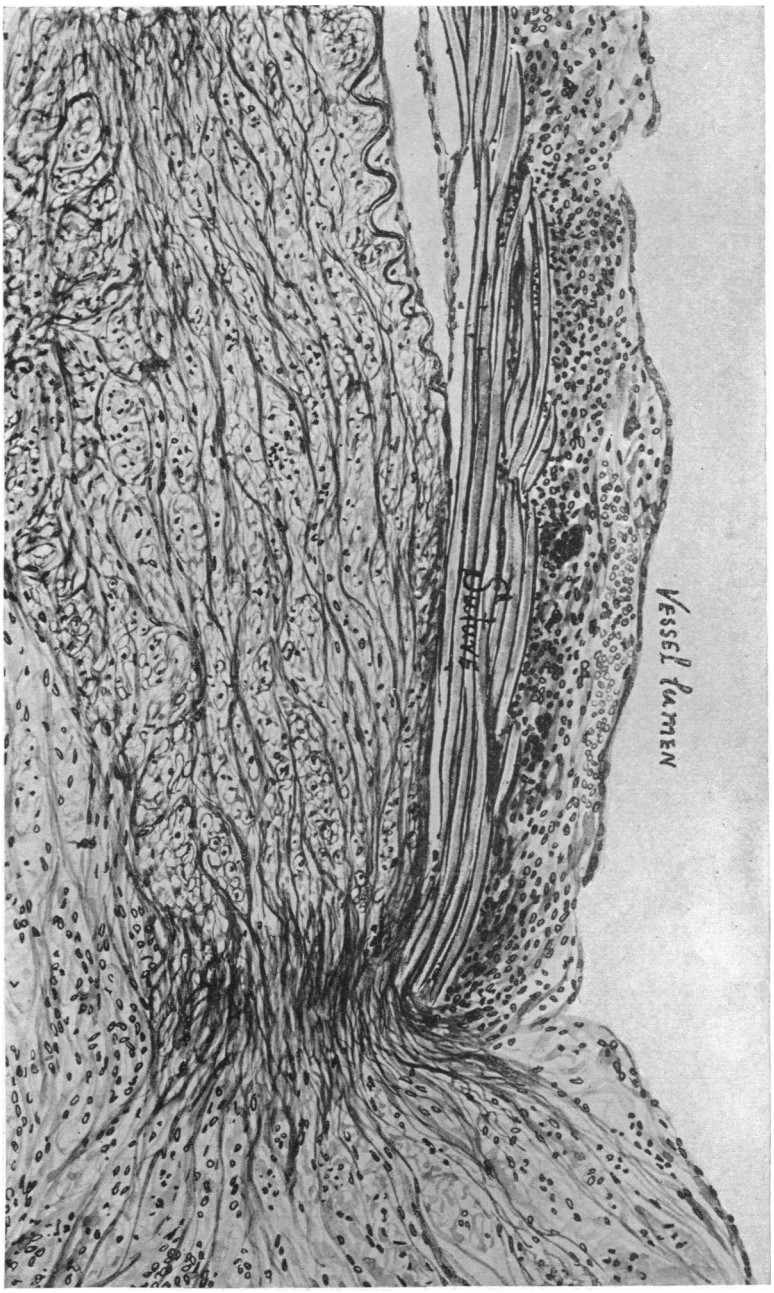

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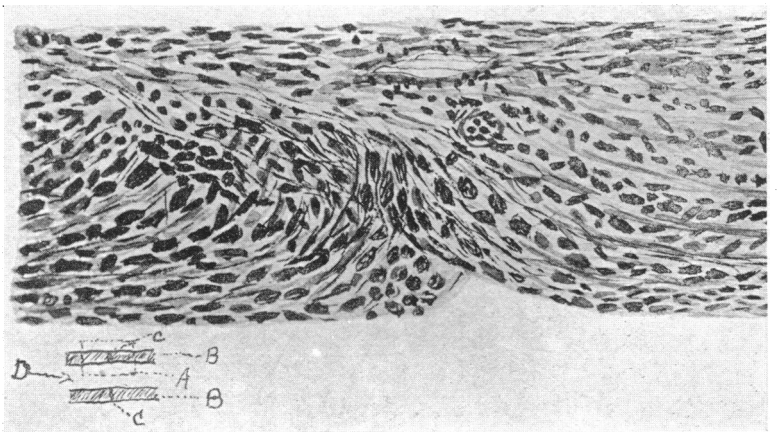

