

ARTERIOVENOUS ANASTOMOSIS—REVERSAL OF THE CIRCULATION—AS A PREVENTIVE OF GANGRENE OF THE EXTREMITIES.

REVIEW OF THE LITERATURE AND REPORT OF SIX ADDITIONAL CASES.

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A DISCUSSION has arisen of late between Coenen of Breslau and Wieting of Constantinople as to the efficacy of an arteriovenous anastomosis—reversal of the circulation—in preventing the spread of a real or threatened gangrene in the extremity of a human. Coenen claims that Carrel's statements and experiments in regard to the possibility of reversing the circulation in the limb of a dog are not conclusive. That, in fact, the valves of the veins do not give way as asserted and that as a result a true and complete reversal is never attained, the blood simply being shunted off to another vein and promptly returned to the heart without ever getting to the foot or hand. Furthermore, he asserts that the procedure is both anatomically and physiologically wrong, and he therefore warns against the indiscriminate performance of this operation.¹

Wieting on the other hand says that his clinical work, which has been highly successful, speaks for itself.² He admits that there are several questions, such as the return of the blood to the heart, still unsettled, but believes they will be solved only through clinical experience, theories and experimental work not having given the required solution.

¹ H. Coenen and Wiewiorowski: Ueber das Problem der Umkehr des Blutstromes und die Wietingsche Operation, *Beit. z. klin. Chir.*, Aug., lxxv, Nos. 1-2, pp. 1-473, also *Cent. f. Chir.*, No. 29, 1911.

² Wieting: Treatment of Angiosclerotic Gangrene by Diverting Arterial Blood into Venous System, *Deut. Zeit. f. Chir.*, cx, Nos. 4-6, pp. 313-634.

In view of the increasing number of successful reversals, it would seem that Wieting's stand-point is deserving of some support. Indeed, it would be a sad state of affairs if, after all the brilliant experimental work done in the field of vascular surgery, we should still hesitate to attempt the practical application of our knowledge.

A careful search of the literature has revealed forty-six cases of arteriovenous anastomosis—reversal of the circulation—in the human, to which I wish to add the following six cases, two of which were done on the same individual, though at different times.

CASE I.—H. L., colored, male, age twenty-seven. (From the wards of Dr. W. S. Halsted, the Johns Hopkins Hospital.) This patient came in complaining of a growth in the right popliteal space. At operation, January 21, 1910, by Dr. Halsted, the growth was found to be a sarcoma originating in the popliteal nerve and involving the popliteal artery and vein. A defect of about four inches between the ends of the vessels remained after radical extirpation of the tumor. Believing then that the lower leg was in danger, I was graciously allowed to remove about five inches of the left saphenous vein and transplant it between the severed ends of the right popliteal artery and vein; in other words doing a typical reversal. (The distal end of the artery was so small that it was thought best to use the vein as its lumen more nearly corresponded in size with that of the saphenous transplant.) Following operation there was an oedema of the lower leg, a dilatation of the superficial veins, and an elevation of temperature in the right leg as compared to the left. The leg continued to have a good circulation, and the patient left the hospital in good shape and able to walk. He died 18 months after operation. No autopsy was obtained, as death occurred at his home, but the probabilities are that the growth returned.

According to E. Wolff,³ out of thirty cases of popliteal aneurism, gangrene in various degrees occurred in fourteen

³Die Häufigkeit der Extremitätennekrose nach Unterbindung grosser Gefasstämme, *Beit. z. klin. Chir.*, No. 58, 1908, p. 787-788.

following extirpation. It is necessary therefore to consider this a doubtful case, inasmuch as the chances were about even that the leg would have lived had no transplantation been done.

