

ARTERIAL HOMOGRAFTS

III. Use of Preserved Grafts in the Treatment of Neoplastic Disease Involving Peripheral Arteries

HENRY SWAN, M.D.

AND

H. MASON MORFIT, M.D.

DENVER

THE USE of homogenous arterial grafts in the aorta has been demonstrated to be practical both experimentally and clinically for periods up to at least two years.¹ Previous communications from our laboratory have described the fate of experimental preserved aortic grafts and the clinical use of this technique in the resection of a thoracic aortic aneurysm.² Experimentally, smaller arterial transplants were recently investigated and found to function effectively as conduits for blood.³ The method, therefore, appears to offer the possibility of enlarging the scope of operative procedures for lesions involving peripheral arteries.

Several such possibilities come at once to mind. In localized inflammatory, degenerative or traumatic conditions of important peripheral arteries, the ability to perform resection followed by insertion of a replacement for the diseased segment should solve many of the current difficulties in the treatment of arterial aneurysm, arteriovenous fistula and acute traumatic injury of crucial arteries. The potentiality of this technique in military medicine might thus prove to be extensive.

In addition, arteries may become involved by neoplastic disease. In certain circumstances the limiting factor precluding adequate resection of a malignant growth is the discovery that it surrounds or invades an artery which cannot be sacrificed without extreme risk to the organ which it nourishes or even to the life

Aided in part by United States Public Health Service Grant H-241.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

From the Bonfils Tumor Clinic and the Department of Surgery, University of Colorado School of Medicine.

1. Peirce, E. C., II; Rheinlander, H. F.; Moritz, A. R.; Gross, R. E., and Merrill, K., Jr.: Transplantation of Aortic Segments Fixed in 4 Per Cent Neutral Formalin: Report of Experiments in Dogs, *Am. J. Surg.* **78**:314-323 (Sept.) 1949. Gross, R. E.; Bill, A. H., Jr., and Peirce, E. C., II: Methods for Preservation and Transplantation of Arterial Grafts: Observations on Arterial Grafts in Dogs; Report of Transplantation of Preserved Arterial Grafts in 9 Human Cases, *Surg., Gynec. & Obst.* **88**:689-701 (June) 1949.

2. (a) Swan, H.; Robertson, H. T., and Johnson, M. E.: Arterial Homografts: I. The Fate of Preserved Aortic Grafts in the Dog, *Surg., Gynec. & Obst.* **90**:568-579 (May) 1950. (b) Swan, H.; Maaske, C.; Johnson, M., and Grover, R.: Arterial Homografts: II. Resection of Thoracic Aortic Aneurysm Using a Stored Human Arterial Transplant, *Arch. Surg.* **61**:732-737 (Oct.) 1950.

3. Miller, H. H.; Callow, A. D., and Welch, C. S.: The Fate of the Arterial Graft in Small Arteries; abstracted, *Bull. Am. Coll. Surgeons* **35**:55-56 (Jan.) 1950.

of the patient. The ability to extend the radical attack on the neoplasm by including resection of the involved arterial segment, followed by a suitable replacement to restore the vital blood flow, should enable the surgeon in selected circumstances to execute wide removal of the tumor and to diminish significantly the mutilating aftermath of such resection. The present paper reports on three patients in whom this concept was given clinical trial.

The use of this technique presupposes the availability of arterial grafts, and thus a stored supply or "artery bank" becomes essential. The problems involving such a bank have not yet been entirely solved. These problems are under current investigation in several laboratories. The grafts used in two of our patients were arterial segments stored in the blood bank refrigerator at 4 C. in a Mason jar containing Ringer's solution to which had been added 10 per cent by volume of human plasma together with small amounts of penicillin and streptomycin. However, arteries are not always easy to obtain. At the present time, we feel that the following criteria should be observed in selecting a homogenous artery as a graft: 1. The artery should be removed from a person between 10 and 35-years of age. 2. The donor must not have died from any disease whose transmission to the recipient is a possibility.* 3. The artery should be removed within four hours of death. 4. Use of a graft stored in excess of a three month period is not recommended.

At the time of admission of our first patient, no suitable vessel was on hand. Operation was delayed for five weeks in an attempt to secure one, but a suitable opportunity did not occur within that time despite a search made in the clinical material from four large hospitals in a community of 500,000 persons. Since further delay seemed unwise, an alternate method for bridging the arterial gap, an autogenous vein graft, was necessarily employed. In the second case, a delay of four weeks was likewise encountered.

