miniature feet, the tiny toes of which continued to be identifiable although reduced to the size of nipples. The reduction in girth and length extended cuff-like as far as the lower third of the forearm, and we are not acquainted with any disease in which arms and forearms as muscular as those of adults are provided with the wrists and hands of a child of 2. The nose and ears had undergone less marked changes in shape. The affected extremities showed no vascular disturbances; the pulsations disappeared on palpation of the arteries. The changes of the skin were a mixture of paper-like atrophy, keratosis, and bands of cyanosis. The nails had been reduced to a thin film and their surfaces corresponded with the size of fingers and toes.

Obviously osteolysis of the extremities had taken on such a grotesque appearance in these patients because it had occurred in infancy. There is no doubt, however, that the other endocrinopathic and trophic changes of the soft tissues elsewhere described and particularly stressed in adults had also occurred in this brother and sister. These endocrine changes, however, are inconstant, for both primary and secondary sex characteristics in the brother and sister described by Hozay (1953) showed a development in keeping with their age.

Changes of the skin, muscles, and vessels as well as the endocrine constitution have not been taken into account in adopting the term acro-osteolysis.

Conclusions

Ulcers and mutilating lesions of the extremities are due to affections of the spinal ganglia, of the spinal nerve roots, and, to a certain extent, of the peripheral nerve trunks and networks. The pathological lesions may predominate in any of these structures. Neurological manifestations are accompanied by changes in the vascular system of variable severity, in the pathogenesis of which several factors probably are operative.

The disease is hereditary in some cases; other forms either bear a resemblance to myelodysplasia in the broad sense of the term or to hereditary degeneration of the spinal cord and cerebellum. The disease may be observed in an isolated state or it may constitute an initial or late stage of hereditary degeneration.

It may be congenital and appear very early in life, be accompanied by extensive and complex lesions of the skin, and be associated with only slight neurological disorders (syringomyelic dissociation of the lower extremities), though of a type similar to that usually observed in young patients.

On the other hand, there are cases of non-mutilating familial acro-osteolysis showing endocrine anomalies, without neurological disturbances, but associated with changes of the soft tissues. Up to now, these cases have not been definitely classified from the clinical point of view.

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PERIPHERAL ARTERY GRAFTING

DESCRIPTION OF AN OPERATION

BY

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During recent years there has been increasing experience of the surgery of the aorta and great vessels. Reconstruction of these with a variety of different substances has achieved considerable success, but there is not yet unanimity of opinion on the best material to use. In general an end-to-end anastomosis is used in these vessels. That so many different materials have proved successful is probably due to the large diameter of the anastomosis and the rapid rate of blood flow. In the peripheral vessels, where the diameter of an end-to-end anastomosis is smaller and the blood flow slower, thrombosis is common. Many consider that there is only a limited use for peripheral grafting, particularly when atherosclerosis is the cause of the condition requiring treatment (Fontaine *et al.*, 1952; Rob and Eastcott, 1953). Since the introduction of the end-to-side technique of anastomosis, first suggested by Kunlin *et al.* (1951) and later modified by Cockett (Linton and Menendez, 1955), the outlook in peripheral grafting has improved.

During the past 10 years we have inserted 78 peripheral grafts in the lower extremities, most of them for the treatment of atherosclerosis obliterans, and on the basis of this experience we have drawn certain conclusions.

Materials Used for Peripheral Arterial Reconstruction

Synthetic Materials.—Although many synthetic substances are available, the only material that we have used for peripheral arterial replacement is polyvinyl alcohol sponge. This substance has been used on six occasions; all the prostheses functioned initially, but only one, an end-to-side anastomosis between the aorta and the common femoral artery, remains patent. In our experience polyvinyl alcohol prostheses, though successful in the aorta and iliac vessels,

do not appear to be suitable for use in the peripheral vessels. Eversion of the material in anastomoses of small diameter is difficult, thrombosis is common, and sinus formation has occurred with secondary haemorrhage. We no longer use polyvinyl alcohol prostheses in reconstruction of the limb vessels.

Autogenous Vein Grafts.—These have certain obvious advantages. An autogenous vein graft is readily available, and the long saphenous vein can conveniently be obtained through the incision used to expose the femoral artery. The graft is sterile, it survives transplantation, and the necessity for an arterial bank is obviated. Contrary to what is often stated, we have not experienced technical difficulties with the anastomosis. A disadvantage of a vein graft is that where a long segment of artery has to be replaced a sufficient length of vein of adequate calibre is not always available, and in the region of the knee-joint the long saphenous vein is often of narrow diameter. It is, of course, essential that the direction of the vein should be reversed so that the valves do not obstruct the arterial flow. Although transplanted veins dilate from the unaccustomed higher arterial pressure, we have seen no ill effects from this. In some they may regain their normal diameter, possibly from hypertrophy or from deposition of a layer of mural thrombus, or perhaps a combination of both.

In general, autogenous vein is valuable to bridge arterial defects caused by trauma or by excision of arterial segments infiltrated by malignant tumours. In atherosclerosis, when

thrombosis may be extensive, a sufficient length of vein of adequate diameter is seldom available.

Arterial Homografts.—Arterial homografts preserved either by freeze-drying or storage in saline to which antibiotics have been added are most generally useful. If freeze-dried they can be stored indefinitely. Their disadvantage is that an artery bank is necessary and that suitable donor material is scarce.

