PERIPHERAL ARTERIAL RECONSTRUCTION

By DAVID A. MACFARLANE, F.R.C.S.
Surgical Registrar, St. James's Hospital, London

Historical

A brief review of the development of arterial reconstruction may clarify the problems of the various procedures used today. The ancients realized the importance of rejoining a divided artery and used goose quills and chicken bones.

In an attempt to maintain blood flow through a repaired channel Hallowell in 1759 closed a small wound of the brachial by placing a pin through its margins, elevating and ligaturing the lacerated areas. By 1903 Hopner had collected 30 successful cases of lateral suture. The first successful case recorded in man of arterial anastomosis was performed by J. B. Murphy in 1897 after careful experiments; he resected a traumatic arterio-venous fistula and performed an end-to-end anastomosis. At the beginning of this century much pioneer work on this subject was done by Carrel and his associates. They were the first to produce successes with venous and arterial grafts in animals; they preserved arterial homografts, and they described the 'triangulated method' of arterial suture used in anastomosis today. Lexer was the first to apply Carrel's teaching to man and in 1907, after excising a traumatic axillary aneurysm, successfully sutured a segment of saphenous vein into the arterial defect.

Sporadic attempts at using a prosthesis were made from time to time. In 1894 Robert Abbe, and later Carrel, used glass tubes and this was followed in 1900 by Payr using a magnesium tube which had to be abandoned because of tissue necrosis. Tuffier's silver tubes had a vogue for a time in the first World War, but, as with the others, clotting in the tubes was the rule. Interest flagged until the introduction of heparin, and Murray and Janes (1940) then had some success using glass tubes in dogs. The impetus of a second World War, adequate blood banks and better facilities for the transport of wounded resulted in Blakemore, Lord and Stefko (1942) obtaining successes with the inert metal vitallium. Using it first as a long tube, they later used two cuffs and lined them with a free vein graft. This was popular for some years, but has now been

replaced by the free graft using direct suture. Plastics (Donovan, 1949; Le Veen, 1949) were next tried, but have not been generally acceptable.

The storage of arterial homografts presented an obstacle to their use, but Gross, Bill and Peirce (1949) and Hufnagel and Eastcott (1950) have described satisfactory methods for banking arteries. The most recent method is the preservation of the graft by freeze-drying (Eastcott, 1953). This advance enables the artery to be kept at room temperatures.

Disobliteration, which has a more limited field, was first recorded by Sévérineau in 1894 when using a gum-elastic catheter he broke up and detached a thrombus from the femoral artery at the time of amputation and enabled it to be carried out at a lower level. The method was again used with more success in 1947 by J. C. dos Santos and improved by Reboul (1950).

Clinical Considerations

As long ago as 1903 Matas stated that restoration of the circulation through the damaged artery is the ideal to be aimed at. The experimental work of Miller and Welch (1949) showed disability and contracture in those legs which survived a 12-hour ischaemia. De Bakey and Anspacker (1949) find that clinical experience sets an arbitrary six to eight hours' limit in man, and Herrmann (1949) states that, despite ligation of an artery, the viability of the tissues may be maintained, but the circulation is insufficient to permit muscles functioning normally under stress and claudication develops.

The clinical effects, both general and local, of sudden division of an artery do not require stressing. Such effects will vary according to the site of the division and the state of the collaterals. Linton (1949) drew attention to the fact that the flow from the distal cut end of the divided artery will indicate the adequacy of such collateral circulation, a brisk flow indicating an adequate blood supply, and the limb exhibiting this will not develop gangrene. Mustard (1946) states that, if active movements of the digits are no longer present and the digital skin cold and in-

sensitive and of an unnatural colour, then the limb is dangerously ischaemic. In the chronic obliteration the effects are less dramatic and intermittent claudication and more gradual colour changes in the extremity occurring over periods of weeks and even months bring the patient to hospital in a more leisurely manner, whilst in the case of aneurysms there may be a rapid increase in their size. Clinical examination of the patient as regards the general condition and the local lesion is important with particular reference to the nutritional state and the level of the block, as estimated clinically by oscillometry and arteriography. The best results are obtained in those cases with a localized block where the remainder of the artery is fairly normal (Kunlin, 1951). Those exhibiting generalized arterio-sclerosis or with an extensive block are deemed unsuitable for restorative surgery. An arteriogram is shown where grafting would be suitable.