REPORT OF CASES

CASE 1.—Mr. M., a 75 year old white retired truck driver, entered the surgical service at Colorado General Hospital on March 7, 1949, complaining of a firm tender lump in his right upper thigh. When first noticed 18 months previously, the mass was about the size of a marble. It had been steadily growing and during the two months prior to the patient's admission had occasioned him considerable pain and discomfort. For the past seven years, the patient had been under treatment in the medical outpatient department for hypertensive arteriosclerotic heart disease with auricular fibrillation and had remained fairly well with administration of digitalis. In addition, two years previously dietary management of mild diabetes had been instituted. When he was first seen in the surgical tumor clinic four days before his admission, the mass in the upper anterior aspect of the right thigh was noted to be approximately 7 cm. in diameter and apparently arose from the soft tissues. It was fixed to the underlying fascia but not to bone. An aspiration biopsy was performed and admission to the hospital arranged. The biopsy diagnosis was "soft part sarcoma, type undetermined." Study in the hospital revealed the blood pressure to be 160/100, the heart to be enlarged and fibrillating and the urine to contain sugar occasionally. The pulses in the right lower extremity distal to the tumor were weaker than those in the left. No evidence of tumor metastasis could be found.

It seemed clear, because of the location of the tumor and the diminished pulses distally, that excision of this tumor would surely require resection of the femoral artery. The possibility of the extremity surviving femoral artery ligation in an arteriosclerotic 75 year old man with auricular fibrillation seemed remote. Accordingly, the decision was made to attempt an arterial transplant. Since no suitable vessel was then available in our "artery bank," the patient was discharged, to be called in when a vessel was obtained. In spite of the alert cooperation of four

4. For example, overwhelming septic disease, virus disease or leukemia.

large general hospitals in the area, no suitable opportunity for obtaining a vessel occurred during the next four weeks. Since further delay seemed unwarranted, the patient was readmitted for operation, and it was planned to use a vein graft if arterial resection proved necessary (fig. 1).

On April 18, 1949, a block dissection with wide skin excision was performed, including all muscular and fascial structures surrounding the firm tumor. The superficial femoral artery was found to enter the tumor above and to emerge with its lumen considerably narrowed below. The deep femoral vessels were not involved in the tumor. Resection, therefore, included a segment of superficial femoral artery about 2 inches (5 cm.) in length together with the accompanying vein. With the use of a segment of the deep femoral vein which had thickened walls containing sclerotic plaques, the gap in the artery was bridged with suture technique.⁵ On release of the temporary arterial clamps, the graft was seen to bulge somewhat, but there was

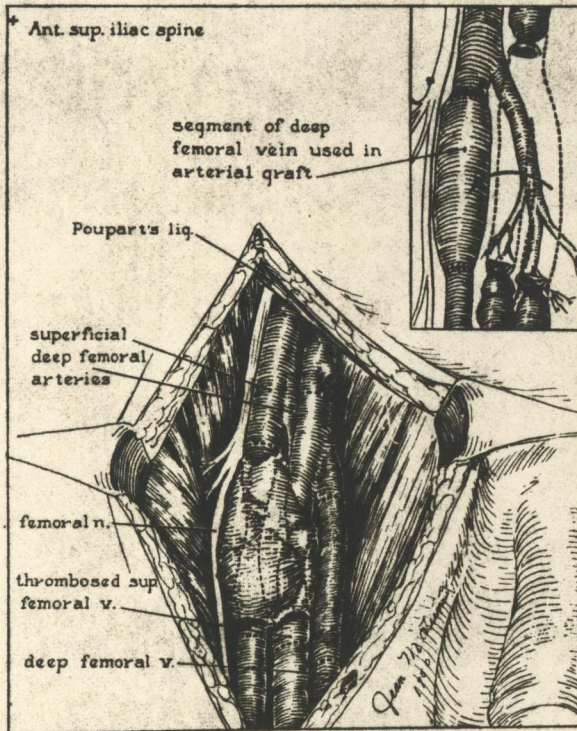


Fig. 1.—Semi-diagrammatic sketch of the operative findings and vascular reconstruction in case 1.

no palpable thrill and blood flow appeared excellent. When the wound was closed, there appeared to be some tension on the suture line because of the wide skin excision.

