STATED MEETING, HELD MAY 6, 1907.

The President, JOHN B. ROBERTS, M.D., in the Chair.

SURGERY OF THE VASCULAR SYSTEM.

I. LIGATION OF THE DUCTUS ARTERIOSUS.

BY JOHN C. MUNRO, M.D.,
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THAT I may be allowed to bring this suggestion for a new operation before your Society, I ask on the basis that it has not been hastily conceived. On the contrary, long ago I demonstrated its technical possibility on the cadaver of new-born children, and felt that it was justifiable on the living. At various times I have tried to inspire the pediatric specialist with my views, but in vain. Now, in view of the recent advances in cardiac surgery, for much of which we are indebted to the surgeons of this city, I will venture to place my ideas before you, asking that you do not dismiss them hastily.

Nineteen years ago I saw a healthy girl baby that, soon after birth, exhibited symptoms of some cardiac lesion, out of keeping with the general appearance of perfect health and development. On severe exertion, such as straining at stool, it would become cyanotic, and the cardiac beat would cease. At times the child would apparently die, only to recover as soon as the heart was stimulated with electricity. In a few weeks atelectasis developed for which I tried artificial expansion of the lungs under negative pressure in a pneumatic cabinet. This met with only temporary success. Auscultation at this time revealed a cardiac murmur with the pulmonary râles, but cyanosis was not a marked feature. After death, which took place without œdema or marked cyanosis, examination showed an open ductus arteriosus lying easily within reach

behind the sternum, without any other defect or lesion except a dilated right ventricle. The simplicity of the remedy was so striking that I at once made further dissections, and satisfied myself that it would be possible to ligate the duct provided a diagnosis could be made beforehand. In regard to making a diagnosis, however, my pediatric advisers were not reassuring. In the hope that it may be possible to detect such a lesion in time to allow surgical interference, I would urge those skilled in the diagnosis of infantile lesions to lend their aid.

To attempt to disentangle the confusion of signs that attach to the various congenital lesions of the heart would be folly. Only faint light can be gained from authorities like Vierordt and others.

In the new-born the duct of Botalli is a little over 5 mm. in diameter and 10–15 mm. long. The length increases generally up to the time of obliteration which normally is complete by the twentieth day. Thus there must be an early period in the infant's life when the patency of the duct cannot be considered as pathological. It seems as though auscultatory signs during this period would throw some light on those which we should expect when the persistence of the duct forms a pathological factor. Townsend, however, examined 100 new-born babies during the first three days of life with this in view, but was unable to hear anything distinctive.

The causes for a persistent duct are not known. It may be due to some histological variation in the circular fibres, or to an absence of the inflammatory reaction that normally obtains. Very rarely is there an aneurysmal condition, or is the duct so short that a direct communication between the aorta and the pulmonary artery exists. The cases collected by Vierordt do not number a hundred, but that must be quite far from a correct estimate. It is not at all necessary that other congenital anomalies co-exist with the anomaly under consideration. Most writers find hypertrophy and dilatation of the heart, and the pulmonary artery may exceed the aorta in diameter. In typical cases the foramen ovale is closed, but not because of the theoretical reason that an open duct is dependent on a foramen that has closed prematurely.

In typical cases cyanosis is wanting. One finds rather an anemia or later a waxy appearance. Cyanosis is less characteristic of this than of other serious cardiac malformations. In late life it may be present, however. Cardiac dullness is increased laterally, and there may be projection and pulsation of the dullness, leftwards, in the upper costal spaces. This projection is visible by X-ray. The pulse shows little change though Franck considers that there is a fall with inspiration and a rise with expiration. We may find true attacks of suffocation, and bleeding from the mucous membranes as in other serious malformations. A loud systolic whir conducted into the cervical vessels may be heard, but as a matter of fact there are no definite auscultatory signs established as yet.

Of 26 cases recently collected about half lived to puberty, but it seems as though this must be an unduly large proportion owing to the lack of autopsies in infants. Death follows from atelectasis, general œdema, pleural exudate, pneumonia, endocarditis, etc.

Among the cardiac anomalies to be differentiated is, first of all, an open foramen ovale. The distinguishing signs are not well determined and it is useless to take up the question here. In open ventricular septs, in congenital pulmonary stenosis, in persistent truncus arteriosus, where the patient dies as a rule shortly after birth, we must expect marked cyanosis. Congenital aortic-pulmonary communication and stenosis of the various ostia are so rare that they may be disregarded.

Why should we consider surgical interference in cases of open ductus arteriosus? Because in spite of the fact that some cases may live to puberty, the chances of which must be small, we have the one cardiac-valvular lesion which is, relatively speaking, superficial. Furthermore the anomalous vessel is of good size, its ligation must be followed by instant and permanent restoration to a normal function of the lungs and arteries, and it can be reached by a short surgical route.

The operation I would propose, as demonstrated on the cadaver, is as follows. Under ether, which I prefer to chloroform in any case involving collapse of the lung, the sternum

can be easily split along its centre or a little to the right, opposite the second costal cartilage. This is easily done with a knife. The sternal halves are then retracted, ample room for working being obtained. The right pleural cavity will probably be opened but the left one will not. Judging from analogous cases in surgery, this should not be serious, but if necessary the physiologist's apparatus for maintaining artificial respiration could be employed. I hardly believe that it would be needed. After retracting the thymus upward, the pericardium is exposed. Its reflection lies so high on the large vessels that the ductus to all intents and purposes is intrapericardial. In the upper angle the aorta will be seen on the patient's right and the pulmonary artery on the left. By following close to the aorta towards the under surface of the arch the ductus, as large as the aorta itself, will be seen as the first vessel to the left pointing upward and a little to the right. Both pulmonary branches lie too far posteriorly to be seen, and by keeping close to the aorta the main pulmonary trunk will escape injury. On pushing through the tissues by blunt dissection the ductus, theoretically, should be easily surrounded with a ligature. It is a question whether or not simply crushing it would not accomplish as much, and in case of necessity, I believe that it would be worth trying. After closing the anterior pericardial wound the sternum can be sutured or not and the skin closed.

Would it be justifiable to subject a child to this risk without knowledge of the exact lesion? In a case with beginning atelectasis or other evidences of impending death from circulatory disturbances, with a reasonable basis for believing that the duct were open, it seems as though such an operation would be justifiable. I doubt if it would materially hasten a fatal issue in case the diagnosis were not confirmed.

II. ARTERIOTOMY FOR THROMBOSIS AND EMBOLISM.

BY FRANCIS T. STEWART, M.D.,
OF PHILADELPHIA.

THE usual treatment for arterial obstruction involving the limbs and depending upon thrombosis or embolism, is in brief to keep the part dry, warm, sterile, and slightly elevated, in order to prevent gangrene, or at least limit it and cause it to assume a dry and circumscribed form. With the development of aseptic surgery and the progress which has been made in the suture of arteries more active measures demand at least consideration. These measures will vary according to the cause of the arterial obstruction, since the problems to be solved differ with the lesion encountered. We shall confine ourselves to the two forms which we have an opportunity to investigate by operation.

1. *Traumatic thrombosis* due to contusion of an artery.—By contusion we mean an injury produced by blunt violence which does not result in immediate dissolution of the continuity of the external coat of the vessel, in other words, such injuries as are often described as partial ruptures. The lesions found after a contusion of an artery vary with the violence of the contusion and the state of the arterial walls. The slightest grade, in which there is perhaps no change but a little ecchymosis of the vessel wall, may be disregarded, as such causes neither immediate signs nor remote ill effects. The older surgeons explained some of the cases of obliteration of an artery after contusion, by rupture of the vasa vasorum, and extravasation of blood between the vessel and its sheath in sufficient quantity to press upon and considerably narrow the lumen of the vessel. This was supposed to be followed by a traumatic arteritis with consequent thrombosis. It is now known that in practically all instances the inner coats of the vessels rupture and that such leads to thrombosis. As in the application of a ligature, although the force acts from without inwards, the

lesions, owing to the friability of the internal coats, are produced from within outwards. The injury may expend itself on the internal coat alone, leaving the outer coats intact and practically normal. The lesion here observed is a fissuring of the intima, which may be complete or incomplete, *i.e.*, involving the entire circumference or only a part thereof. Complete circular division is best seen after the application of a ligature. In contusions by blunt violence the fissures are apt to be multiple, and frequently involve only a portion of the circumference of the vessel, usually that first struck. The sole result of clinical importance is thrombosis with its consequences. If the fissure is small and incomplete, there may be a minute mural thrombus, which causes no interference with the blood current, but simply protects the wound until healing is complete. Obliteration of the vessel by clot is liable to follow, however, if the rent in the internal coat is large, if the fissures are multiple, if the tunic is sufficiently detached to wave in the blood stream, if the detached tunic is infiltrated with lime salts, if tight compression is applied after the accident, or if the state of the heart or the blood is such as to predispose to coagulation. The conditions just mentioned determine also the rapidity with which an occluding thrombus forms. It may immediately follow the injury or it may not develop for several hours or even days. Generally speaking, complete obliteration after a lesion of the internal coat alone is delayed, although in the femoral artery we have observed it to occur within a few minutes. Yielding of the internal and middle coats is much more likely to be followed by immediate thrombosis, since they curl up within the vessel in obedience to the elasticity of the middle coat. The adventitia maintains the continuity of the vessel and prevents extravasation, although the blood may make its way for some distance between this coat and the media, sometimes for an inch or more. Ordinarily the clot extends centrally in a conical form as far as the first collateral branch. Peripherally its length varies; it may fill the main branch and the smaller arteries or it may terminate like the central portion near a collateral. Upon its extent and upon the

activity of the collateral circulation depends the integrity of the limb. If the injury is confined to the artery alone, and the vessels are healthy and the collaterals abundant, no harm need follow. If the clot forms slowly, ample opportunity is afforded for the development of an adequate collateral circulation, which becomes progressively more efficient the more the lumen is closed; thus pulsation may never be absent from the peripheral vessels, even though the vessel at the contused point becomes impervious. If, however, the vessels are narrowed by disease, or if the collaterals are involved in the injury or pressed by extravasated blood or a tight bandage, the collateral circulation will be insufficient and the thrombosis may extend to the finer vessels. In either event the limb falls into gangrene. Another possible factor in the production of gangrene is the detachment of portions of the clot during the formation of the thrombus, the emboli plugging the smaller vessels and leading to circumscribed gangrene. In the absence of sepsis secondary hemorrhage does not occur.