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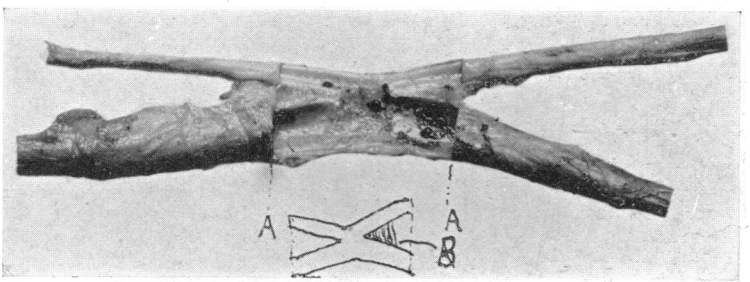

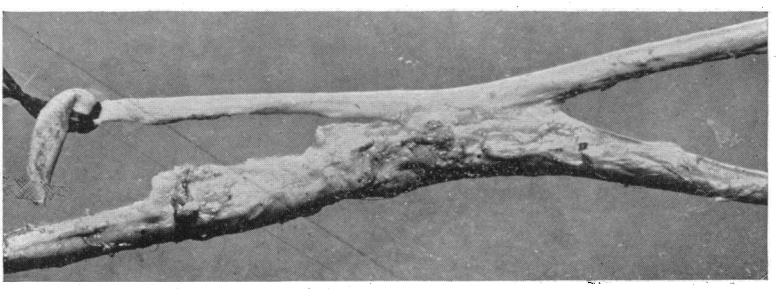

FIG. 5.—Side-to-side anastomosis, jugularis externa and carotid. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916.

FIG. 6.—Photomicrograph. Side-to-side anastomosis between external jugular and carotid. Dog No. 386. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916. Intimal surface joins intimal surface through the opening. Cicatricial tissue joins adventitia to adventitia adjacent to the opening. Sutures are well buried in the media and adventitia.