Postoperatively, the patient did well; the foot remained warm although arterial pulsations were barely palpable and were definitely less on the involved side than on the opposite side. The patient's diabetes remained under control. Moderate separation of the wound occurred which prolonged hospitalization during secondary skin grafting to obtain closure. In retrospect, the patient should have been placed in a hip spica postoperatively to assist wound healing, as is our custom with all patients in whom radical dissection of the groin has been carried out.

Since the procedure involved the resection of both the superficial and the deep femoral veins together with the greater saphenous vein, it is not surprising that there was considerable edema of the extremity postoperatively. However, with the aid of an elastic bandage this swelling

5. Ordinarily we would prefer to avoid the use of any graft in which atheromatous disease is present. The absence of any such disease is one advantage of the homogenous arterial transplant.

was kept from being excessive, and the leg remained comfortable and functional. The patient was discharged from the hospital in good condition, and when he was seen in October 1950, one and one-half years after operation, the right femoral pulse and the right anterior tibial pulse were palpable. The patient is leading an active life and having minimal edema with the use of the elastic bandage. There has been no evidence of local recurrence of the tumor or of distant metastases. The pathologic diagnosis was neurogenic sarcoma.

CASE 2.—Mrs. M. H., a 33 year old housewife, was seen in consultation on Sept. 25, 1949, at the Fitzsimons General Hospital. Seven years previously a small tumor was noted in the region of the right femoral triangle. During the intervening years, three operative attempts at removal of the tumor had been made, the last one about two years previously. The pathologic diagnosis had been established as neurosarcoma. At the time of this admission, the tumor had recurred under the upper end of the incisional scar about 2 inches (5 cm.) below Poupart's

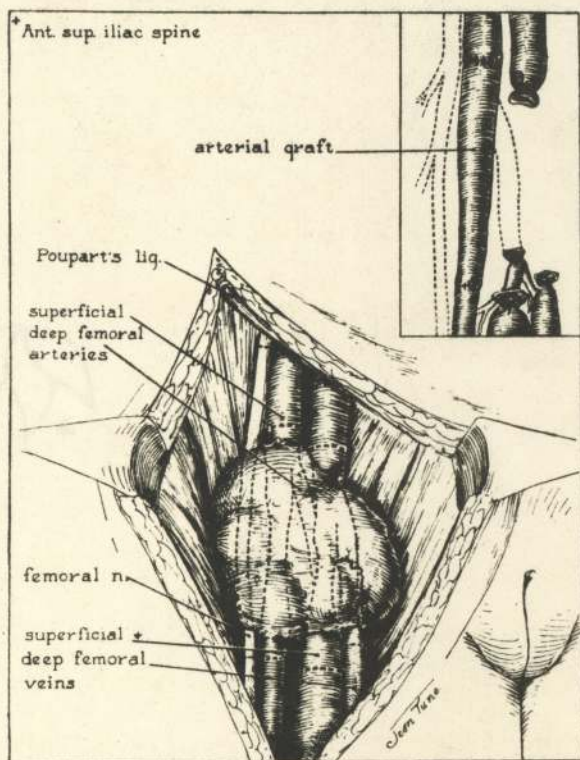


Fig. 2.—Semidiagrammatic sketch of the operative findings and vascular reconstruction in case 2.

ligament and measured approximately 3 by 4 cm. in size. It was not attached to bone and was movable beneath the skin, and it appeared to lie directly over the course of the femoral vessels. Once again at this time we had no vessel in our "artery bank" which was not outdated, and a period of four weeks elapsed before a suitable vessel was obtained for transplantation, in spite of the fact that the aid of four large army general hospitals as well as our own local hospitals was enlisted. Three such vessels were then obtained almost simultaneously, and accordingly operation was undertaken on Oct. 26, 1949 (fig. 2).