CASE II.—Miss M. G., white, age twenty-seven. Diagnosis Raynaud's disease. (Patient of Dr. J. C. Bloodgood, St. Agnes Hospital.) Five years ago the patient had a general infection from a wound on the index-finger. In May, 1910, she began to have pain in both feet, followed by some discoloration of the second toe of the right foot, necessitating removal of the toe. In January, 1911, two toes of her left foot became gangrenous and were removed. She constantly had pain in her legs, and her feet were always cold. On examination the pulse in the dorsalis pedis artery and the popliteal artery could not be felt in the left leg. The pain in this case was so severe and so constant that, believing the poor circulation had something to do with the condition, a reversal of the circulation in this leg was decided upon in the hope of giving relief. An end-to-end anastomosis between the femoral artery and vein in Scarpa's triangle was done on February 27, 1911. This being our first typical case, we made the mistake of cutting the vessels, vein, and artery at the same level and not allowing for the usual retraction following section of any vessel. It was not exactly a mistake either, because we started out to do a complete reversal, that is unite artery to vein and vein to artery, the latter to take care of the back flow. We did not know at that time, as we do now, that the complete reversal is all but impossible in the human without transplanting a piece of vein between one or the other of the vessels; nor did we know then, as we do now, that the complete reversal is unnecessary, because there are always enough veins in the limb to care for the back flow.

After trying for some time to bring the artery and vein together in spite of the retraction, we took about one inch off the upper end of the vein and transplanted it between the proximal end of the artery and the distal end of the vein, making a very satisfactory anastomosis. Following operation the pain gradually disappeared and now the left leg is apparently as good as it ever was. There is a powerful thrill to be felt and auscultated over the site of anastomosis and extending down to the knee.

For a time following this operation, strange to say, the patient obtained considerable relief in her right leg, and the dorsalis pedis and popliteal pulse, previously absent, could be obtained again. Gradually, however, the old pain recurred, the pulse was lost, and the foot began to get discolored in patches. The sciatic nerve was stretched, but only seemed to aggravate matters, in addition to giving the patient a foot-drop.

CASE V.—On May 27, 1911, therefore (10 days after stretching the sciatic nerve), a lateral anastomosis between the femoral artery and vein of the right leg according to the method of Bernheim and Stone,⁴ was done, the vessels being exposed and sutured in Scarpa's triangle. The vein was tied off proximal to the site of suture to prevent back flow to the heart, but the artery was left intact. We considered this an improvement over the old end-to-end anastomosis, because it did not disturb the arterial circulation at all, but simply gave an added channel of arterial blood by means of the vein. The anastomosis has been perfectly satisfactory, as is evidenced by the thrill and pulsation over the site of anastomosis and the splendid circulation of the foot.

At this date, 11 months after the first and 7 months after the second operation, the left leg has a circulation apparently as good as normal and gives no pain. The right leg also has an apparently normal circulation, but there is still a foot-drop, anæsthesia of the muscles of the lower leg, and pain along the course of the sciatic nerve. This condition is slowly improving, and strong hopes of a complete recovery are held out by the neurologists.

CASE III.—M. R., white, male, age forty. (Patient of Dr. J. C. Bloodgood. St. Agnes Hospital.) Patient had been a sufferer from Raynaud's disease for nearly five years, having suffered extreme pain at times in all his extremities. The circulation in his right toes was very poor, and they became gangrenous, one by one, until all but the big toe had to be removed. He seemed to get along fairly well as regards his left foot, until March, 1911, when he came in with beginning moist gangrene of all the toes of this foot. The arterial tension was not increased. The urine was negative; the Wassermann was negative.

⁴ANNALS OF SURGERY, October, 1911.

The usual remedies failed to check the gangrene or to relieve the pain, so it was decided to reverse the circulation in the limb as a last resort. The operation was done March 27, 1911, an end-to-end anastomosis being done between the femoral artery and vein in Scarpa's triangle. The artery seemed smaller than normal, even when distended with blood, and the fibrous sheath as well as the adventitia was more adherent and perhaps a little more dense than usual. The calibre of the vein was smaller than usual, though in other respects it seemed normal.

On the day following operation, the leg was quite oedematous, all the superficial veins were dilated, a popliteal pulse could be felt (it was absent before operation), and the patient seemed to have less pain, although the condition of the foot had changed little, if at all. After this, the pain gradually became worse and the gangrene progressed, so that three days after operation the leg was amputated at the thigh. At this operation the site of the blood-vessel anastomosis was exposed and found to be working beautifully.