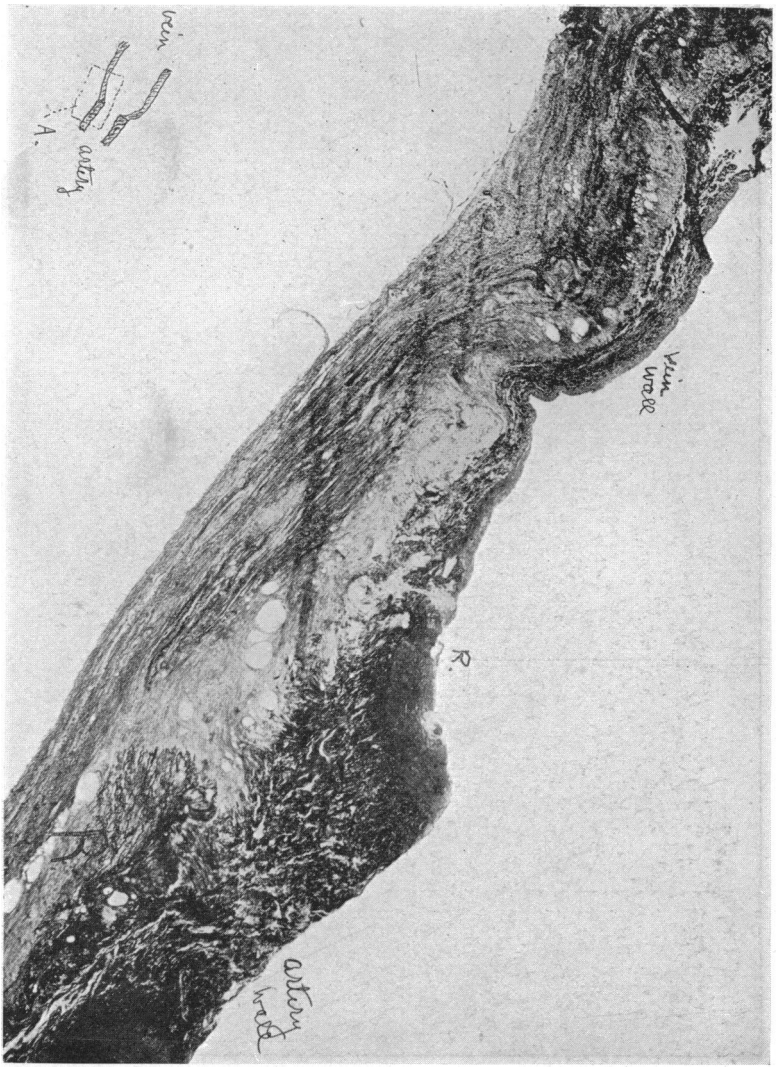

FIG. 7.—Photomicrograph, mag. 20. Autotransplantation of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective-tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

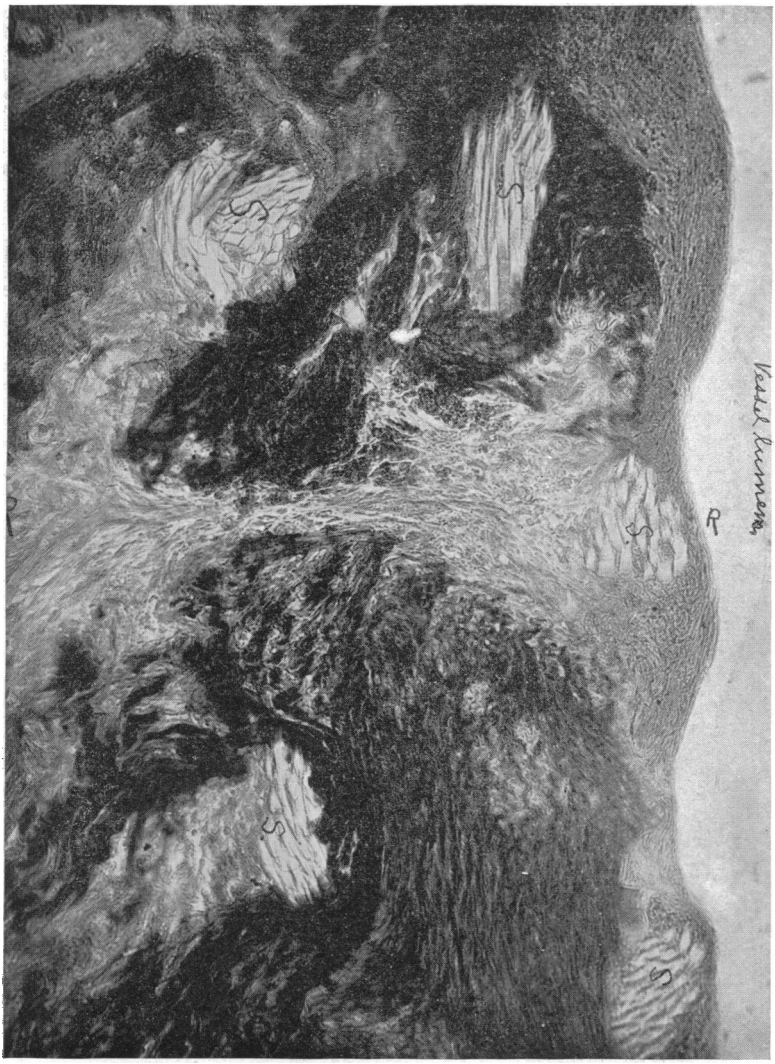

FIG. 8.—Photomicrograph, mag. 300. Autotransplantation of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective-tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