Treatment

In discussing the cases suitable for peripheral arterial reconstruction, one must consider the acutely divided artery with loss of substance, and the more chronic form of obliteration. First-aid methods directed to preservation of the patient's life by arresting the haemorrhage and early transport to hospital are the first essentials. Lord (1950) states that 'the time lag between injury and definitive surgery is the most critical factor in leading to failure of restorative arterial surgery.' The adequate treatment of haemorrhagic shock is important in severe cases, if necessary using intra-arterial transfusions (Bingham, 1952) and the patient prepared for operation. In the chronic obliterations the patient's general condition is improved as much as possible and, when convenient, operation by one of the following methods may be undertaken.

(1) *Disobliterative Endarterectomy*

This method of reconstruction is employed only for chronic obliterative arteritis and Reboul (1950) restricts the operation to cases of arteritis of non-acute form which are not compensated by the collateral circulation. He considers it should not be performed in cases of active or progressive lesions, especially if present in several arteries.

Reboul performs arteriography beforehand and the coagulation time is done every ten minutes throughout the operation to maintain it at a minimum of 15 minutes. With the patient in position a longitudinal incision of sufficient length is made over the artery and the latter exposed. A small strip 2 to 5 mm. wide over the superficial part of the artery is cleared of fat, but the adven-

Femoral arteriogram showing a lesion anatomically suitable for reconstructive surgery.

titia is preserved. Clamps are placed above and below to control the flow through the artery. A longitudinal incision is made in the artery and a plain of cleavage sought, which is usually between the external elastic lamina and the media. The inner surface of the external elastic lamina is carefully examined and endarterectomy is only proceeded with if this layer is viable and normal. The internal elastic lamina and necrotic media are adherent to the thrombus and removed with it. On extracting it from the collaterals a Carrel clamp is placed on each. A two-layer continuous suture is performed and a drain placed down to, but not touching, the artery.

Post-operatively the blood loss is corrected by transfusion, and heparin is given for three to four days to keep the clotting time at 15 minutes.

Reboul has shown that the inner surface of the external elastic lamina becomes rapidly lined with leucocytes and that, from the upper and lower ends of the main artery, the intima grows again replacing the leucocytes and the lining is complete within a month.

Because of the relatively high proportion of failures due to clotting in the previously thrombosed vessel—Reboul had only 44 successes out of 93 cases, and most authors (Fontaine and dos Santos, 1952) put it at a failure rate of 50 per cent.—the operation is now mainly reserved for a localized block in the main trunks of the aorta where there is a quick stream, or as an adjunct to grafting in certain cases (Eastcott, 1953).

(2) *Venous Graft*

This type of graft is suitable for peripheral arterial reconstruction, whether in the acute injury or in the chronic obliterative type or localized aneurysm of the peripheries. It is a convenient form of graft, as any desired length may be obtained from the patient; the internal saphenous vein is most often used and can be spared without ill-effects. It is an easily obtainable form of graft in both civilian life and in times of war, requiring no special technique for obtaining and storing grafts as an arterial bank, and has been used successfully in the Korean war. In cases of chronic obliterative arteritis Kunlin (1951) claims 10 successes in 17 grafts. Fontaine and dos Santos (1952) in treating chronic arterial obliteration have had 72.5 per cent. clinically satisfactory results in 40 cases. They state that the risk of thrombosis in the graft is greatest during the first year. The coagulation and prothrombin time are measured before operation and in the non-acute type arteriography performed. Histologically, Carrel found that in the transplanted grafts there was intimal thickening and an increase in the connective tissue in the media and adventitia; there was also a reduction in the number of elastic fibres. He assumed that the histological alterations which occurred, that is of fibrous re-enforcement, resulted from the arterial pressure exerted upon the transplant. The venous graft, in other words, took on the appearance of an artery. Johnson, Kirby and others (1949) did not find, up to 14 months, any evidence of aneurysm formation, although dilatation did occur in some of the longer grafts, but aneurysm formation does not appear to be a danger in these 'arterified grafts.' Lowenberg and Shumacker, Jun. (1949), in their experimental studies were able to demonstrate that the repaired artery will withstand without leaking pressures higher than the systolic blood pressure even within a few hours of repair. They also conclude that in the young the circumference of

FIG. 1.—Femoral artery and internal saphenous vein exposed.

the line of anastomosis and that of the unsutured wall of the artery increase comparably.