Looking backward, it would seem that this case was badly selected and the blood-vessel operation ought never to have been done, because apparently the gangrenous process had progressed so far that the nerves had become involved as well as the smaller vessels, thus making an attempt at saving the limb utterly hopeless.

CASE IV.—M. B., white, female, age sixty-one. (Patient of Dr. J. C. Bloodgood, St. Agnes Hospital.) This patient came in complaining of sharp pains and an extensive ulcer of her right foot, which had been present for about two and a half months. There was tingling and numbness, the skin was white and cold, and there were dark brown areas of gangrene from the toes to the ankle. The patient had a general arteriosclerosis, there was no sugar in the urine.

On March 27, 1911, the femoral artery and vein were exposed in Scarpa's triangle; on severing the artery preparatory to doing an end-to-end anastomosis, the vessel was found to be two-thirds occluded by an old thrombus; the vessel wall was quite thick and sclerotic. Although the outlook under such circumstances was very discouraging, the thrombus was pressed out of the vessel with the thumb and fore-finger and the usual

end-to-end anastomosis done. The blood went over in the usual manner and continued to do so as long as the vessels were exposed. Following operation, although no pulse could be felt over the site of anastomosis and no thrill could be elicited by the stethoscope, the condition of the patient's foot gradually became better and the ulcers healed. Just before the patient left the hospital a faint pulse could be felt in the femoral vein below the site of anastomosis. The success of this case from an operative stand-point is naturally doubtful, but the circulation in the patient's foot and leg was so poor before operation that it seems that had the anastomosis been a complete failure, the foot must surely have become gangrenous.

CASE VI.—W. L. B., white, male, age fifty-two. (Patient of Dr. J. M. T. Finney, at the Union Protestant Infirmary.) For about two years the patient had been suffering with severe pain in his left hand and arm, the fingers at times becoming quite cyanosed. He had had the tips of three fingers of this hand amputated because of gangrene. The other extremities were involved in a similar manner, but to a lesser degree, although the pain was so severe that the patient had become addicted to morphine. The patient had had a suspicious venereal sore and had been a heavy drinker; he had also had at one time, in 1900, a severe case of dysentery. There was a generalized arteriosclerosis; the urine was negative, the Wassermann was negative; no radial pulse was to be felt in the left wrist.

Under expectant treatment the patient improved for a time, but later on the condition in the left hand became so threatening that a reversal of the circulation in the upper arm was done in the hope of avoiding amputation. The operation was done on June 7, 1911. It had been our intention to do a lateral anastomosis, but on exposing the vessels the artery was found almost completely occluded by an organized thrombus. We therefore went above this thrombus and did an end-to-end anastomosis between artery and vein at the lower limit of the axilla. Following operation the patient's pain was completely relieved, the color in the arm and hand became far better than before operation, and motion in the fingers was considerably improved. No pulse, however, could be felt below the site of

anastomosis, and the success of this operation from an operative stand-point is also in doubt. It is fair to state, however, that the vein branched immediately below the suture line and thus divided up the pulse considerably. In addition to this, the patient left the hospital in such good condition that it seems as if some blood must have been going down to the hand through the venous channels, otherwise gangrene must have ensued.

A list, then, of all the cases in the literature, including my own, will be as follows:

CASES OF ARTERIOVENOUS ANASTOMOSIS REPORTED IN LITERATURE.

Case 1.—San Martín y. Satrustegui: Male, 52; situation leg, for gangrene of foot; lateral anastomosis. Failure; amputation 6 days post-operation, death 13 days post-operation.

Case 2.—San Martín y. Satrustegui: Male, 75; situation leg, for gangrene of foot; lateral anastomosis. Patient recovered, although before operation gangrenous part removed. Case negative.

Case 3.—Jaboulay: Male, 47; situation leg, for beginning gangrene; lateral anastomosis. Failure.

Case 4.—Jaboulay: Male, 67; situation leg, for threatened gangrene. Failure; amputation 4 days post-operation, death 6 days post-operation.