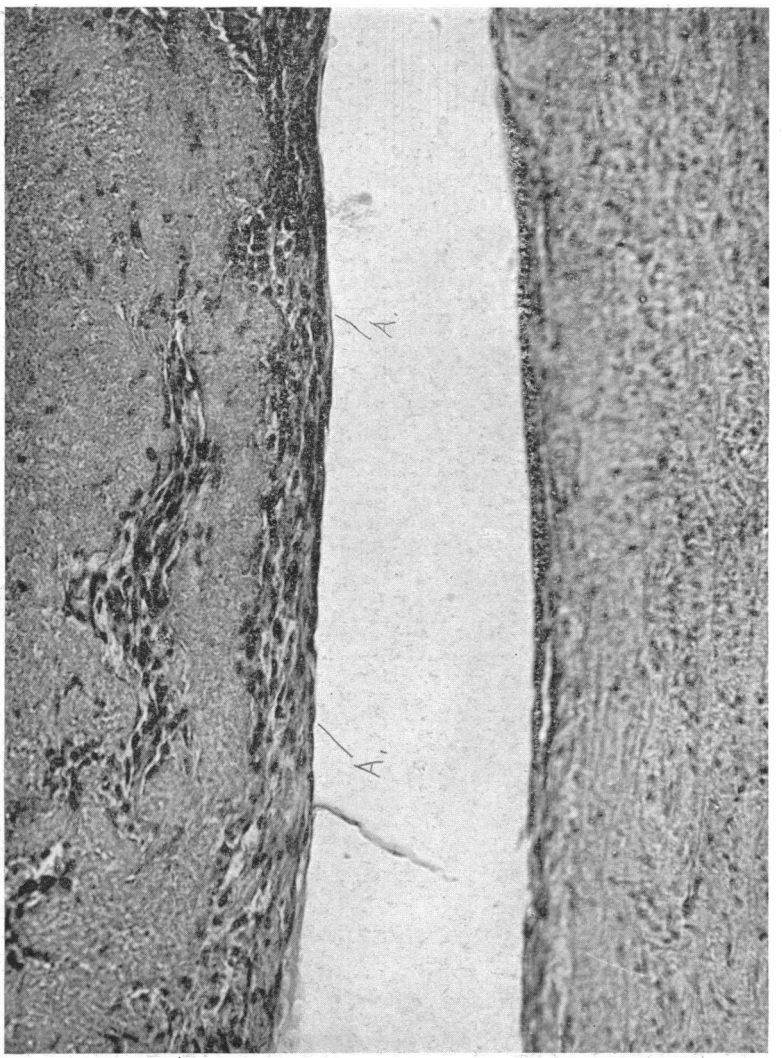

FIG. 9.—Photomicrograph, mag. 415. Autotransplantation of vein into carotid. Surg. Path. No. 2283. Operation January 3. Specimen removed January 17. Vessel partially occluded by coagulum. Surface of coagulum presents connective-tissue cells and apparently no accretion has taken place. Blood coagulum covered by growing fibroblasts also infiltrating coagulum. No further tendency for blood to form a clot in the coagulum which presents a smooth surface as shown here.

FIG. 10.—Photomicrograph, mag. 200. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular, but not covered by fibrin, except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