The technique may be briefly stated with reference to the diagrams. The limb is prepared and the incision made. The internal saphenous vein and the occluded artery are exposed and a longer length of the former than would seem necessary for grafting is isolated (Fig. 1). This permits retraction of the graft. The occluded segment of artery is next resected after clamps have been applied and after ligating the tributaries the distal end of the saphenous vein is joined to the proximal end of the artery (Fig. 2). Finally the distal end is sutured as shown in Fig. 3. On releasing the clamps, gentle gauze pressure controls any oozing. Where anti-coagulants are used, the skin should be left unsutured at the time of operation and the method of delayed primary

FIG. 2.—Anastomosis of proximal femoral artery to distal part of internal saphenous vein.

suture on the fourth to fifth day employed (Rob, 1952). Kunlin (1951) describes a method of anastomosis in which the venous graft is laid in a separate tunnel so that it may obtain more nourishment from the surrounding tissues; he performs a side-to-side anastomosis. The added technical difficulties and the good results of end-to-end anastomosis by other workers do not indicate that it has any great advantage.

(3) Arterial Graft

This method of grafting is convenient and satisfactory where the facilities of an arterial bank are at hand. Eastcott and Hufnagel (1950, 1952) have shown histologically that in the graft there is a tapering wedge of endothelioid cells sloping downwards from the anastomosis to the middle of the graft where there is a laminar clot covered by flattened cells which resemble endothelium.

FIG. 3.—Completed anastomosis—graft in position.

The media is thinner and less cellular than normal; there is fibroblastic invasion without persistence of donor cells, but there is good preservation of elastic tissue. In the adventitia the fibroblasts and collagen are well marked; there is a perivascular response further out in the adventitia and foreign body reaction at the suture lines with lymphocytes in the outer layers. In performing the anastomosis the adventitia is removed over the ends of both graft and artery and the graft itself is cut short so that the second and proximal anastomosis is performed under tension. In the special 'arterial centres' this would appear to be the method of choice.

Adjuncts

Adequate supplies of the correct group of blood are essential for a successful outcome; the blood pressure should be restored as soon as possible and a normal or near-normal pressure maintained.

If the pressure falls then the pressure power of the blood flowing through the anastomosis will be less with a slower stream and greater tendency to coagulate.

The use of substances such as heparin, dicoumarol and more recently of tromexan and dindevan in the treatment of acute arterial injuries has not been entirely settled; in the chronic case it is customarily given. Shumacker, Abramson and Lampert (1947) advocate the use of anti-coagulants, but stress the importance of adequate haemostasis before the wound is closed and suggest that fibrin foam is helpful in controlling capillary bleeding without interfering with the anastomosis. They consider that the possible dangers are minimal if haematoma formation is recognized promptly and treated if necessary by surgery, the cessation of anti-coagulant therapy and by the use of reversing agents. Herrmann (1947) is also in favour of using anti-coagulants and makes the suggestion that to determine the mean clotting time it should be estimated two hours after the material is injected into the vein. In war-time the dangers of anti-coagulants are greater where supervision may not be so easy, and in Korea the anastomoses have been performed without anti-coagulants. Eastcott (1953) considers that heparin need not be used in a patient with normal arteries for arterial grafts, but in most cases he uses it to maintain a clotting time of 12 to 15 minutes and continues it until the pulses return in the foot. It would appear that anti-coagulants are indicated in most cases of limb arterial anastomosis where the divided parts are of small calibre.