The tumor was excised en bloc with a liberal margin of tissue on all sides. It was found that the tumor enclosed the common femoral artery and vein at a point just above the bifurcation. Its origin appeared to be from the femoral nerve. Accordingly, a long segment of femoral nerve together with sections of femoral artery and vein including the bifurcation were removed with the tumor. The deep femoral vessels were ligated. To bridge the arterial defect a segment of brachial artery obtained at operation from a young man having a disarticulation of the shoulder

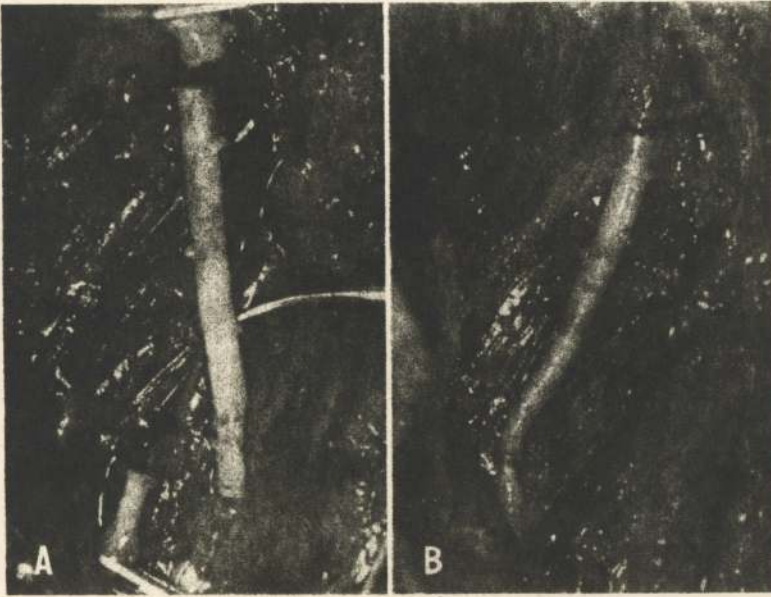


Fig. 3.—*A*, the arterial graft before insertion in case 2. *B*, after insertion of the graft, blood flow is resumed. Note the even contour of the reconstructed vessel.



Fig. 4.—An arteriogram made one year after operation outlines the apparently normal lumen of the reconstructed femoral artery in case 2.

seven days before was utilized. The graft was 8 cm. in length and matched rather well in size the patient's common femoral artery at the upper end and superficial femoral artery at the lower end. After removal of the temporary clamps, the blood flow seemed satisfactory (fig. 3). Muscles were approximated over the vessels, and the skin was closed primarily. On the venous side, of course, the operation included ligation of the superficial and deep femoral and the saphenous veins. The patient was placed in a hip spica to facilitate primary healing.

Postoperatively, her course was uneventful. There was moderate swelling of the extremity, which remained warm with palpable pulsations distally. The edema has been reasonably controlled with the use of an elastic bandage. The muscular disability caused by resection of the femoral nerve has been largely overcome by the strong will of the patient to reeducate herself in the use of her leg. At the present time, one year after operation, she leads a normal life which



Fig. 5.—A photograph of the lower extremities shows the moderate swelling but good function of the right leg six months after operation in case 2.

includes going to dances with her husband. The artery appears normal on arteriography. There is no evidence of recurrence of the tumor, which proved to be neurogenic sarcoma (fig. 5).

CASE 3.—W. K., a 79 year old man, was admitted to the Colorado General Hospital on Jan. 20, 1950, with a tumor in the right femoral region which had been growing rapidly in the past year and a half. About ten years before his admission, he noticed a small nodule in this area about the size of a marble. The mass remained relatively unchanged in size until about one and one-half years previously, when it began to enlarge slowly until it approximated the size of a hen's egg. Three months before his admission, partial excision was carried out in another hospital. The pathologic report was "anaplastic sarcoma." After the partial excision the tumor began to grow rapidly, and at the time of the patient's admission it was a somewhat lobulated, purplish red, highly vascular mass over the femoral triangle on the right side. The leg was edematous, and there were diminished pulsations in the right peripheral arteries as compared with those in the opposite leg. The tumor invaded the overlying skin and was adherent

to underlying fascial tissues but was not fixed to bone. On the day of admission a needle biopsy was performed, which confirmed the diagnosis of sarcoma. The chest roentgenogram was normal, and no other evidence of metastasis was present. The patient had advanced arteriosclerotic heart disease with compensated heart failure when given digitalis therapy.