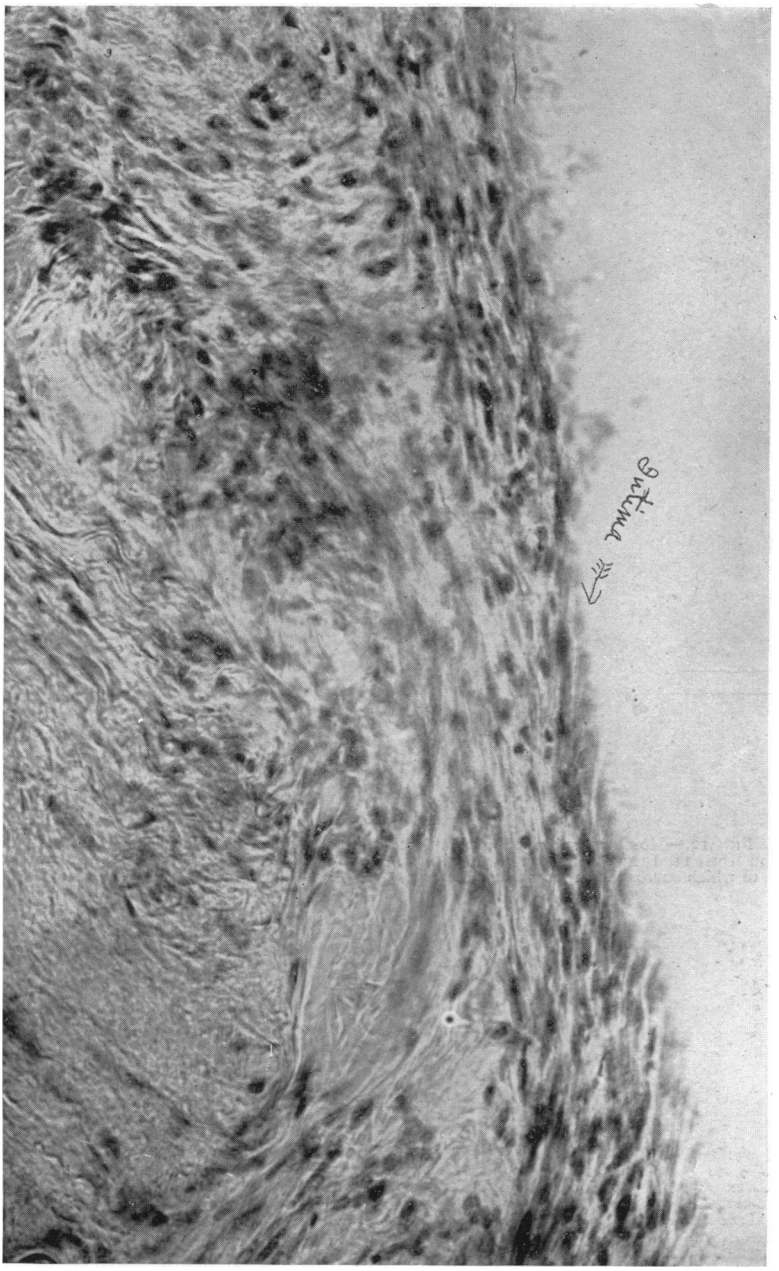

FIG. 11.—Photomicrograph, mag. 415. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Operation January 14, 1913. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular but not covered by fibrin except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

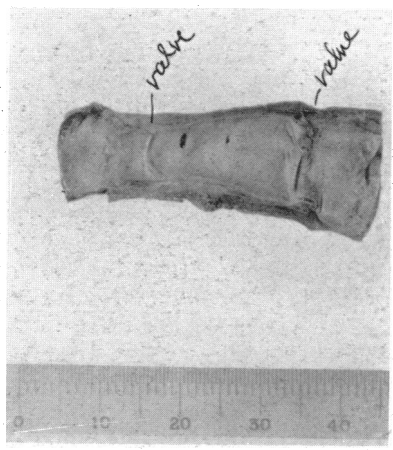

FIG. 12.—Homotransplantation of femoral vein to jugular vein. Surg. Path. No. 2477. Operation April 11, 1913. Specimen removed April 18, 1913. Shows two valves in transplanted vein, one of which encroaches upon suture line.

FIG. 13.—Photomicrograph. Homotransplantation of femoral vein to the jugular. Dog No. 346. Surg. Path. No. 2477. Femoral vein transplanted from donor 178. Operation April 11, 1913. Specimen removed April 18, 1913. Complete union between transplant and jugular. Sutures are *in situ*. Accumulation of leucocytes about sutures. Intima smooth and even throughout. No formation of fibrin on intimal surface. Minute amount of connective tissue between apposed ends of vessels.

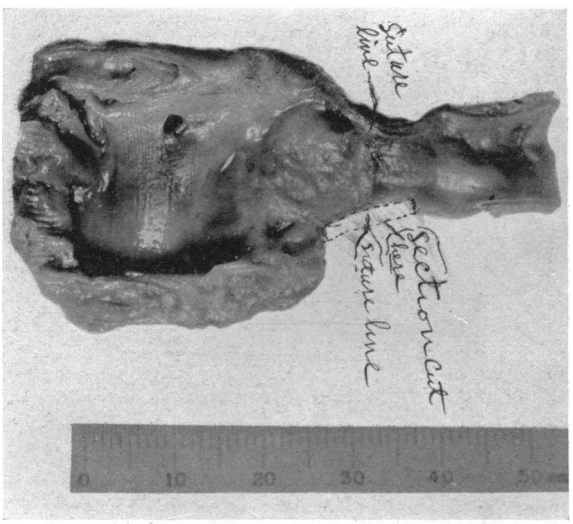

FIG. 14.—Arteriovenous anastomosis of femoral vessels. Male adult, aged thirty-five. Surg. Path. No. 3550.