Case 5.—J. C. Hubbard: Male, 80; situation right leg, for beginning gangrene; artery invaginated into vein. Unimproved; amputation.

Case 6.—H. Lillenthal: Male, 20; situation left leg, for beginning gangrene; end-to-end. Death 31 hours after operation, shock.

Case 7.—C. A. Ballance: Female, 75; situation right leg, for beginning gangrene. Successful; patient died 5 months after operation of gangrene of the large intestine. No autopsy.

Case 8.—Wieting: Male, 40; situation left leg, for threatened gangrene; intubation. Successful; patient discharged after 2 months, well.

Case 9.—Orhan: situation leg, for beginning gangrene; intubation of popliteal artery and vein. Failure; amputation.

Case 10.—J. C. Hubbard: Female, 60; situation leg, for beginning gangrene; artery invaginated into vein. Failure; amputation.

Case 11.—F. B. Lund: Male, 32; situation left leg, for threatened gangrene; end-to-end. Failure; amputation.

Case 12.—J. C. Hubbard: Female, 84; situation left leg, for beginning gangrene; end-to-end. Failure; death from senility 2 months after operation.

Case 13.—D. J. Armour and E. A. Smith: Male, 69; situation right leg, for threatened gangrene; end-to-end. Failure; amputation 2 weeks post-operation.

Case 14.—J. C. Hubbard: Male, colored, 77; situation right leg, for beginning gangrene; end-to-end. Temporarily successful; amputation 5 weeks post-operation because of pain and edema.

Case 15.—G. P. Muller: Male, 51; situation left leg, for beginning gangrene; end-to-end. Failure.

Case 16.—Bier: Male, 38; situation leg, for beginning gangrene; intubation. Failure; amputation.

Case 17.—Payr: Male, 70; situation leg, for beginning gangrene; intubation; profunda artery intubated into femoral vein. Failure; death 16 days post-operation.

Case 18.—Abalos: Male, 62; situation right leg, for beginning gangrene; lateral anastomosis femoral artery and saphenous vein. Failure; amputation.

Case 19.—Imbert: Male, situation leg, for gangrene; lateral anastomosis, femoral artery and saphenous vein. Failure; death 2 days post-operation.

Case 20.—Celesia: Female, 52; situation leg, for gangrene; lateral anastomosis, femoral artery and vein. Failure; death 20 days.

Case 21.—Goldberg: Male, 64; situation leg, for gangrene; intubation. Successful, but death 15 days post-operation from erysipelas.

Case 22.—Jaboulay: Male, 66; situation leg, for gangrene; end-to-end. Failure; amputation.

Case 23.—Tuffier: Male, 50; situation leg, for threatened gangrene; end-to-end. Successful.

Case 24.—Imbert: Male, 25; situation leg, for popliteal artery and vein ruptured by lightning stroke; end-to-end anastomosis of popliteal artery and vein. Failure; amputation.

Case 25.—Tuffier: Male, 56; situation left leg, for beginning gangrene; lateral anastomosis. Failure; death.

Case 26.—Doberauer: Male; situation arm, for thrombus and threatened gangrene; invagination. Successful.

Case 27.—Tuffier: Male, 50; situation leg, for beginning gangrene; end-to-end. Successful.

Case 28.—Lacroix: Male, 25; situation leg, for gun-shot wound; end-to-end. Failure; amputation.

Case 29.—Schmeiden: Female, 48; left leg, for gangrene; end-to-end. Death 24 hours post-operation.

Case 30.—Enderlen: Situation leg, for threatened gangrene; end-to-end. Failure; amputation.

Case 31.—Enderlen: situation leg, for beginning gangrene; end-to-end. Death 3 days post-operation.

Case 32.—Goyannes: situation leg, for aneurism; end-to-end. Successful.

Case 33.—Kruger: Female, 48; situation right leg, for beginning gangrene; intubation. Failure; amputation.

Case 34.—Tietze: Female, 69; situation leg, for gangrene; intubation. Failure; death 19 days post-operation.