The signs of obliteration of the vessel (pain, pallor, loss of pulsation, loss of heat, hypesthesia of anesthesia, paresis or paralysis) when marked are followed by gangrene, but when present in a lesser degree complete recovery is still possible. Such, however, is the exception and the limb usually perishes for several reasons. Unlike simple ligation, after which gangrene is comparatively rare, in a contusion the accompanying vein also may be involved and thrombosed. The collateral vessels are too apt to suffer from the trauma, or if they escape direct injury they may be compressed by the extravasated blood resulting from the associated laceration of the environing tissues. Of 34 cases of traumatic thrombosis collected by Lears 18 recovered, and of these only 4 escaped gangrene.

If the pulse alone has disappeared and there are no other signs of impending gangrene, the treatment mentioned at the beginning is all that is needed. A hematoma, however, should always be opened, in order to lessen the compression on the collateral vessels. If the hematoma is of large size, one can never be sure that the artery has not been opened, hence in

these cases incision has a double rôle, to permit evacuation of the blood and to ascertain the condition of the artery. The clots adhere strongly to and infiltrate the surrounding tissues, but the tissues should not be scrubbed in order to remove them. If the bleeding has completely ceased we believe it good practice to suture the wound without drainage, since the latter always predisposes to infection, particularly in bruised tissues.

On theoretical grounds ligation of the artery above the injured part has been suggested in order to prevent the detachment of emboli. If the pulse has disappeared, indicating complete obliteration of the vessel, no reason exists for this procedure; if the pulse is still present, although of lessened force and volume, we believe the chances of embolism should be accepted rather than completely to suppress the circulation. Although the possibility of opening the artery, removing the thrombus, then suturing the wound in the vessel has probably occurred to many surgeons we imagined at the time of our first operation that we were the first to put the idea into practice. On looking over the literature, however, we find that both Sabanajew and Lejars have attempted to relieve arterial obstruction by arteriotomy.

Sabanajew's operation was performed in 1896 (Höpfner, Archiv f. klin. Chir. Bd. 70, S. 417, 1903). His patient, suffering with polyarthritis rheumatica, was suddenly stricken with signs of gangrene of the leg depending upon obstruction of the femoral artery, which was believed to be due to an embolus. The femoral artery was exposed, but no occlusion found in the expected situation. Owing to the desperate condition of the patient, further search was deemed inadvisable, and the vessel was closed with sutures and the limb amputated at a lower level. The patient died 19 days later of endocarditis.

Lejars' (Bull. et mem. de la soc. de chir. de Paris, 1902, p. 609), patient was a man, aged 26 years, who was caught between two cars, sustaining a severe contusion of the left inguinal region. Signs of thrombosis of the femoral artery were in evidence, and the foot became gangrenous. Six days after the accident the artery was exposed below Poupart's ligament, a soft black clot removed, and the wound in the vessel closed with sutures. The gangrene progressed, however, and one month later the leg was amputated below the knee.

For our first case we are indebted to Dr. Robert G. Le Conte, who was absent from the city when the patient was admitted to

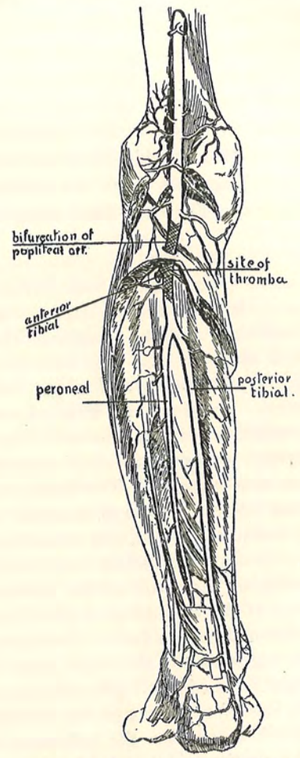
the Pennsylvania Hospital, June 20, 1905. The patient was a man, aged 60 years, who presented all the evidences of advanced atheroma, with mitral regurgitation and hypertrophy of the heart. He had been squeezed between the tail-board of a wagon and a wall. Over the lower portion of the left abdomen and upper part of the corresponding thigh was a diffuse swelling due to extravasated blood. The skin was unbroken and there were no other injuries. Both legs were bluish and covered with a network of small varicose veins. Pulsation in the tibial vessels was as strong and full on the left as on the right side. During the night of the same day, or about twelve hours after the injury, he complained of severe pain, first in the popliteal space, and later radiating down the leg to the foot and toes. The following morning we found the pulse absent from the tibial vessels and popliteal artery. The femoral could not be satisfactorily palpated because of the swelling mentioned above. The pain had disappeared, but the leg as far as the knee was pale and cold, and the toes and foot shriveled. Sensation was present but markedly reduced in the entire foot and leg. There was no power in the toes, and the ankle could be flexed only with difficulty. Movements of the knee were unimpaired. The thigh was warm and apparently in the same condition as on admission. Owing to the condition of the thigh, the very sudden onset of symptoms, and the seat of the initial pain, it was believed that a large clot embolus had been swept from the point of injury and lodged at the bifurcation of the popliteal. About 12 hours after the onset of pain and 24 hours after the injury the patient was anesthetized with ether, and the popliteal artery opened by a small longitudinal incision. There was a slight flow of dark blood, but no clot could be found. A probe was gently passed up into the artery for about 6 inches and no obstruction found nor flow of blood induced. The wound in the artery was closed with through-and-through silk sutures and the skin approximated. A longitudinal incision was next made over the femoral artery, from just above Poupart's ligament downwards. The sartorius muscle had been ruptured and all the tissues were infiltrated with dark clots. The vein was uninjured. The artery was not discolored, but was hard to the touch from Poupart's ligament down to its bifurcation. Poupart's ligament was severed in order to permit an assistant to grasp the vessel above the thrombus, and the artery was opened by a longitudinal incision.

After removing the clot, which was almost black in color and firmly adherent, it was discovered that, like a valve, a calcified portion of the intima had been turned into the artery from the anterior wall, probably occluding it one-half. The posterior wall of the artery, although calcareous in places, was apparently uninjured. The detached atheromatous plate was removed, and the compression on the artery diminished for an instant in order to wash out any remaining débris. The artery was then closed with through-and-through silk sutures. The circulation was immediately reëstablished, but after the lapse of a brief period pulsation below the injured point ceased. The arterial stitches were then removed and the vessel again found filled with clot. This was removed and the artery resutured. The same phenomena were repeated, and the hopelessness of securing a patent lumen by simple removal of the thrombus realized. The injured portion of the artery was therefore excised by a diamond-shaped incision, with the idea of closing the wound transversely. This, however, was found to be impossible, so that the artery was completely severed and each end split on the posterior wall, the flaps thus formed being turned outwards and the segments of the artery united with through-and-through silk sutures, bringing intima in contact with intima. Although the circulation was again reëstablished, at the time the skin wound was sutured pulsation in the artery below the site of anastomosis had become very feeble and no pulse could be felt in the tibial vessels. The gangrene, which was of the moist septic type, progressed rapidly and the limb was amputated through the upper thigh 10 days later by Dr. Le Conte. The flaps subsequently sloughed and reamputation was performed about one month later by Dr. Hutchinson. The patient finally recovered.