FIG. 15.—Photomicrograph, mag. 100. Arteriovenous anastomosis (human vessels). Surg. Path. No. 3550. The artery in close apposition with vein, especially in adventitia and media. Mass of connective tissue which has grown beneath the intima reinforces the junction. In the section at points the endothelium is intact. A thin layer of fibrin with a few round-cells in it is in the venous portion of the section.

Experiment No. 35.—Fig. 5. Side-to-side anastomosis. Jugularis externa and carotid. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916.

Fig. 6. Photomicrograph. Side-to-side anastomosis between external jugular and carotid. Dog No. 386. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916. Intimal surface joins intimal surface through the opening. Cicatricial tissue joins adventitia to adventitia adjacent to the opening. Sutures are well buried in the media and adventitia.

Experiment No. 12.—Fig. 7. Photomicrograph. Mag. 20. Autotransplant of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

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Experiment No. 7.—Fig. 10. Photomicrograph. Mag. 200. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular, but not covered by fibrin, except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

Fig. 11. Photomicrograph. Mag. 415. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Operation, January 14, 1913. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular but not covered by fibrin except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

Experiment No. 11.—Fig. 12. Homotransplantation of femoral vein to jugular vein. Surg. Path. No. 2477. Operation April 11, 1913. Specimen removed April 18, 1913. Shows two valves in transplanted vein, one of which encroaches upon the suture line.

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Experiment No. 14.—Homotransplantation of femoral artery to carotid. Dog No. 325 and Dog No. 294. Surg. Path. No. 2753. Shows a nice apposition of vessel ends with a minimum of cicatricial tissue with complete regeneration of intima. Operation March 7, 1913. Specimen removed March 21, 1913.

Experiment No. 30.—Homotransplantation of carotid. Three weeks. Dog No. 223 and Dog. No. 224. Surg. Path. No. 3529. Transplanted portion is undergoing degeneration though the coil of elastic lamina is still present but becoming fragmented. Elastic fibres can be seen in the degenerating portion. Beneath the adventitia of the transplant connective tissue is growing and infiltrating the adventitia. A minimum amount of cicatrix between transplant and original artery. Intima is intact. No functionating blood-vessels present in the transplant.

Experiment No. 50.—Homotransplantation of carotid to carotid. Surg. Path. No. 3526. Intima line of suture shows small dimple. Just beneath the lining cells a suture. Muscularis thrown up into a tent-like fold. In the connective tissue, outside of the muscularis several small deposits of chalk are seen. The adventitial line of suture shows considerable old blood pigment, several small round-cells and fibroblasts. No evidence of real bone formation.

Experiment No. 53.—Homotransplantation of carotid to carotid. Surg. Path. No. 3527. At the intimal side of suture line is thrown up a fibrinous plastic deposit. Muscularis on either side separated by considerable fibrous tissue. Suture line very irregular and shows much more connective tissue production than the others.

Experiment No. 56.—Homotransplantation of carotid to carotid. Surg. Path. No. 3528. Suture line shows usual indentation which is partially filled up by fibrin and blood clot. Just beneath this are seen large irregular masses of calcium. Beneath this the muscularis is apparently continuous. No break in the muscularis or evidence of fibrous union.

There is more or less unanimity of opinion in the manner of restoration of all the coats of the vessel excepting of the intima. Some believe that the surface connective tissue cells become adapted and form the lining endothelium, while the majority believe that the undamaged adjacent endothelial proliferation should cover the exposed connective tissue.

This latter conception is in accordance with the uniformly accepted

interpretation of the repair and regeneration of epithelial defects in the skin and in the mucosæ where epithelium proliferates from the margins and covers the denuded area. It seems to be a question of specificity; of the epithelium it is recognized; of the endothelium, it is questioned.

H. von Schulte after extensive and exhaustive studies on the early stages of vasculogenesis in the cat makes deductions which seem to cast doubt upon the specificity of endothelium. He believes that endothelium may be adapted from connective tissue cells.

The recent studies of W. C. Clarke lend support to his deductions. Clarke holds that the following hypothesis premised in his article is tenable, that is, the surface cells of serous membranes and those lining blood-vessels may regenerate from deep connective tissue cells, and do not necessarily arise from adjacent intact mesothelial or endothelial cells.