Case 35.—Tietze: Male, 64; situation right leg, for gangrene; intubation. Successful, but death from erysipelas 15 days post-operation.

- Case 36.—Payr: Male, 70; situation leg, for beginning gangrene; profunda artery intubated into femoral vein. Failure; death 16 days post-operation.
- Case 37.—C. Beck: Male, colored; situation right leg, for gangrene; lateral anastomosis. Failure; amputation.
- Case 38.—Wieting: Male, 40; situation right leg, for threatened gangrene; lateral anastomosis. Successful.
- Case 39.—Orhan: Male, 40; situation left leg, for gangrene; intubation. Failure: amputation.
- Case 40.—Wieting: Male, 33; situation left leg, for beginning gangrene; lateral anastomosis. Temporarily successful; amputation 3 months post-operation.
- Case 41.—Wieting: Male, 35; situation right leg, for threatened gangrene; intubation. Successful; although half of foot had to be amputated.
- Case 42.—Wieting: Male, 32; situation left leg, for threatened gangrene; lateral anastomosis. Successful.
- Case 43.—E. Heymann: Male, 47; situation left arm, for beginning gangrene; end-to-end. Successful; patient well 11 months post-operation.
- Case 44.—Quenu: Male, 48; situation left leg, for Raynaud's disease; end-to-end. Temporarily successful; amputation 4 months post-operation.
- Case 45.—Coenen: Male, 51; situation right leg, for beginning gangrene; end-to-end. Failure; amputation 4 days post-operation.
- Case 46.—Glasstein: Male, 38; situation right leg, for threatened gangrene; end-to-end. Successful.
- Case 47.—B. M. Bernheim: Male, colored, 27; situation right leg, for sarcoma of popliteal space necessitating resection of popliteal vessels; end-to-end. Doubtful; death from metastases 18 months post-operation.
- Case 48.—B. M. Bernheim: Female, 27; situation left leg, for Raynaud's disease; end-to-end. Successful.
- Case 49.—B. M. Bernheim: Female, 27; situation right leg, for Raynaud's disease; lateral anastomosis. Successful.
- Case 50.—B. M. Bernheim: Female, 61; situation right leg, for beginning gangrene; end-to-end. Successful.
- Case 51.—B. M. Bernheim: Male, 40; situation right leg, for Raynaud's disease; end-to-end. Failure; amputation 3 days post-operation.
- Case 52.—B. M. Bernheim: Male, 52; situation left arm, for threatened gangrene; end-to-end. Successful.

In studying these 52 cases I find that 38 were done on males, 10 on females, and in 4 the sex was not stated. The ages varied all the way from 20 to 80 years. Fifteen out of the 52 cases must be considered successful ones, that is, cases in which the reversal, as far as one can judge, actually saved the limb from real or threatened gangrene—a percentage of 30 per cent. I have included Case 7 among the successes, because death was in no way related to the vascular condition in

the leg, but I have thrown out Cases 14, 40, and 44 because, though apparently successful as far as the actual operation was concerned, an amputation later on became necessary. Case 47, as said above, I consider doubtful, and Case 2 negative.

Among the failures there were 13 deaths; 2 from shock and 11 from senility and erysipelas. Most of these patients were in a desperate condition physically at the time of operation, thus rendering an operative procedure precarious to say the least.⁵ It is difficult to see how the operation of reversal of the circulation could have contributed any more to the cause of death than any other operative procedure that may have been performed on the limbs of the same individuals. Just why there should have been so many cases of erysipelas is a mystery to me, unless it can be laid to the door of operative technic. It has not occurred in my own series of cases.⁶

In the remaining 22 cases the course of disease was uninfluenced by the reversal, although there was a temporary improvement in several cases. Amputation was performed in each instance.

The operation was done twice in the upper extremity, once for thrombus and threatened gangrene, once for threatened gangrene, both times successfully. The remaining cases were in the leg, the operation being done four times for Raynaud's disease, once for sarcoma of the popliteal space, which necessitated removal of about four inches of the popliteal artery and vein, once for aneurism, once for rupture of the popliteal artery and vein, once for gun-shot wound, and the remainder for real or threatened gangrene.