The chief difficulty in an operation like the foregoing is to prevent the reformation of the thrombus. The clot intimately adheres to the internal tunic and can be completely removed only with some difficulty, thereby subjecting the delicate lining membrane of the artery to further injury. If the artery is simply opened, the clot removed, and the vessel sutured, the cause of the thrombosis, *i.e.*, the multiple cracks in the intima or the curling up of the internal coat, is not suppressed, and the thrombus will quickly reform as it did in our case. There

are several ways in which this may possibly be prevented. If the contusion is sufficiently limited, the injured portion of the artery may be resected, and the vessel anastomosed by Carrel's technic. The advantages of this method over Murphy's anastomosis by invagination are quite obvious, as the latter considerably diminishes the lumen of the vessel and does not permit the removal of as much artery as the former. The extent of vessel which may be excised without exerting too much tension on the sutures will vary somewhat with the situation; thus in resection near joints flexion may be utilized to diminish tension, while in other regions, particularly where the artery is bound to the surrounding parts by branches, it will be impossible to effect anastomosis after the removal of a large extent of vessel. In the latter instance severances of the collaterals would probably facilitate this manœuvre, but generally would be contraindicated. Kümmel was able to approximate the ends of a femoral artery after resecting two inches, during an operation for cancer of the inguinal region. Another method of restoring the circulation after traumatic thrombosis which at once suggests itself is to substitute a segment of a vein for the injured portion of the artery, a procedure which has already been employed in the treatment of aneurysm. Whether or not the operation is feasible cannot be definitely stated at the present time. Experimentally varying results have been obtained. Höpfner transplanted a segment of a vein to an artery in 10 animals. The vein at once became twice the size of the artery. The twirling of blood within it could be seen and, as in aneurysm, this led to thrombosis. Efforts were made to prevent the dilatation of the vein by doubling it, *i.e.*, by turning one end back like a cuff, and also by suturing the surrounding tissues over it. The ultimate results were negative, as secondary hemorrhage occurred in one and thrombosis in all the others. The success obtained by Carrel in the transplantation of vessels in animals is well known and need not be recited here. Whether or not the companion vein should be employed for this purpose would depend upon the artery involved. One would not think of

transplanting a segment of the popliteal or the femoral vein to its accompanying artery, as in case of failure both the arterial and venous circulations would be suppressed and the



Showing thrombus in popliteal artery.

chances of gangrene very great. Probably the best vein to substitute would be the external jugular, although one of the brachial veins or even the opposite femoral vein might be employed. If the saphenous vein is sufficiently large, it like-

wise might be transplanted. In the arm where there are two venæ comites one of these could be selected.

Embolism.—The difficulty mentioned above would not be encountered in dealing with an embolus soon after its lodgment, indeed the chances of thrombosis would be no greater than after the most favorable form of arteriorrhaphy, since the intima is likely to be smooth at the point of impaction of the embolus. Case two we submit as one of embolism, although we have no means of definitely excluding primary thrombosis. As an impacted embolus quickly becomes the nucleus of a thrombus, the exact diagnosis from the standpoint of arteriotomy is unimportant. The important thing is the condition of the intima.

The patient was a man, aged 61 years, who had never been seriously ill before. He was suddenly attacked with generalized abdominal pain, vomiting, and constipation. This persisted for two days, at which time we saw him with his physician, Dr. James M. Montgomery, who feared the case might be one of intestinal obstruction. There was no fever, the pulse was about 100, and the intrathoracic organs normal. The abdomen was flat, soft, and slightly tender in the region of the left kidney. Rectal examination was negative. The blood vessels were distinctly atheromatous. With the use of laxatives and enemas the bowels were finally induced to move, and the abdominal symptoms subsided. In the meantime the patient developed a cystitis with bloody urine, possibly as the result of the catheterization which was found necessary at the beginning of the illness. About five days after the abdominal pain subsided the patient experienced a sudden excruciating pain in the right foot, which rapidly extended to the lower third of the thigh, and was accompanied by pallor, loss of heat, loss of tactile sensation, inability to move the limb, and coldness. We saw him the following day and found the limb cold as far as the middle of the thigh. The foot was shriveled, and the leg purplish as far as the upper third. Pulsation could not be felt in any of the vessels below the bifurcation of the femoral. Thirty-six hours after the onset of pain the patient was sent to the Jefferson Hospital, and the common femoral artery exposed by a longitudinal incision. It pulsated

vigorously to within one inch of the bifurcation. From this point to the bifurcation it was hard, and below the bifurcation collapsed. The vessel was isolated, compressed, and opened by a longitudinal incision about one inch long. The thrombus was Y-shaped, corresponding to bifurcation, the base of the Y being about one inch long and tapering at the tip. The limb corresponding to the superficial femoral was ½ inch long and also tapering at the tip. The limb corresponding to the deep femoral was one inch long and likewise tapering. The color of the thrombus was dirty white, with bright red spots and black blotches, except the terminal ½ inch of the limb corresponding to the deep femoral, which was jet black. The intima was smooth, although the vessel wall was decidedly thickened. On removal of the thrombus blood flowed freely from the peripheral part of the deep femoral, but not from the peripheral part of the superficial. The vessel was closed with a continuous through-and-through suture of silk, and over this a second layer uniting the outer coats only. Pulsation immediately reappeared in the femoral below and in the popliteal, but not in the tibial vessels. The skin wound was closed without drainage. After operation pulsation continued in the popliteal about one-half the strength for three days, then began to grow weaker, finally disappearing on the eighth day. In the meantime a large vessel on either side of the patella (superior external articular, anastomotica magna) pulsated more vigorously as the pulsation in the popliteal became weaker. The pain in the leg continued, being particularly marked in the popliteal space. The line of demarcation which formed was an irregular oval, the inside reaching to the junction of the lower with the middle third of the leg, and the outside to the junction of the upper and middle third. In the deeper structures the gangrene ascended to a higher level. Forty-two days after the first operation the leg was amputated below the tubercle of the tibia, lateral flaps of equal length being employed. About 15 ligatures were necessary, and the bone bled freely on section. The popliteal artery contained a small clot, and a probe passed up into the artery for several inches caused a slight flow of blood.

Perhaps the first thought which strikes one after reading the above cases is the inability which was encountered in two

instances to locate definitely the obstruction by the mere symptoms. In our first case we feel sure that the mistake would not have occurred could we have palpated the femoral artery itself. It seems that the symptoms are caused, not by the thrombus itself or even the sudden impaction of an embolus, but by the result of the arterial obliteration, *i.e.*, the acute anemia, thus the pain, etc., are referred to the area from which the blood is excluded, and not to the seat of obstruction. It will be seen, however, that the operation of thrombectomy or embolectomy, if it may be so called, can be readily performed without danger of secondary hemorrhage. We believe it to be indicated particularly when the intima is smooth, and that to be of value it must be performed as soon as possible after the arterial obstruction develops. Even though the vessel again becomes obstructed with clot, as in our second case, this may form slowly and give the collateral vessels a chance to dilate, thus saving at least a portion of the limb.

III. TECHNIQUE OF BLOOD-VESSEL SUTURE.

BY J. EDWIN SWEET, M.D.,
OF PHILADELPHIA.

If we will remember for a moment that the first suggestion of repairing wounded blood vessels, as well as the first attempt to carry out the suggestion, dates from the year 1759, —when Hallowel, an English surgeon, at the suggestion of his fellow, Lambert, attempted to repair a wounded brachial artery, and perhaps succeeded,—it is not surprising that many have endeavored, experimentally and clinically, to elaborate a successful technique for the suture of blood vessels.

Longitudinal wounds of blood vessels, and transverse wounds involving only a portion of the circumference, are easily repaired, the technique of such procedure being the common property of all surgeons of experience. The question before us to-night is the technique of the repair of wounds which completely divide the vessel,—the question of the end-

to-end anastomosis of blood vessels; a question involving accident cases, the treatment of aneurisms, the transfusion of blood from one human being to another, and, possibly, the transplantation of organs.

A most superficial consideration of the tubular structure known as a blood vessel leads to the conclusion that such a tube may be reunited in one of four ways,—I mean from the mechanical standpoint, (1) the ends may be brought as nearly as possible into their original position, approximating the various coats of the vessel to each other; (2) the edges may be everted, turning the cut edges outward; (3) one end may be inserted into the other end, invagination; (4) a mechanical aid may be employed.

I am personally inclined to the belief that the method of exact end-to-end approximation,—the method which has given such remarkable results in the hands of Carrel and Watts,— is easier of execution, and since it accomplishes that great surgical desideratum, the restoration of tissues as nearly as possible to their original position, is perhaps theoretically correct.

There seems to be unity of opinion as to the choice of suture material,—fine silk, of a size carefully chosen so that it will completely fill the hole left by the needle. The needles should be of the smallest possible size, round, either straight or curved, according to the individual and the site of operation. Experimenters are further agreed that the stitches should include all the coats of the vessel, since the penetration of the intima is a matter of no consequence.

The actual technique is, then, as follows: the exposed vessel is clamped by some means which must be very gentle, the simplest and best clamp being, in my opinion, the one devised by Herrick. The loose connective tissue of the external coat of the vessel must then be dissected away, the best procedure being to draw it down over the cut end of the vessel and to snip it off even with the vessel end; it will then retract, leaving the vessel free. This must be done, else the loose tissue will interfere by being dragged with the suture into the needle

holes. All insult to the vessel wall, such as grasping it with forceps, must be religiously avoided. If the edges of the wound have been crushed they should be freshened by resecting a bit with a very sharp scalpel; since the cut of scissors is always a crushing cut they should not be used.

Three tension sutures of fine silk, impregnated with vaseline, are then laid at equidistant points of the circumferences of the vessel ends. An assistant then applies traction to two of these guide sutures in turn, stretching the portion between the two sutures into a straight line, facilitating the laying of the continuous suture, and preventing a narrowing of the lumen. If at this time the third tension suture is weighted by means of a hemostat the circumference of the vessel will be arranged in the form of a triangle, the points of which are determined by the three traction sutures, and there will be no danger of catching the opposite wall while laying the suture, The suture is a continuous, overhand stitch, through all coats; the separate stitches should be drawn just tightly enough to secure absolute approximation, but not too tightly else the tissues be everted; they must be laid very close together. After the completion of the suture and the removal of the clamps there will often be some hemorrhage; if this is too free a few interrupted stitches may be laid, but a considerable hemorrhage will almost always stop under gentle digital compression. I wish to emphasize this fact, because of its bearing upon the later theoretical discussion. The danger of aneurism formation is very small; secondary hemorrhage is also as rare.