Histological studies tend to demonstrate that in the absence of infection, even if the lines of the vessels are not evenly approximated, the chink will be filled in with blood clot. As long as this minute blood clot does not project into the lumen of the vessel there is no accretion and it does no harm. Fibrous connective tissue will grow in and organize the blood clot, and the cells which finally reach the surface will become competent as endothelial cells. In other words, a foreign body in blood-vessels, such as a suture if it is not contaminated, will not produce thrombosis. This may be observed in No. 3729, Fig. 3.

The following conclusions are the result of these studies:

The continuous circular suture with fine silk (vaselined or paraffined) penetrating the media and intima is thoroughly practicable and of ready application.

The circular suture restores the continuity of the vessel without impairing the integrity of its walls or diminishing its lumen.

Side-to-side anastomosis between an artery and a vein can be readily accomplished without the formation of thrombosis.

Fusion of the approximated ends of the vessels takes place by connective-tissue proliferation.

A slight bulging at the suture line does not seem in any way to interfere with the functional efficiency of the vessel, as is shown in two of the specimens.

In the absence of infection, sutures penetrating the intima and entering the lumen of the vessel will do no harm. Connective tissue will grow in and cover the sutures. The cells covering the suture line may become flattened and fuctionate eventually as endothelial cells, or, as many believe, the connective tissue is covered by proliferating endothelium.

In end-to-end anastomosis, by the introduction of one retaining

suture posteriorly, a minimum amount of twisting of the vessels is brought about. This has been found of special importance in the suture of a shorter vessel (splenic and renal).

Autotransplantation and homotransplantation of segments of veins and arteries are perfectly practicable. While a tendency to degeneration of the transplant is indicated, the functional results of the transplant do not seem to be impaired.

In my opinion all transplanted tissue that degenerates sooner or later undergoes connective tissue infiltration, and becomes replaced by the tissue of the host. The transplant acts as a scaffold for the support of the connective tissue of the host.

BIBLIOGRAPHY

Aschoff, L.: Pathologische Anatomie, Dritte Auflage, Band 1, p. 630.

Bernheim, B. M.: Surgery of the Vascular System. J. B. Lippincott Company, Philadelphia, 1913.

Borst and Enderlen: Ueber Transplantation von Gefaessen und ganzen Organen. Deutsche Zeitschr. f. Chir., 1909, v. 99, p. 54.

Bouglé: Arch. de méd. exp. et d'anat. path., 1901, p. 205.

Burci, E.. Del processo di riparazione delle ferite arteriose trattate colla sutura, Pisa, 1890.

Capelle: Ueber Dauerresultate nach Gafaess- und Organtransplantationen, Berl. klin. Wochenschrift, 1908, vol. xlv, pt. 2, p. 2012.

Carrel, Alexis: La technique opératoire des anastomoses vasculaires et la transplantation des viscères. Lyon méd., 1902, v. xcviii, pt. 1, p. 859.

Idem et Morel: Anastomose bout-à-bout de la jugulaire et de la carotide primitive. *Ibid.*, pt. 2, p. 114.

Idem and C. C. Guthrie: The Reversal of the Circulation in a Limb. ANNALS OF SURGERY, 1906, vol. xliii, p. 203.

Idem: The Surgery of the Blood-vessels. Bull. of the Johns Hopkins Hospital, January, 1907.

Castiglioni, Giovanni: Untersuchung ueber Transplantation von Blutgefaessen. Zieglers Beitr., 1913, v. lxv, p. 63–77.

Clarke, William Cogswell: Experimental Mesothelium. Anat. Record, February, 1916, vol. x.

Clermont, G.: Suture laterale et circulaire des veines. Presse méd., 1901, vol. ix, p. 229.

Decastello, A. von: Ueber experimentelle Nierentransplantation. Wiener klin. Wochenschr., 1902, vol. xv, p. 317.

Doerfler, Julius: Ueber Arteriennaht. Beitr. z. klin. Chir., 1899, vol. xxv, p. 271.

Faykiss, Franz von: Ueber Gefaesstransplantation. Bruns Beitr. z. klin. Chir., 1908, vol. lxxviii, heft 3.