On Jan. 30, 1950, resection was undertaken (fig. 6). The tumor appeared to arise just beneath and lateral to the femoral vessels but did not involve the femoral nerve. The common femoral vein traversed the tumor and was thrombosed; the lateral wall of the femoral artery at the bifurcation was firmly attached to the tumor. The block resection included parts of all structures adjacent to the tumor, the external oblique fascia, Poupart's ligament and ileopsoas and pectineus fascia, as well as the right testicle and the spermatic cord. The portion of artery resected was about 2 inches (5 cm.) in length and included the bifurcation. An arterial homograft 5 cm. in length obtained from a 30 year old man killed in a cave-in 44 days previously was used to bridge

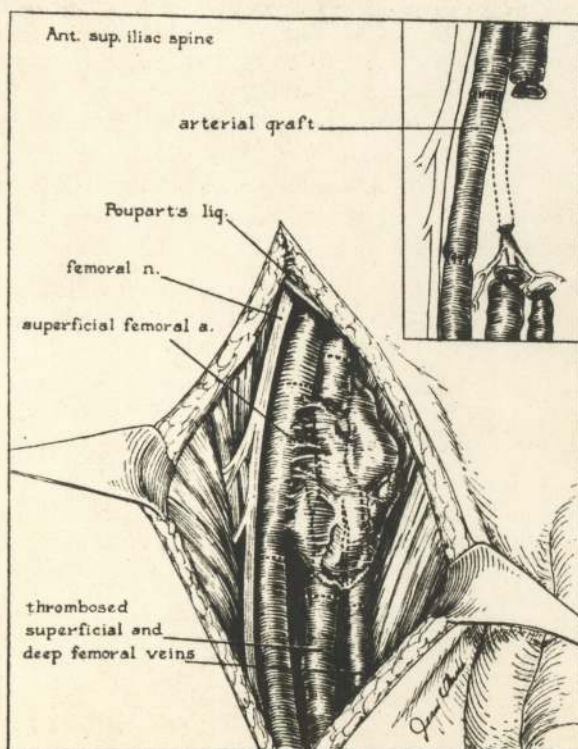


Fig. 6.—Semidiagrammatic sketch of the operative findings and vascular reconstruction in case 3.

the gap. After the suture anastomosis, the blood flow appeared adequate and palpation of the dorsalis pedis revealed a strong pulsation. Fifty milligrams of heparin was injected into the artery above the graft. Closure was extremely difficult because of the wide resection. An attempt was made to cover the graft by pulling muscle flaps over the top, and this appeared to have succeeded. The skin defect was so extensive that split-thickness grafts were used to cover the wound. A hip spica was applied, and the patient returned to the ward, having tolerated the procedure well.

During the next week his course was uneventful, and the extremity was warm with good arterial pulsations and minimal swelling. However, six days after operation, at the time of the first change of dressing, a most alarming situation was found. The muscle bellies which had been pulled across to bury the graft had separated, and in the center of the wound a small area of skin graft had melted away, exposing about 1 cm. of the upper segment of the arterial graft which could be seen pulsating well but which was completely uncovered. The following morning, therefore, a sliding flap from the scrotum was pulled across the wound in order to cover this

defect. That evening the graft ruptured at the site where it had been exposed, and severe exsanguinating arterial hemorrhage took place. With multiple transfusions the circulating blood volume was restored while temporary clamps were applied to the femoral artery to control hemorrhage. The patient was rushed to the operating room, where an attempt was made to repair the graft by suture reinforced with gelfoam® (absorbable gelatin sponge). Hemorrhage was controlled, and the wound was again closed, with the use of a pedicle skin flap together with muscle flaps swung from the lateral portion of the leg. However, 12 hours later he suffered from another acute exsanguinating arterial hemorrhage, which was again controlled by temporary compression of the vessels. His general condition was restored by vigorous transfusions. At this point, it became evident that we were jeopardizing the patient's life by further attempts to save his leg. Accordingly, defeat was admitted, the patient was taken to the operating room, and the common femoral artery was ligated. Since the gangrene which developed ended just below the knee, a supracondylar amputation was performed three days later. After this, the patient made an uneventful recovery and at the present time is leading an active life with the aid of crutches, which he has learned to use with extraordinary facility for a man of 80 years with arteriosclerotic heart disease. There is no evidence of local or metastatic recurrence of the tumor, which was found to be a rhabdomyosarcoma.