Now this sounds very easy, and, in truth, it is not very difficult, except for the extreme delicacy of the needles and the silk, and of the vessel walls; it is unusual surgery, since it partakes of the art of the watch-maker. Why, then, cannot everybody succeed in performing these simple, though delicate operations? Why do we read reports varying between absolute failure and uniform success? Why, out of four operations on the neck of the same animal, do we sometimes find the arteries perfect, the veins thrombosed, or the veins patulous and the arteries closed, or only one success, or all failure, or

all success? This is the question which, I think, leads us far away, into the fields where fact and theory too often establish a circulus viciosus.

In the first place, every author since Jassinowsky, whose work formed the first real contribution to our knowledge of this subject, has emphasized the necessity of a perfect aseptic technique. Carrel goes so far as to express his opinion that under ordinary "aseptic" conditions there are always a few bacteria which gain entrance to the wound; now these are so few that under ordinary conditions the tissues are able to destroy them. Not so in blood vessel surgery,—here we must have "absolute asepsis."

That infection around an uninjured blood vessel will cause thrombosis is banal. But I cannot believe that infection is the cause of the frequent thrombosis after blood vessel suture for several reasons; first, we find thrombosis with none of the usual macroscopic signs of infection, and, secondly, an early examination will show small non-occluding thrombi, and older specimens will show such thrombi completely healed over. In the third place, I have often observed that a thrombus will form in a sutured vessel, especially a vein, within a few moments after the clamps are removed, certainly hours too soon for these few bacteria to have caused it. Further, if this thrombus be removed by gently "milking" the vessel, another thrombus will replace it. In other words, the causes of thrombosis lie nearer at hand than bacterial action.

Just what happens when a blood vessel is wounded? The final processes of repair have been studied sufficiently to enable us to say that the vessel wall is completely repaired. The wound of the interior is covered with proliferated endothelium; some elastic fibres may regenerate, though the elastica is possibly not as perfectly repaired as are the other coats; the external coats are reconstructed by that excess of reaction so common in Nature as to be universal, and the vessel wall becomes stronger at that point than it was before the injury.

The problem of the coagulation of the blood is an extremely complex one. We know various factors in the process;

we know that foreign bodies and roughenings of the intima favor coagulation; that an interference with the free current of the blood is a favoring factor. We know that the tissues contain a substance or substances which cause rapid coagulation of the blood plasma, and that these substances are present in the tissues of the vessel wall. The formed constituents of the blood also contain these same or analogous substances. Calcium salts are necessary for the formation of fibrin. Experiments upon the vessels of animals whose blood had been made incoagulable by injections of hirudin or of peptone have shown that another process enters into the play, an agglutination of the blood plaques or platelets.

It is not necessary for us to decide between the theories concerning what happens first, or what happens further, as whether the action is a ferment action or whether it is not.

Let us think of the action of some of the factors in coagulation which I have mentioned. The suture, being inelastic, must offer a point where the current of the blood is more or less influenced; the sutures are the foreign bodies; the holes in the intima are rough; the tissue coagulins contained in the vessel wall have access to the blood through the needle holes; blood platelets are deposited in the wounds of the intima, even in incoagulable blood, and we know that a true coagulum can start from such a deposition of platelets. Further, if two factors are united in these biological phenomena, the result is usually much greater than the sum of the separate action of each factor.

That some coagulation occurs in every case seems to me to be proven by the statement to be found in every report of extensive work,—that slight hemorrhage is to be controlled by gentle digital compression. Such a method could only stop hemorrhage, it seems to me, by favoring the filling of the needle holes with a coagulum.

I therefore think that those who report uniformly successful results have succeeded not because they enjoy a monopoly of aseptic technique, but of mechanical technique. In other words, the man who will master the numberless details of

asepsis in experimental work on animals, where matters are more complicated than in human surgery, is probably the man who will master the delicate mechanics of the operation. The vessels are brought together with the least possible stretching or narrowing of the lumen, thus affecting the blood stream as little as possible. The foreign body is made less active as a foreign body by impregnating the silk with vaseline. The silk is so chosen as to fill the holes made by the needles and thus prevent the admixture of tissue coagulins from the vessel wall. Having excluded these factors, the deposition of blood platelets, which, I believe, always fills the wound of the intima at least, may perhaps be insufficient to cause the formation of fibrin and thrombosis.

The exclusion of these factors brings me to the consideration of a mechanical aid to blood vessel anastomosis, which is commonly called the method of Payr, but which, if my literary researches are correct, should be accredited to von Quirolo, his report appearing in 1895. The method consists in drawing the cut end of the vessel through a tube of glass, or ivory, or metal; the internal diameter of this tube is the same as the external diameter of the blood vessel. The vessel is then turned inside out, back over the tube, so that the intima is on the outside. This cuff is fastened in place by a ligature, and is then inserted into the other end of the blood vessel, which is fastened in its place by a second ligature. The ligatures are prevented from slipping off the little tube by placing them over grooves cut in the tubes, or back of a raised thread made on the outside of the tube. By this method broad surfaces of endothelium are placed in contact, and no wounds are made by the needles; the cut edges of the vessel, exuding coagulins, are entirely outside the vessel lumen. The method does not appear to have given specially good results except for temporary anastomoses, as in transfusion, where it seems to me to approach the ideal. It is not so easy to execute as it may seem. Crile has improved upon the original suggestions by attaching a handle to the tube, which greatly facilitates the eversion of the vessel.

The theories of the coagulation of the blood have carried me far out to sea; I was left there by the following facts concerning an operation little known, because of no practical importance. In 1876 a Russian army surgeon named Eck conceived the idea of making an artificial opening between the portal vein and the vena cava, in order to relieve the congestion in the portal system in cases of cirrhosis of the liver. He not only conceived this idea but executed it experimentally; and since that time the operation has been often performed, yet in no report do we find that thrombosis or embolism has resulted.

The operation has been done in several ways, none of which is calculated to prevent thrombosis. The vessels are brought together by interrupted sutures; wires or threads are then placed in position in the lumen of each vessel so that when the small scissors, the blades of which are fastened to the wires, are drawn through, after a second row of sutures has been laid, each blade must cut a linear incision through the wall of its respective vessel, an incision limited by the points of entry and exit of the guiding wires; the line of this incision is then enclosed by a second row of interrupted sutures parallel with the first, and the scissors are pulled through between the two rows of sutures. In my own method the wire of an electro-cautery is substituted for the scissors. The portal vein is then tied off at the hilus of the liver, thus forcing all the blood through a torn or burned wound through all the walls of the veins. The interrupted sutures also pierce the intima.

We have then a beautifully torn, rough wound, sutures with no attempt to neutralize their action with vaseline, undoubted coagulation,—since we have no hemorrhage between the sutures, which are laid from one-sixteenth to one-eighth of an inch apart,—and yet no thrombosis. The explanation may be that the portal vein has no collateral branches to open and enlarge, and the blood is forced to pass through this artificial opening; but on the other hand the pressure cannot be so great as it is in an artery. It might be that the portal blood contains peptone-like bodies which inhibit coagulation, but this

is hardly probable, for the portal blood coagulates outside the vessels as rapidly, if not more rapidly, than does blood from any other vessel. I have thought that the burned wound made by my cautery sealed the edges so that the tissue coagulins could not exude; yet equally good results have been obtained by using scissors; further, I have attempted to prove my idea by cutting the vessels of the neck with the cautery, and then joining them according to various methods; the results are possibly not so good as after the vessel wall had been severed by a sharp scalpel. In short, I am willing to admit that the processes governing thrombosis are not sufficiently clear to my own mind.

For the practical surgeon I feel that we may draw these conclusions: in any case where the anastomosis of a blood vessel is indicated, it should be tried; aneurisms and secondary hemorrhages should not occur. If immediate thrombosis occurs we would be as well off as though the vessel had been ligated; if gradual thrombosis occurs, we might well hope that such a process would be more favorable to the formation of a collateral circulation than would immediate ligation; and if we should succeed, the literature of surgery would undoubtedly be enlarged and enriched.

IV. ENDO-ANEURYSMORRHAPHY (MATAS).

BY CHARLES H. FRAZIER, M.D.,
OF PHILADELPHIA.

One of the most fascinating chapters in the history of modern surgery concerns the application of the suture as applied to lesions of the vascular system. These revolutionary measures have attracted wide attention not only because of their applicability to the treatment of the everyday lesions of the vascular apparatus, but because in simplifying the technic of direct transfusion they open a field of speculation, the possibilities of which are just beginning to dawn upon us.

The history of the development of the suture in the surgery of the vascular system and its applicability to the treat-

ment of aneurysm has been so graphically described by Matas that I will confine my remarks to my personal experience with his operation, adding such comments as may be suggested by the conditions which presented at or after the operation.