Fischer, B., und Schmieden, V.: Experimentelle Untersuchungen ueber die funktionelle Anpassung der Gefaesswand. Frankfürter Zeitschr. f. Pathol., 1909, vol. iii, p. 8.

Floresco: Transplantation des organes. Journ. de phys. et de path. gén., 1905, vol. vii, p. 47.

Guthrie, C. C.: Blood-vessel Surgery. Longmans, Green & Co.

Hoepfner, Edmund: Ueber Gefaessnaht, Gefaesstransplantation und Reimplantation von amputierten Extremitaeten. Arch. f. klin. Chir., 1903, vol. lxx, p. 417.

Horsley, J. S.: Notes on the Technic of Transfusion of Blood. Journ. A. M. A., 1910, p. 663, vol. lv.

Jaboulay, M., et Brian, E.: Suture artérielle. Lyon méd., 1896, vol. lxxxvi, pt. 1, p. 97.

Jacobsthal, H.: Zur Histologie der Arteriennaht. Beitr. z. klin. Chir., 1900, vol. xxvii.

Jassinowski, Alex.: Ein Beitrag zur Lehre von der Gefaessnaht. Arch. f. klin. Chir., 1891, vol. xlii, p. 816.

Jeger, Ernst: Die Chirurgie der Blutgefaesse und des Herzens. Hirschwald & Co., Berlin, 1913.

Jensen, Georg: Ueber zirkulaere Gefaess-suturen. Arch. f. klin. Chir., 1903, vol. lxix, p. 938.

Lespinasse, V. D., Fischer, Karl, and Eisenstadt, J.: Practical Mechanical Method of End-to-end Anastomosis of Blood-vessels Using Absorbable Magnesium Rings. Journ. A. M. A., 1910, vol. xl, p. 1785.

Murphy, John B.: Resection of Arteries and Veins Injured in Continuity—End-to-end Suture—Experimental and Clinical Research. N. Y. Med. Record, 1897, vol. li, p. 73.

Payr, Erwin: Beitraege zur Technik der Blutgefaess- und Nervennaht nebst Mitteilungen ueber die Verwendung ines resorbierbaren Metalles in der Chirurgie. Arch. f. klin. Chir., 1900, vol. lxii, p. 65.

Salvia: Giorn. Internaz. delle scienze med., 1902, p. 14.

Smith, Archibald: Ueber Arteriennaht. Arch. f. klin. Chir., 1909, vol. lxxxviii, p. 729.

Schulte, H. von W.: Early Stages of Vasculogenesis in the Cat (Felis Domestica) with Especial Reference to Mesenchymal Origin of Endothelium. Memoirs of the Wistar Institute of Anatomy and Biology, No. 3, Philadelphia, 1914.

Silberberg, O.: Ueber die Naht der Blutgefaesse. Inaugural Dissert, Breslau, 1899.

Stich, Rudolf: Ueber Gefaess- und Organtransplantation. Ergeb. der Chir. u. Orthop., 1910, vol. i, p. 1.

Idem und Makkas, M.: Zur Transplantation der Schilddruese mittels Gefaessnaht. Beitr. z. klin. Chir., 1908, vol. lx, p. 431.

Idem, Makkas, M. und Dowmann, C. B.: Beitraege zur Gefaess-chirurgie (zirkulaere Arteriennaht und Gefaesstransplantationen). Beitr. z. klin. Chir., 1907, vol. liii, p. 113

Tomaselli, G.: Sutura circolare delle arterie coll'affrontamento dell'endotelo. Clin. Chir., 1902, vol. x, p. 497.

Ullman, Emerich: Experimentelle Nierentransplantation. Wiener klin. Wochenschr., 1902, vol. xv, p. 317.

Villard et Tavernier: Presse méd., 1910, vol. xviii, No. 52.

Ward, Wilbur: Histological Changes in Transplanted Blood-vessels. Proc. of the Soc. for Exper. Biology and Med., July, 1908.

Yamanoüchi, H.: Ueber die zirkulaeren Gefaessennaehte und Arterienvenenanastomosen sowie ueber die Gefaesstransplantationen. Deutsche Ztschr. f. Chir., 1911, vol. cxii, p. 1–119.