Sympathectomy is not necessary as an adjunct to arterial reconstruction in either the acute or chronic obliteration (Medical Research Council, 1944; Mason-Brown, 1948), although in the former a paravertebral block using a long-acting anaesthetic or 6 per cent. phenol may be life saving to a limb (Maybury, 1952).

Post-Operative Care

On returning the patient to the ward after operation certain conditions are necessary if the limb is to survive. As well as ensuring sufficient sleep and that the blood pressure and haemoglobin level are maintained, the care of the ischaemic limb itself is of the utmost importance and is well described by Mason-Brown (1948).

(1) *Environment*

This must be cool and the limb should be exposed to room temperature without the cover of the bed clothes. An electric fan may be necessary to cool the air.

(2) *Position of the Limb*

This should be slightly dependent, 6 in. below heart level causing an important slight venous congestion. This may be best obtained by raising the head of the bed. If the extremity becomes mottled or cyanosed, elevation above the level of the heart for one to two minutes may be advisable and gentle stroking of the skin from the distal parts proximally will frequently free the superficial capillaries of the static blood (Herrmann). Heat must never be applied to the affected extremity, as it only increases the local metabolism of the tissues without greatly increasing the supply of blood to the particular part.

(3) *Avoidance of Pressure*

Circular bandages cause constriction and the limb should be wrapped in a sterile towel.

(4) *Care of the Skin*

Care should be taken to prevent sores and infections, especially in the webs between the digits.

(5) *Rest*

Muscular activity increases the demand for blood, hence the limb should be kept at rest. This does not preclude gentle active exercises of the small joints two to three times per day or passively one to two times per day where active movements are not feasible.

Conclusion

From the foregoing it will be seen that peripheral arterial reconstruction can be carried out on an increasing number of cases. For the chronic obliterative arteritis, disobliterative end-arteriectomy may be suitable in certain cases. In both the acute injury and in the chronic obliteration, reconstruction may be successfully carried out with either a venous autograft or an arterial homograft. The former is more universally available, but the latter is probably preferable in the arterial centre and certainly for larger arteries such as the aorta. Avoidance of delay in operating in the acute cases, adequate supplies of blood, anti-coagulants and rigid post-operative care all play their part in successful peripheral arterial reconstruction.

Summary

(1) A historical review of blood vessel anastomosis is recounted.

(2) The various types of peripheral arterial reconstruction are indicated, together with their histology, technique and advantages.

(3) The associated adjuncts to arterial reconstruction are discussed with reference to the acute injury and the chronic obliterative lesion.

I should like to express my thanks to Mr. Norman C. Tanner, F.R.C.S., and Mr. Andrew M. Desmond, F.R.C.S., for their kind interest and help in the preparation of this paper, and to Mrs. J. Mace and Miss Mason for the drawings.