CASE 1. B. T. (University Hospital, No. 1313, Series 2.) *Popliteal Aneurysm: (Sacciform) Endo-Aneurysmorrhaphy (reconstructive): Recovery.*

A colored man, 38 years of age, was referred to me by Dr. C. S. Weeks in April, 1906. He was a waiter by occupation. He had had syphilis about eighteen years ago and was addicted to the free use of alcohol and tobacco. Eight months ago (September, 1905), the patient began to complain of a dull pain in the popliteal space. The knee joint felt stiff and the patient thought he had rheumatism. The pains and stiffness increased but it was not until two months later (December, 1905) that he noticed a small swelling, about the size of a chestnut, in the right popliteal space. The swelling gradually increased in size, until one month before his admission to the hospital, when it began to increase so rapidly that he was obliged to give up his work.

Upon examination there was found a pulsating tumor occupying the lower portion of the popliteal space measuring 10 cm. in its longitudinal and 11 cm. in its transverse axis. The circumference of the limb over the tumor was 32½ cm. as compared with 29 cm. on the unaffected limb. The leg below the aneurysm was somewhat swollen and the superficial veins quite prominent. There was a visible expansile pulsation and a marked bruit on auscultation. Pulsation could not be felt in the anterior tibial vessel. Operation. April 28, 1906. Under nitrous oxide-ether anæsthesia, an Esmarch tube having been applied to the thigh, a longitudinal incision was made directly over the tumor. Upon opening the sac a careful inspection proved that we were dealing with an aneurysm of the saccular or sacciform type, having but one communication with the parent artery. The operator then proceeded to remove the clot which partially filled the aneurysmal sac. This proved to be a rather slow process because the laminæ, particularly the deeper ones, were well organized and quite adherent to one another. These were peeled off as one peels an onion. Microscopically these clots were found to be well

organized, being composed of a stroma of young connective tissue within which were sprouting newly formed blood vessels. When the sac wall was finally stripped of its clots the single communication with the artery was closed with a continuous silk suture and the sac cavity obliterated by means of two layers of fine silk sutures. The cutaneous wound was closed with silk worm gut suture, the dressing applied, and fixation assured with a posterior splint. The post operative convalescence was devoid of interest. At no time was there any cause for apprehension as regards the vitality of the limb below the seat of operation. The temperature of the foot on the affected side was unaffected, the limb was not swollen so that I was quite sure neither the arterial nor venous circulation had been affected by the operative manipulations. The patient complained of numbness in the limb for a few days but this sensation soon passed off. There was some suppuration in the upper layers of the wound. While accidental infection may occur in any wound there are two factors, which in this particular operation may be regarded as predisposing causes, one traumatism, such as may be inflicted in removing the laminated clot, the other, impairment of circulation; Matas, in speaking of the chief points to be observed in closing the wound, says "too tight or too many sutures must be avoided in order not to compromise the circulation of the sutured tissues."

When the patient was discharged from the hospital there was no pulsation detected in the anterior tibial artery, a condition which was noted before the operation. The patient was examined in October, 1906, nine months later, when there were no signs of recurrence.[1]

Comments.—In this case I was surprised with the comparative simplicity of the procedure from the technical standpoint. There was of course no difficulty in rendering the field of operation bloodless, the aneurysm was easy of access. At no time was there any danger or fear of injuring the popliteal vein, which there would have been had any attempt been made to remove the sac. Whatever difficulty there may have been was entailed in removing the laminated clot and in determining when the intima had been reached. The layers which com-

[1] The patient died January, 1907, of pneumonia, at which time it was reported that there was no recurrence.

posed the clot were firmly adherent one to the other, in fact there was, as proven by microscopic examination, absolute union between the layers. A good deal of force had to be applied to separate them from the sac wall, and on several occasions I thought the intima had been reached only to find one or more layers still adherent. With more experience and with greater familiarity with the gross appearance of the structures involved this step of the operation could have been conducted more expeditiously. The necessity of removing everything necessary to lay bare the intima is apparent; inasmuch as the success of the operation depends absolutely upon the apposition and union of the serous coat of the aneurysmal sac and arterial orifice. The single communication with the parent artery was situated at the bottom of the sac near its upper extremity and not in the middle. We are accustomed to see the communication with the artery, in cases of saccular aneurysm, diagrammatically represented about the middle of the sac. This was the position in which I expected to find it in this case; failing to find it there, it was some time before I discovered it near the upper pole.

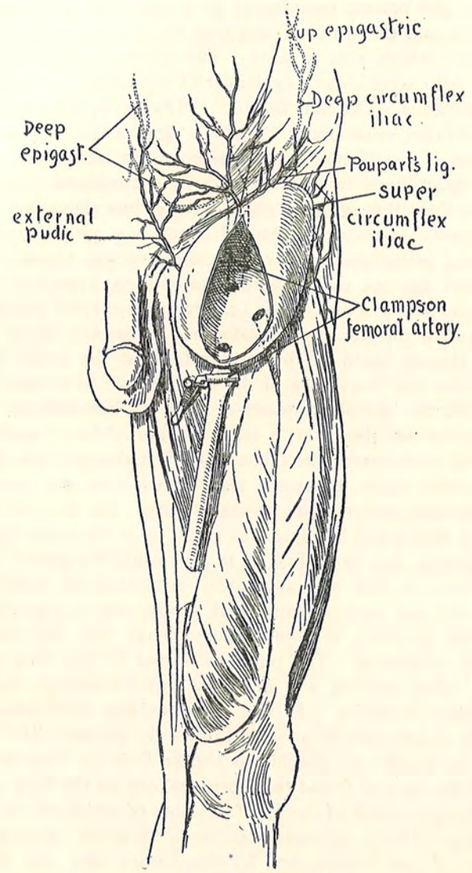
Case 2. T. S. (University Hospital, No. 1785) *Femoral Aneurysm (Sacciform: two communications with parent artery): Endo-Aneurysmorrhaphy (Obliterative), Gangrene, Amputation, Recovery.*

A colored man, 34 years of age, presented himself for treatment at the University Hospital, October 8th, 1906. He had contracted syphilis eight years ago, he used alcohol very freely and his occupation, as a porter, required him to lift heavy objects. Although by occupation and habit he had paved the way for aneurysmal formation he attributed the lesion to an injury which he had received three months ago. He struck the groin against the corner of a table and two weeks later he noticed in the femoral region a small lump, which increased in size and soon began to pulsate. An examination revealed a powerful subject with numerous cicatrices on the cutaneous surface, the result of old syphilitic lesions. The arteries did not seem to be sclerotic. Extending from Poupart's ligament to the apex of Scarpa's triangle and some 12 cm. in width was the aneurysmal tumor.

Pulsation was controlled by pressure upon the femoral artery just below Poupart's ligament. Below the knee the limb was swollen, the patient complained of a sense of numbness about the knee, and of so much pain that for the past two weeks he has been scarcely able to walk. The character of the operation and its risks were clearly explained to the patient.

Operation.—October 10, 1906. Owing to the situation of the aneurysm, close under Poupart's ligament, it was quite evident that it would not be feasible to use a tourniquet. I proceeded accordingly to close temporarily the external iliac artery: this was done through an oblique incision just above and parallel to Poupart's ligament an arterial clamp was applied and as an additional precaution a heavy silk ligature was thrown around the vessel, but not tied. This accomplished, a vertical incision was made over the site of the tumor, the aneurysm exposed, the artery below the aneurysm isolated and an arterial clamp applied here. Having taken the precaution to close the artery on both the cardiac and distal side of the sac, I hoped to be able to proceed with the operation unembarrassed by hemorrhage. Upon opening the sac, however, a large column of blood spurted out a foot or more above the table. My first thought was that the blood which made its escape represented what was present in the aneurysm under more or less tension, but it soon became apparent that active bleeding was going on in the aneurysmal sac. The bleeding was so profuse as to give cause for alarm. I have never seen so free and apparently uncontrollable hemorrhage. The cavity was packed firmly with gauze, and an attempt made with firm pressure to control hemorrhage, but this was only partially successful. The pulse soon rose to 160 then to 170; normal saline solution was given by hypodermoclysis and other appropriate remedies. It was quite evident that some more effective means must be adopted to save the patient's life. I proceeded as rapidly as possible to expose little by little the inner wall of the sac and found two openings, one on the floor and one on the lateral aspect of the sac, from both of which the blood was streaming. Direct pressure was made upon the openings with the tips of two fingers, and by this means only was bleeding finally arrested and an opportunity offered to inspect the sac. The latter was found to have three openings, two on the floor and one on the side. These were closed as rapidly as possible

with fine catgut sutures. The laminated clot was then peeled off, as in the first case, and the cavity of the sac obliterated by taking



Femoral aneurism:—showing openings in floor of sac.

up the lateral folds and bringing them together with a continuous mattress suture after the manner prescribed by Matas. Three

layers of sac superimposed over the arterial orifices sufficed to obliterate most of the aneurysmal sac; there still remained a small pocket at the upper pole, so far distant from the artery itself, that there seemed to be no objection to leaving it undisturbed. A drainage tube was introduced, the wound closed with interrupted silk worm gut sutures. After the dressing was applied the limb was enveloped in cotton and elevated. The patient's condition when he left the table was better than it was earlier in the operation. On the following day the toes were exposed and found to be warm, but anæsthetic; there was no pulsation in the dorsalis pedis. On the fourth day the patient complained of pain in the calf of the leg, there was marked tenderness when pressure was exerted over the course of the posterior tibial vessels, the limb was evidently swollen, and the foot was cold. It was quite evident that the circulation was seriously impaired and that gangrene would follow. The line of demarcation soon formed and the limb was amputated. A careful dissection of the specimen made for me by Dr. B. A. Thomas revealed the cause of the gangrene in a thrombus which had formed in the popliteal vessel just above its bifurcation, and extending for a short distance into both tibial vessels.