COMMENT

We feel that the success of an arterial homograft depends primarily on technical factors relating to its insertion, although it is probable that a graft which has not been stored in excess of 90 days is preferable to one with a greater duration of storage.^{2a} Meticulous attention to asepsis, delicacy in handling of the tissues, avoidance of desiccation and careful suture technique, factors common to all vascular anastomoses, must of course be carefully observed. When grafting is involved, additional factors must be considered. The exact matching of the graft to the recipient vessel at both ends of the defect is of primary importance. Any sudden change in the caliber of the vessel at a suture line has been demonstrated experimentally to be a strong initiating factor for thrombosis and failure. Moreover, as demonstrated in the third patient, the closure of the wound must be so devised that the grafted artery shall be totally and completely covered with viable soft tissue. We feel sure that this is the technical factor which resulted in the breakdown of the graft and the failure of the procedure in this patient. Extreme care, therefore, must always be taken to insure adequate closure.

We believe that the possibility of adequately treating soft part sarcomas without routinely resorting to amputations, hemipelvectomies and other procedures productive of lasting deformity deserves a greater place in the plan of treatment. For many years it was passed down as an axiom to younger surgeons that when it was found necessary to perform an amputation for malignant bone tumor the amputation must be performed at a level at least as far proximal as the next major joint, for example, amputation for an osteogenic sarcoma located in the tibia should be done at or above the knee joint and amputation for osteogenic sarcoma at the lower end of the femur should involve hip joint disarticulation. Over the ensuing years there have been enough cases in which this axiom has been ignored to enable us to state with some surety that the value of this original concept has been largely disproved. It has now become the practice to carry out high thigh amputations for osteogenic sarcoma located at the lower end of the femur. If this departure from the old axiom of proximal joint amputation had proved wrong, clinical evidence would consist of recurrences in the soft tissues or the bone of the stump. Coley⁶ has shown that

6. Coley, B.: *Neoplasm of Bone*, New York, Paul B. Hoeber, Inc., 1949.

such stump recurrences do not result after high thigh amputations except in the rarest of instances. Most deaths from osteogenic sarcoma result from distant metastases, and local recurrences in the stump are not a problem.

It is our belief that in selected cases, soft part sarcomas likewise can be adequately resected without necessarily resorting to amputations. It is certainly true that a review of the histories of patients with neurogenic sarcoma, fibrosarcoma, synovioma, and similar tumors will show that local recurrences following limited surgical removal have been frequent. In one case presented here today, the patient had been previously operated on three separate times. We have a feeling that it is the fear of damaging or sacrificing vital nerves or vascular structures which has prevented adequate removal in the initial operative attack in many such cases.

On previous occasions we have noted the practicality of sacrificing such structures as the main veins in an extremity and, on some occasions, a major nerve trunk and still leaving the patient with the functional result that far supersedes that which can be obtained through the use of prostheses following amputation. Specifically, we have found that when the femoral nerve is totally sacrificed a useful limb is still possible through the innervation of remaining muscle groups carried by the obturator and sciatic nerves. Similarly, we have sacrificed the sciatic nerve and found the patient able to carry on provided the femoral nerve is preserved.

Up to the present time, despite recognition of the above facts, our ability to circumvent the tumor in some cases has been blocked by the ill effects resulting from interruption of a main arterial vessel. That is, although it may have been possible to circumvent the tumor adequately by sacrificing major muscle groups, nerves and veins, nevertheless, if the main artery was sacrificed, gangrene was such a routine complication that amputation was usually resorted to as the initial procedure, despite the fact that adequate removal of the tumor could be accomplished without sacrificing remaining major neuromuscular groups which would leave the patient with a functional result better than any that could be obtained by the usual prosthetic restoration.

We should not like our remarks construed as a plea for limited surgical attack on malignant soft part tumors. Nevertheless, we feel that in selected cases it is possible to carry out radical excision of these growths and leave behind weight-bearing and neuromuscular components whose additive value supersedes that of ordinary prosthetic restoration. These cases demonstrate that the barrier to removing such sarcomas, even though they may be invading a major arterial vessel, can be eliminated.

SUMMARY

Three patients have been presented in whom radical local excision of sarcoma in the right femoral area of necessity included significant portions of the femoral artery. The gap in the arteries thus created was repaired by the insertion of arterial homografts in two patients and of a free autogenous venous graft in the third. Good functional survival of the limb was obtained in two patients, but failure was experienced in the third because of inadequate wound closure.

The use of a preserved arterial homograft for bridging large defects in main peripheral arteries seems to offer considerable promise as an adjunctive technique in the adequate resection of certain peripheral malignant neoplasms.