As to methods of operation, the end-to-end suture of Carrel and Stich was done 23 times with 8 successes, lateral anastomosis 12 times with 4 successes, invagination (end of artery into end of vein) twice with 1 success, and the intuba-

⁵In a personal communication to Coenen, Gottstein said that he had done three cases of reversal, with death in each case.

⁶It is interesting to note that in the last 16 cases there have been no deaths, and that of these cases 9 were successful, 5 unsuccessful, and 1 doubtful.

tion of Wieting (end of artery into side of vein) 9 times with 2 successes. The method was not stated twice and one of these operations was successful.

I believe, and Wieting also seems to lean toward a similar belief, that in the future the method of choice for reversal will be a lateral antastomosis, and in conjunction with Stone⁷ have advocated a method whereby the artery and vein are incised transversely through one-third of their diameter and then sutured. Following the suture and before turning on the blood stream, the vein is tied off proximal to the site of anastomosis to prevent back flow to the heart. The flow through the artery is not interfered with whatsoever, the only thing that happens being an added arterial channel through the vein. In this way the artery will continue to carry nourishment as far as it is patent, while the vein will supposedly carry it to the foot or hand. Should a thrombus occur at the site of anastomosis, it will form in the side of the artery (as we have proved experimentally) and the limb will be no worse off than before. On the other hand, in the event of success, the limb will have an abundant supply of blood. I have so far done this operation once clinically (Case 49), and have been very much gratified at its success. Wieting did a somewhat similar operation in Cases 38, 40, and 42, the first and last being successful.

Just how far down the vein the blood will go is a question that can be decided only by clinical cases. That the arterial pressure will force the blood beyond the valves of the femoral vein in a dog I have demonstrated experimentally, as well as Carrel, and I am firmly convinced that a similar phenomenon takes place in the human. To say that Wiewicorowski was unable to inject the veins of a cadaver from above and that, therefore, a reversal of the circulation in a limb is impossible, shows a lack of understanding of conditions as they are in the living.⁸ The constant pounding of the arterial blood

⁷ ANNALS OF SURGERY, October, 1911.

⁸ Coenen and Wiewicorowski have only done one case in the human and that was unsuccessful.

against the valves of the vein gradually wears them down and forces them to give in the dog; why cannot a similar condition take place in the human? I believe it does, just as the constant pounding of the surf wears down the hardest rock, just as the fearful pounding of a thoracic aneurism at times slowly but surely wears away a man's vertebræ.

But as Wieting says, success is the best of all refutations, and as time goes on the successful cases will increase in number. In the past, the cases have not been selected with sufficient care. It is obviously impossible to bring the dead back to life, yet that has all but been attempted. Around every fulminating gangrenous area the neighboring vessels, veins as well as arteries, are partially or wholly thrombosed. If this condition prevails only to a slight degree, well and good, but if it is extensive, if all the toes, or half the foot, or all the foot is involved, to do a reversal is only inviting failure. The cases must be gotten before the gangrene arises. If this is impossible, it is best to let the process subside or localize and then do a reversal in the hope of preventing further encroachments. The age of the patient has little or nothing to do with the question, but rather the age and condition of his vessels.

Another most important factor to be considered is the skill and experience of the operator. It is my belief that the frequent failure following reversal of the circulation in the past has been due not so much to the failure of the valves of the veins to give way as to a thrombus at the site of anastomosis—in other words, to a faulty technic in the suture. Animal experimentation and lots of it is an absolute necessity to the surgeon who wishes to do clinical work in the field of vascular surgery. Too much stress cannot be laid upon this point, and a more general observance of it can but bring better results.

It is indeed a great pleasure to be able to acknowledge my indebtedness to Dr. W. S. Halsted, Dr. J. M. T. Finney, Dr. J. C. Bloodgood, and Dr. Harvey Cushing. Without their aid and kindly sympathy neither the experimental nor the clinical work which forms the basis of this paper could have been accomplished.

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