This case has been presented in greater detail than would at first sight seem warranted, because of two more or less distinctive features; the tremendous hemorrhage and the gangrene. Of the 35 or 40 cases that are on record this is the first case in which gangrene followed an uncomplicated endo-aneurysmorrhaphy. This was a very unfortunate occurrence, inasmuch as one of the strongest arguments in favor of the Matas operation is its safety to the patient and to the parts involved, because of the non-interference with the collateral circulation and the avoidance of gangrene. The operation is founded upon such sound principles and the mode of procedure has been so carefully elaborated by Matas that I am quite willing, if not anxious, that in this case some error in technique may be discovered which will account for the thrombus formation and ultimate gangrene. From the subjective and objective symptoms it would seem that the thrombus had obliterated the vessel on the third or fourth day. The process may have

originated at the site of the thrombus or it might have been due to the lodgment at that point of an embolus. There was an accidental infection of the wound, but there could be no relation of cause and effect between an infection above the seat of the aneurysm and the thrombus below the aneurysm, a segment of obliterated vessel intervening between the two. It seems much more reasonable to attribute the thrombus formation to an inadequate collateral circulation.

The second rather distinctive feature was the tremendous hemorrhage. One of the conditions which Matas considers essential for the success of the operation is provisional or temporary hemostasis. The aneurysm should be so situated that provisional hemostasis may be obtained by controlling the proximal arterial supply of the tumor on the cardiac side. "When circular constriction (as in my case) is impossible great care must be observed," writes Matas, "in securing the distal as well as the cardiac side of the main trunk in order to obtain a comparatively bloodless field." Accordingly I closed temporarily with arterial clamps the vessel on the distal and proximal side with what results has already been told. While the hemorrhage was most profuse, it was at the same time a most instructive demonstration, for it proved at once how utterly futile in this case it would have been to have practiced one of the older operations, particularly ligation, and illustrated beautifully the point upon which Matas has so frequently laid stress, namely, that the complete obliteration of the sac and the freedom from recurrence depends not only upon closure of the parent artery, but the collateral branches.

Had the reconstructive rather than the obliterative type of operation been carried out gangrene might not have occurred. There were two communications with the parent artery, but there was nothing left by which the course of the parent artery between the two openings could be recognized. It was blended with the aneurysmal sac throughout its circumference. Even had it seemed possible or desirable to reconstruct the artery the operation in this case could not have been carried out in the presence of so much free and uncontrollable bleeding.

Because of the evidence of so free a collateral circulation I was disposed to give a favorable prognosis as to the preservation of vitality and was much surprised when gangrene developed. While there is an erroneous impression that the Matas operation implies the reconstruction of the artery, "for all practical purposes the preservation of the continuity of the artery is not essential to success and is only indicated positively in the sacciform aneurysm with a single opening, when the parent artery already exists as a formed vessel." (Matas.) With this experience, however, I should be disposed in the future particularly in femoral aneurysms and under favorable conditions to attempt to reconstruct the artery, rather than depend entirely upon the collateral blood supply.

V. ENDO-ANEURYSMORRHAPHY (MATAS).

BY JOHN H. GIBBON, M.D.,
OF PHILADELPHIA.

THE ideal operation for the cure of aneurism is one which arrests completely and permanently the circulation of blood in the sac, without interfering with the blood supply in the parts beyond the aneurism. These two objects have always been in the mind of the surgeon and numerous operations have been devised which have accomplished them in certain situations.

The Matas operation comes nearer the ideal than any other, and is more generally applicable. Certain aneurisms, like those of the thoracic aorta, are probably beyond the field of operative surgery, but in every accessible variety where the circulation can be temporarily controlled, the Matas operation can be employed. Accessibility and temporary control of the circulation are essentially necessary, and where impracticable the operation should not be attempted. These limitations, however, do not prevent endo-aneurismorrhaphy being more universally applicable than any other operation for the cure of aneurism. It is not, however, the general applicability of the operation which has caused it to take first rank as a

radical cure, but especially the fact that it interferes less with the blood supply beyond the aneurism than any other.

The experimental work of Carrell, in this country, and of San Martin, Höpfner, Payr, Ullman, Jassinowski, Glück, and others abroad, together with the clinical and experimental work of Abbe, Murphy, Crile, Brewer, Hubbard and Matas, has shown with what readiness the blood vessels lend themselves to plastic operations. Suture, anastomosis, transplantation, substitution of vein for artery, arteriotomy for embolism, all of which have now been shown to be perfectly practicable, give some idea of the possibilities of vascular surgery.

The Matas operation has for its foundation this experimental and clinical work. It having been shown that when intima is approximated to intima union occurs just as when two peritoneal surfaces are placed in contact, Matas conceived the idea of closing the openings of the blood vessels in the aneurismal sac and of obliterating the sac by approximating its walls. He first operated by this method in 1888,[1] and reported a case, but his paper attracted little attention. At the time of publication of his second paper, in 1903,[2] he had done this operation four times. He suggested two other possibilities; first, the repair of the artery in sacciform aneurism, and second, the reconstruction of the artery in fusiform aneurism when the openings of the vessel were on the same line and not too far apart. To show that these were good suggestions it is only necessary to point to the successful cases since reported.

Bickham,[3] in an excellent paper, has shown that the principle of endo-aneurismorrhaphy is equally applicable to all accessible arteriovenous aneurisms, a variety in which ligation is especially dangerous, because of the likelihood of gangrene resulting from obstructed circulation.

Matas' own papers are so complete and comprehensive that it is unnecessary to go minutely into the technique. Briefly, the operation consists in controlling the flow of blood in the diseased vessel by compression; the free incision of the sac from end to end; the evacuation of its contents; the closure

by suture of the arterial openings in it; and then the obliteration of the sac by plication and infolding of the skin. In the case of a sacciform aneurism but one opening requires closure, and when this is done the caliber of the vessel is, of course, reëstablished. In the fusiform aneurism there are two courses open to the operator—one, of closure of the two openings of the artery into the sac, and of any collaterals which may originate within the sac, and then the entire obliteration of the sac by continuous rows of sutures; or, he may reconstruct the arterial caliber by suture over a catheter which is withdrawn before the last sutures are tied. Although I consider that the operation is no longer on trial, yet it is important that all cases operated on should be reported in order to compare the results with those of the older operations. In Matas's last paper [4] he classified 34 operations performed by twenty-one American surgeons, and referred to 6 foreign cases done by three operators, in which there was considerable variation of the technique—so much in fact that he is not inclined to combine them with the American cases. He believes that there has been a great misapprehension regarding the technique on the part of foreign surgeons, many of whom have on this account disapproved of the operation. In this series of 34 cases there have been but two deaths, neither attributable to the operation itself. One patient died fifteen days after operation from associated pyelitis and nephritic coma, the wound having healed completely. The other patient died on the seventeenth day after operation. This patient had an aneurismal diathesis and after operation developed multiple aneurisms. He was first operated on for a ruptured aneurism of the right popliteal, the sac was extirpated; he then developed a left femoral aneurism which was operated on by the Matas method. Twenty days later the vessel above the aneurism dilated and ruptured at a point where a traction loop had been applied for the temporary control of the circulation. Ligation of the femoral high up was then done but suppuration took place and later gangrene of the foot. Six days after this a secondary hemorrhage occurred and the external iliac was

ligated, the gangrene extended, and the leg was amputated in the mid thigh. The patient died in about two weeks from exhaustion. It should be noted that in this case neither secondary hæmorrhage nor gangrene took place until the vessel was ligated.

In none of the other cases did either hemorrhage or gangrene occur as a complication.

In considering the question of permanent cure, Matas divides the operations into obliterative, those in which the arterial openings were closed and the sac obliterated; restorative, those in which the aneurisms were sacciform and the arterial opening was closed without interfering with the circulation in the artery; and reconstructive, those in which a new vessel was constructed from the aneurismal sac. There were 22 of the obliterative cases with no relapses; there were 7 restorative cases with no relapses; there were 5 reconstructive cases with 2 relapses. In one of these an amputation was done at the patient's request. In the other case a second operation was done, the openings in the sac being occluded by suture, and a cure resulted.

I have been able to add to this collection of 34 cases 3 from recent literature, (McCord,[5] Brown,[6] and Yocum,[7]); a second case of my own, and a second case of Frazier's,[8] making in all 5 additional cases. Two of these were reconstructive operations, both of which were followed by good recoveries without complications; one was a restorative operation with an equally good result; two were obliterative operations, in one gangrene occurring on the fourth or fifth day necessitating amputation, after which the patient recovered; and in the second, my own case, death occurred on the 59th day from uræmia, the patient having been in a bad condition from chronic Bright's disease at the time of operation. The wound in this case was practically healed and the œdema of the limb had disappeared. My first case was operated upon on October 26, 1904.[9] I examined this man a few days ago and there was no evidence of any return of the aneurism, and after two years and a half it is unlikely that any recurrence will take place.