BIBLIOGRAPHY

- BINGHAM, D. L. C. (1952), *Lancet*, **II**, 4.
 BLAKEMORE, A. H., LORD, J. W., Jun., and STEFKO, P. L. (1942), *Surgery*, **12**, 488-508.
 CARREL, ALEXIS (1907), *Bull. Johns Hopkins Hosp.*, **18**, 18-28.
 CARREL, ALEXIS (1910), *Ann. Surg.*, **52**, 462.
 DONOVAN, T. J. (1949), *Ibid.*, **130**, 1024-1043.
 dos SANTOS, J. C. (1947), *Mem. Acad. Chir. Paris.*, **73**, 409.
 EASTCOTT, H. N. G. (1953), Hunterian Lecture, Royal Coll. Surg. Eng.
 EASTCOTT, H. N. G., and HUFNAGEL, C. A. (1952), *Lancet*, **I**, 531.
 FONTAINE, R., and dos SANTOS, J. C. (1952), *Proc. Soc. Europ. & Chir. Card.-Vasc.*, **1**, 232-338.
 GROSS, R. E., BILL, A. H., Jun., and PEIRCE, E. C. (1949), *S.G.O.*, **88**, 689.
 HERRMANN, L. G. (1947), *Am. J. Surg.*, **74**, 560.
 HUFNAGEL, C. A., and EASTCOTT, H. N. G. (1950), *Surg. Forum, Amer. Coll. Surg.*, 269.
 JOHNSON, J., KIRBY, C. K., GREIFENSTEIN, F. E., and CASTILLO, A. (1949), *Surgery*, **26**, 945-956.
 KUNLIN, J. (1951), *Rev. Clin. Paris*, **70**, 206.
 LE VEEN, H. H. (1949), *Arch. Surg.*, **58**, 504-510.
 LEXER, E. (1907), *Arch. f. Klin. Chir.*, **83**, 458-477.
 LINTON, R. R. (1949), *New York State J. Med.*, **49**, 2039-2048.
 LORD, J. W., Jun. (1950), *S. Clin. North America*, **30**, 377-386.
 LOWENBERG, R. I., and SHUMACKER, H. B., Jun. (1949), *Arch. Surg.*, **59**, 74-83.
 MASON-BROWN, J. J. (1948), *Brit. J. Surg. War Surgery Suppl.* No. 2, 354.
 MATAS, R. (1903), *Ann. Surg.*, **37**, 161.
 MAYBURY, B. C. (1952), personal communication.
 MED. RESEARCH COUNCIL (1944), *War Memorandum No. 13*.
 MILLER, H. H., and WELCH, C. S. (1949), *Ann. Surg.*, **130**, 428-438.
 MURPHY, J. B. (1897), *Med. Record*, **51**, 73-88.
 MURRAY, G., and JAMES, J. M. (1940), *Brit. med. J.*, **II**, 6-7.
 MUSTARD, W. T. (1946), *Ann. Surg.*, **124**, 46.
 REBOUL, H., and LAUBRY, P. (1950), *Proc. Roy. Soc. Med.*, **43**, 547.
 ROB, C. G. (1953), *Ibid.*, **46**, 123.
 SHUMACKER, H. B., Jun., ABRAMSON, D. I., and LAMPERT, H. H. (1947), *Surgery*, **22**, 950.
 TUFFIER, T. (1915), *Bull. Acad. de Med. Paris*, **74**, 455.

ADRENAL AMYLOIDOSIS AS A CAUSE OF ADDISON'S DISEASE

By S. COPE, M.D., M.R.C.P.

Senior Medical Registrar, David Lewis Northern Hospital, Liverpool

and J. C. WOODROW, M.B., M.R.C.P.

Senior House Officer, Broadgreen Hospital, Liverpool

The first mention of the relationship of adrenal amyloidosis to Addison's disease was by Riesman (1898). Examination of his paper reveals that the patient described was not suffering from Addison's disease, though there was amyloid infiltration of the adrenal glands. A close search shows that a number of the subsequently described cases were based on inadequate evidence. We believe the first acceptable case should be attributed to Schlesinger in 1917.

The most recent review on the subject was that of O'Donnell in 1950 in a paper in which he discusses the changing pathogenesis of Addison's disease. Subsequent to this paper Heller and Camarata (1950) have published a further case.

A patient suffering from generalized amyloidosis and showing definite evidence of Addison's disease was recently under our care.

This patient, a man aged sixty-five, was originally referred to a hospital out-patients' department in May 1951, suffering from cough and loss of weight following an exacerbation of his chronic

bronchitis. At that time he appeared quite ill, and was noted to have a generalized pigmentation, a blood pressure of 110/70 and considerable albuminuria. Apart from the signs of generalized bronchitis, a comment was made that moist sounds were particularly to be heard at the right apex. An X-ray of the chest showed patchy shadowing at the extreme apices, but, despite careful search, no confirmatory evidence of tuberculosis was obtained. A barium meal and follow-through showed no abnormality. Some improvement occurred and the patient was discharged.

We first saw him on March 11, 1952, when he reported that for about three months he had suffered an exacerbation of his cough with the production of considerable quantities of mucopurulent sputum, this following on an upper respiratory infection. He had also noticed swelling of his ankles and feet, frequency of micturition and progressive breathlessness on exertion. There had been a marked feeling of weakness and considerable loss of weight, whilst just prior to