In this connection it is interesting to refer to a case of popliteal aneurism reported by J. Goyanes,[10] of Madrid, in which he ligated the artery above and below the sac, and then transplanted a section of the popliteal vein to bridge the defect in the artery. The result was successful. This operation was suggested by San Martin in 1902, and this is the first clinical case. The anastomosis was made according to the technique of Carrell. It is impossible to say what the future of this operation will be, but it certainly is of limited applicability and requires the most expert handicraft. It is unlikely that one who has not done considerable experimentation with arterial suture would be justified in attempting it, especially when the Matas operation is so much simpler and gives such remarkably good results.

In a ruptured aneurism with a large false sac, such as was found in my second case, it is difficult to carry out completely the Matas technique. The lining membrane has not yet taken on the characteristics of the intima of the vessel, nor is it sufficiently organized to stand the necessary traction by the sutures to permit of obliteration. Even in these cases, however, the openings of the vessels in the sac can be closed by suture and the principal benefit of the Matas operation gained, namely, the cure of the aneurism with the least possible interference with the circulation of the part.

The great disadvantage of the older operations is the extent to which they interfere with the circulation of the part beyond the aneurism, and the consequent frequency of gangrene. The ligation operation not only interferes with the circulation in the sac, but also cuts off a certain number of anastomotic branches which originate between the ligatures and the sac. The extirpation operation, although it allows the ligatures to be applied much nearer the sac, also greatly interferes with the establishment of anastomotic circulation by injury of the surrounding tissue, and gangrene frequently follows.

The Antyllion operation, although not cutting off as many anastomotic branches as the ligation or extirpation operations,

at the same time does require considerable manipulation beyond the sac in order to apply the ligatures and consequently is objectionable. To my mind, the Matas operation is the simplest yet devised, and the least likely to be followed by gangrene. That it is curative the statistics show conclusively.

The following is an account of my second case:

Dr. F., aged 57 years, was operated upon at the Bryn Mawr Hospital, on November 24, 1906. I first saw the patient on October 30th with Dr. Walter Chrystie. At that time he had a small popliteal aneurism about the size of a hen's egg. He had been having some fever and was generally in very bad condition. His urine contained albumin and casts and the secretion was scanty. His vessels were atheromatous and he had valvular heart disease. At this time he was put on increasing doses of iodide. I next saw him on November 13th with Drs. Earnshaw and Gamble. His general condition had not improved, excepting that the kidney secretion was greater. Two days before operation his pulse was 120 and of very high tension. The leg was very much swollen, which had developed since I first saw him. The pain had been so great since the increase in the size of the aneurism that morphia had to be used pretty continuously. On account of his general condition I was very loathe to operate upon him, but he suffered so much that there seemed to be nothing else to do. He had gotten up to 75 grains of iodide a day. Half an hour before operation he was given 1–6 of a grain of morphine and 1–100 of a grain of scopolamine. A tourniquet was applied until the pulsation ceased, and I then injected the line of incision with Schleich fluid. I made an incision, opened and evacuated the aneurismal sac without causing much pain. The aneurism had ruptured and a false sac had been formed in the surrounding tissues. The removal of the organized portion of the clot caused considerable pain, and as I was unable to detect with my finger the arterial openings in the sac, and if I had found them, would have been unable to suture them because any attempt to put the patient's leg straight gave him a great deal of pain, I was compelled to give him ether. I found both openings in the sac and closed them by suture. The sac was very friable and the sutures cut very easily, so that I had considerable difficulty in closing the openings, especially the proximal one. The sac wall was so friable that I could not reef it over, as is done in the Matas operation, and I therefore simply introduced a gauze pack and a few sutures in the muscular structures. The patient stood the operation, which occupied forty-five minutes, very well.

The next day he was passing a sufficient quantity of urine, his pulse had dropped to 104, and was of much lower tension. The swelling of the leg had greatly decreased, he had practically no pain, and his temperature was normal. The circulation in the foot was good, though no pulsation could be felt in the anterior tibial. This pulse could not be detected before the operation. This improvement in the patient's condition was only temporary, however, as the kidney and heart lesions steadily progressed until January 22, 1907, when he died of uræmia. At the time of his death there was no œdema or other recurrence of the aneurism. The wound had gradually filled up with granulation, until there was only a superficial area unhealed.

The only advantage of the operation in this case was that the patient was completely relieved of his pain and was able for a while to get out of bed with comparative comfort.

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[8] Charles H. Frazier, Annals of Surgery, September, 1907.
[9] John H. Gibbon, American Medicine, August 19, 1905.
[10] J. Goyanes, Siglo Medico, September 8, 1906.

Dr. George E. Brewer, of New York, said that for years he had been interested in this phase of surgery, particularly the Matas operation, and has long wished to hear the results of that procedure as detailed in the instances just reported. He has never carried out the procedure himself as none of the cases in which he expected to employ it proved suitable. He has, however, met with a case similar to one of those described by Dr. Frazier. It was one of aneurism of the first part of the femoral artery and

the vessel above and below was ligated with the expectation of later excising the sac. Ten days later he began excision but found excessive hemorrhage, due, as in Dr. Frazier's case, to two or three branches in the wall of the sac. Hemorrhage was with difficulty controlled. Such vessels are apt to be found in aneurismal sacs in this location. Dr. Munro's suggestion regarding the ligation of the ductus is to be thought of in suitable cases. If the diagnosis can be made the treatment is rational as the hopelessness of these cases is well known.

Dr. Brewer's own work has been experimental, based on efforts to close accidental wounds of arteries. The first accident was the wounding of an external iliac during a hernia operation, the suture being introduced from below upward instead of downward. Bleeding was profuse and it was found that a Hagedorn needle had passed through the vessel. Two attempts were made to suture the artery, in which the wound was one-fourth inch long. Tension was high and the sutures tore out each of two times they were inserted. The vessel was then ligated. Fortunately there was a free collateral circulation which maintained such satisfactory conditions that the patient never knew he had more than a hernia operation.

The second case was one of cancer of the breast in which a house surgeon who was operating plunged a knife into the axillary artery. The vessel was sutured and apparently no thrombus formed. Several mattress sutures of fine silk were inserted with a round needle, the walls of the vessel being so thick that the intima was probably not wounded. Six weeks later the clinical result was good. This is the only artery he has ever successfully sutured. These accidents led to the experimental work reported a few years ago, in which he used for wrapping the vessels, an elastic plaster made up of a strip of very thin gum, coated with an adhesive material like that used in the zinc oxide plaster. Experiments were made on a large number of animals and some of the results were good. He regards the method as worthy of trial in accidental wounds of the arteries.

Dr. John B. Murphy, of Chicago, described a case of double embolism involving the right femoral below Poupart's ligament and the left common iliac, the case being one of sepsis and malignant endocarditis following extraction of a tooth.

Removal of the obstruction in the legs was thought of but embolism of the brain caused death before the operation was undertaken.

The work of Dr. Sweet is appalling from the standpoint of the time and labor necessary. Dr. Murphy is pleased with the results obtained, not only in the technical work but also in the train of thinking in respect to thrombosis in arteries and veins. From this one comes finally to the practical results of arterial work shown in the cases of Frazier and Gibbon; the work from 1889 on by Matas and others is showing results. In analyzing the work done in the suture of arteries it may be reduced to three essential methods: first, end-to-end suture; second, end-to-end implantation; third, suture by mechanical support. The third, promulgated by Abbe, was not a bad idea.

For practical suturing of vessels two things are essential; there must be no immediate hemorrhage and no immediate thrombosis. Gangrene results from immediate primary ischemia. If ischemia come on gradually there is no thrombosis, this being shown clearly by specimens in the British museum. If therefore we can devise an operation that will tide over a few days, we will succeed. In an aneurism where it is impossible to employ the Matas operation if we can produce a gradually occluding endarteritis in the proximal vessel the lesion will be cured. Most of the work upon arteries previously reported was too coarse. The greatest element in the production of endarteritis is trauma and not infection; where the artery is pinched is the point of greatest danger. Carrel's great care in handling and suturing the vessels is his dominant point, and this adds more to his success than does any other feature of his work.

Dr. J. C. Hubbard, of Boston, said that his experience in arterial surgery had been obtained by doing an arterial venous anastomosis in two cases for reversal of the circulation.

The first case, already published in the Annals of Surgery for October, 1906, was that of a man of 80 years with senile gangrene of a portion of the right foot. Physical examination showed him to be a decidedly senile old man with atheromatous arteries and a systolic heart murmur. No pulsation could be felt in the right dorsalis pedis artery. In May, 1906, he was operated upon. The femoral artery and vein were isolated in Scarpa's triangle below the origin of the profunda and divided

between Crile's clamps or elastic ligatures. The upper end of the artery was then invaginated into the lower end of the vein and the distal end of the artery into the proximal end of the vein. A complete reversal of the circulation was thus established. The technique of the invagination was as follows: Three double headed sutures were passed equally distant through the entire wall of the artery from inside out. The needles were then passed into the lumen of the vein about a quarter of an inch and at this point through its wall. When these sutures were drawn tight the artery was drawn into the vein. Reënforcing sutures including only the outer portion of the arterial wall were then placed here and there to catch the edge of the overlying vein to the artery. Number 1 Pagenstecker thread was used for all these sutures. When the controlling clamps were removed there was no leaking at either suture line and weak pulsations could be felt in the vein for a short distance below the anastomosis. There was absolutely no shock shown by the patient and recovery from the operation was satisfactory in spite of the fact that the senile condition of the patient made it difficult to keep him in bed or a dressing on the wound. After the operation the appearance of the leg did not change. There was no œdema, dilatation of the veins or cyanosis. The gangrene which existed before the operation spread a little and then a line of demarkation formed. When the foot was later amputated at the point of election on the tibia both tibial arteries contained arterial blood. The stump healed satisfactorily but slowly. In March of this year, ten months after the operation he saw the patient. The stump was well supplied by the circulation and there was no difference in appearance or size of this leg and the unoperated one.

Clinically this case was most successful but the exact meaning of the presence of arterial blood in the tibial arteries at the time of the amputation he did not know. It seems that the arteriovenous anastomosis must have increased in some way the amount of blood in the leg, for it is hard to believe that an amount of blood so small as to permit gangrene of the foot would be sufficient to nourish for ten months an amputation stump made only a short distance above the gangrenous area and had clots formed at the sites of the anastomoses it seems most probable that the gangrene would have extended up the leg instead of remaining localized.

The second case was that of an old woman of 60 years with senile gangrene of the foot and a portion of the leg. The arteries were atheromatous. She was operated upon during February of this year. The femoral artery and vein were divided as in the first operation. The artery was much calcified and was so hard that some force was necessary to drive the needles through it and so brittle that the stitches tore out most easily. The intima formed a distinct lining to the vessel and was much like a second smaller tube inside a larger one. These characteristics of the wall complicated the technique immensely as the attempt was to make the anastomosis according to Carrel's method, turning the walls so that at the suture line intima should come in contact with intima. The artery was so much like a pipe stem that this was impossible although a conscientious attempt was made. The ends of the artery and vein were therefore cut off freshly and the artery invaginated into the vein as in the first case the only difference being in the use of vaseline to smear the ends of the vessels. The distal end of the artery and the proximal end of the vein were then ligated. The vein pulsated after the controlling clamps were removed. Pagenstecker No. 1 was used. There was no shock and no change in the appearance of the leg. Ten days later it was necessary to amputate above the knee for the gangrene which had been present before the operation. During these ten days it had become more pronounced but its limits had extended only a little. During the amputation the anastomosis was cut down upon and removed. The artery was found filled with a loose, easily detached clot. This case was therefore a distinct failure.

From these cases he believed it to be perfectly evident that there is no danger in continuing investigations further as there is no shock to the operation. Carrel's method is not applicable to a certain number of the cases where the operation is done on old persons with atheromatous arteries. On young persons and experimental arteries it doubtless is most satisfactory but as the operation has been proposed to cure conditions dependent upon lack of circulation in the extremities some other technique must be found as practically all cases, except perhaps some due to trauma, will necessarily be in elderly persons. An objection which may be raised to the invagination method as employed in the above cases is the fact that the divided end of the artery

leaves a certain portion of its wall in the blood stream uncovered by intima which favors clot formation. This method was introduced by Murphy in 1897 (*Medical Record,* Jan. 16) for the repair of the continuity of an artery and was recommended only after experimentation. The slight modification of invaginating the artery into a vein instead of into another portion of the same artery would seem not to invalidate the method. However, as at present this objection might be raised, he was working on some scheme to obviate this difficulty, but as yet could not report results. Two ways had occurred to him. One is by smearing vaseline or some other substance onto the cut end of the invaginated artery to keep it out of the blood stream. The other way was suggested by the appearance of the arterial wall in the second case where the intima formed a distinct layer inside the others and one which remained intact when the others cracked away from it. He had thought that it might be possible to cut the outer layers of the artery a quarter of an inch or so back of the intima and thus leave a greater length of intima as a cuff, the back of which could be covered with vaseline so that when invaginated into the vein it might stick to the venous wall and cover over the cut end of the outer portion of the artery.

Dr. Robert H. M. Dawbarn, of New York, said Dr. Sweet's statement, that silk sutures were everywhere admitted to be the best, he must take exception to. A good many years ago Dr. Willy Meyer, of New York, proved by experiments that linen, cotton, and silk threads are tolerated equally well by the body tissues.

Of these linen is, size for size, the strongest, and is not seriously weakened by boiling; whereas silk is distinctly weakened.

For these reasons Dr. Dawbarn said he has not for years past used silk in surgery for any purpose whatever. In bowel and stomach work he has long advocated linen sutures—probably for ten years; though he would not bury it elsewhere in the body, except when exceedingly fine in diameter, as in Dr. Sweet's work upon arteries.

By asking at any large department store for such linen thread as is used in mending Renaissance lace, one can get size one thousand—which is as fine as can be used, practically, in vessel-

work. It would seem to Dr. Dawbarn that if one employs women's finest sewing needles, removing the temper by heat enough to allow of curving them, and avoids having the thread pass through the intima, so that it does not touch the blood current nor invite clotting, it might be a help. And yet Dr. Dawbarn did not wish to claim the least personal experience of work, such as that of Dr. Sweet, and would defer to his opinions in these matters.

Regarding Dr. Brewer's ingenious device for control of an important artery wounded accidentally at operation, Dr. Dawbarn said he must repeat his criticism offered upon the occasion when Dr. Brewer presented before the New York Surgical Society the results of his experimental work upon dogs. These experiments were very ably done, and the results satisfactory. To Dr. Brewer belongs the credit of the thought, and Dr. Dawbarn merely suggested a different material to wrap about the artery after its suture, and before allowing the current to be resumed; namely, Cargile membrane. This is always at hand, and, whether the adhesive or non-adhesive, will be equally satisfactory. It is very strong. After wrapping the vessel several times the final edge is sewn to the layer just beneath.

Being absorbable tissue it will in time disappear. As to the special kind of thin surgeon's rubber plaster advocated for this purpose by Dr. Brewer the life of rubber plaster is short, at best, and nobody would be likely to keep this specially thin kind on hand, and renewed often, to meet so very rare an accident. Also, being non-absorbable, it is capable at times of causing trouble later; becoming finally an irritant, however thoroughly aseptic it may be.

Dr. Dawbarn has tried upon two dogs' common carotids the gold-beater's skin adhesive plaster as just advocated by him, and with excellent results. The specimens, with others to be obtained by later work, he hopes to show in time.

Dr. Dudley P. Allen, of Cleveland, said his first experience in suturing vessels was in connection with wounds of the veins. The first case occurred between ten and twelve years ago. It was a wound of the longitudinal sinus, the length of the wound being ¾ of an inch. The wound occurred in an operation upon the brain and it was closed by a continuous suture of fine silk,

the skull was re-placed, and healing took place without any complications.

There is one condition which has not been mentioned in which suture of the vessels might prove to be of great value. Occasionally sarcomata develop in the popliteal space, being unattached to bone. It may be impossible before operation to tell whether the sarcoma surrounds the popliteal vessels or has pushed them to one side. If the vessels are surrounded, it may be necessary to divide them in order to remove the growth. Under such conditions, if a suture of the vessels could be successfully made it would be an operation of very great value. In a recent case it was necessary to divide the vessels and the operation was followed by gangrene of the leg which required amputation. Could an anastomosis have been made the leg might have been saved.

Dr. J. F. Binnie, of Kansas City, said that in a typical case of sacculated aneurism with one opening of moderate size he closed this opening with a suture and then obliterated the sac in the Matas' fashion thus performing a reconstructive operation although he did not at the time recognize the fact. In other cases, named by Matas fusiform aneurisms, there are two openings into the sac, these two openings being connected by a groove or strip of comparatively healthy vessel wall, along the wall of the sac. Such aneurisms are *not* fusiform, they are sacculated, only a narrow strip of one side of the vessel being diseased and constituting the sac. In this class reconstructive operations are of much value; there is sufficient healthy tissue to give a good prospect of success. Even if complete success is not attained, *i.e.*, if the newly created arterial tube becomes obliterated, this obliteration may take place slowly enough to permit the circulation being kept up while collateral circulation is being established. In true fusiform aneurism the whole circumference of the vessel wall is diseased—no healthy material remains out of which to construct an artery—hence in these cases the ordinary Matas' obliterative operation is proper and easy, the reconstructive operation is out of the question.

Dr. Munro, in closing, said he found in one case the same trouble experienced by Dr. Stewart. There was thrombosis of the femoral resulting from a fracture-dislocation. The clot stuck

to the vessel wall and the artery was then opened below the thrombus and dislodgement attempted by hydrostatic pressure, but this was also unsuccessful.

Dr. Sweet, in closing, said that the needles employed in arterial suture were so fine that if one attempted to sterilize and bend in a flame the steel would at once burn and be ruined. Regarding different suture material, silk probably has the finest individual strands and hence is to be considered better. A point to be considered in the case of arterio-venous anastomosis is that time is gained for the establishment of a collateral circulation.

Dr. Frazier, in closing, said in answer to a question by Dr. Dawbarn regarding the control of hemorrhage from the femoral in operating upon aneurism, that the latter's suggestion to use McBurney's technic in securing a bloodless amputation by opening the abdomen and compressing the common iliac against the psoas was worthy of consideration.

Dr. Gibbon, in closing, said regarding Dr. Stewart's suggestion that the vein be substituted for the artery, that in looking up the literature of the subject he had discovered the report of a case by Goyanes,[1] of Madrid, in which that suggestion had been put in practice. The popliteal was divided distally and the vein substituted for the artery, the expedient proving a success

[1] (Siglo Mèdico, Sept. 8, 1906.)