Grafting in Obliterative Arterial Disease of the Lower Extremities

(a) Atherosclerosis

Incipient or Established Gangrene.—Except in patients with massive gangrene of the foot or leg, no limb should be considered for amputation until an arteriogram has shown that a grafting procedure is impossible. Gangrene of a toe or of the dorsum of the foot can be induced to separate, with subsequent healing of the tissues by a graft; by such means we have saved a limb from amputation in a man of 79 with severe coronary disease.

Rest Pain.—In the absence of local sepsis rest pain is a symptom of impending gangrene which will usually occur within six months of its onset. Sometimes rest pain occurring after a recent arterial thrombosis will ease, with a period of conservative treatment as the collateral circulation develops, but more often the pain persists and gets more severe, and a grafting operation should be done if anatomically possible.

Intermittent Claudication.—This is the commonest symptom of atherosclerosis. Numerous therapeutic methods for relieving this symptom have been tried with varying success. Sympathectomy is of questionable value, because, although the skin blood flow is augmented, the blood flow to muscle is not significantly improved. Since the introduction of grafting procedures it has become possible to re-establish arterial continuity and thus restore the blood flow to both skin and muscle to a degree not achieved by any other method. Patients whose livelihood is jeopardized or whose activity is severely restricted are accepted for operation provided they have no serious coronary disease. Mild claudicants are not accepted, because their symptoms may remain stationary and in some cases may even improve considerably with the development of further collaterals.

Fig. 1 is the left femoral arteriogram of a man aged 54 suffering from bilateral femoro-popliteal arterial thrombosis. Two years previously a bilateral lumbar sympathectomy was done because of calf claudication and coldness of the feet. The operation did not relieve the claudication, but the feet became warmer. On his second admission in July, 1956, he complained that he could not walk more than about 50 yards and he was forced to relinquish his job. Fig. 4 is a pre-operative digital plethysmograph of the right great toe, showing the blood flow of the skin to be 5 ml./100ml./min. A

FIG. 1

FIG. 2

FIG. 3

FIG. 1.—Composite left femoral arteriogram (pre-operative). Femoro-popliteal segment thrombosed, with numerous collaterals around the thrombosed segment. Superficial femoral artery is site of diffuse atheroma. FIG. 2.—Composite left femoral arteriogram (post-operative). Graft extends from common femoral artery to distal popliteal artery, indicated by arrows. Interruption of continuity of contrast medium, indicated by interrupted lines, was because of mistiming in first exposure. Note disappearance of collaterals in relation to thrombosed segment (Fig. 1). FIG. 3.—A composite femoral arteriogram showing thrombosis in a femoro-popliteal bypass graft. The proximal (P) and distal (D) anastomoses are still patent.

by-pass graft was inserted in each leg. Fig. 2 is the post-operative arteriogram. A month after discharge he was able to walk without pain and his feet were warm. Fig. 5 is a post-operative digital plethysmograph of the right great toe. The blood flow is 20 ml./100 ml./min.

(b) *Embolism*.—In some late cases of embolism grafting, if feasible, should be undertaken.

(c) *Thrombo-angiitis Obliterans*

Thrombo-angiitis obliterans is a disease predominantly of small vessels. Grafting is therefore not possible except in the rare case when the disease affects a major artery only.

FIG. 4. — Venous-occlusion plethysmograph of right big toe before operation on reflex heating. Blood flow, 5 ml./100 ml. per min.

FIG. 5. — Venous-occlusion plethysmograph of right big toe on reflex heating post-operatively. Blood flow, 20 ml./100 ml. per min.

venous fistulae, on the other hand, can seldom be treated surgically, because they are often multiple, small, and diffuse, occurring not only in soft tissues but in bone also.

Arterial Injury

Injuries to major arteries should preferably be repaired by direct suture. If this is not possible the defect should be reconstructed by a graft. The excision of the damaged vessel should be liberal to include bruised intima not apparent on naked-eye examination of the exposed artery.

Arteriovenous Fistulae

Acquired arteriovenous fistulae can, when necessary, be corrected by grafting when aneurysmorrhaphy is not possible, and this is preferable to quadruple ligation. Congenital arterio-

Aneurysms

Peripheral aneurysms, though not as dangerous as abdominal aneurysms, are prone to the same complications. They may rupture or thrombose, or give rise to pressure effects. Localized aneurysms should be excised even though symptomless, and continuity should be restored by grafting. The diffuse tortuous dilatation associated with atherosclerosis seldom ruptures and is better left alone and reviewed periodically.

Grafting in Atherosclerosis of the Lower Extremities

Dible (1956) has shown that atherosclerosis of the lower extremities is a disease of major vessels and hardly ever affects the smaller arteries of the foot. Although the disease is generalized, thrombosis is often segmental, and in our experience 50% of cases are anatomically suitable for grafting, though the indications for grafting do not arise in more than about a third. In many instances the femoro-popliteal artery is the only artery thrombosed, although, when the rest pain occurs or gangrene threatens, obstruction of one or

more of the tibial vessels is usual; nevertheless, in many the distal part of the popliteal artery remains patent. This is fortunate, for if blood under sufficient pressure can be delivered through a graft into this patent segment gangrene may be prevented or localized even if two of the three main vessels below the knee are thrombosed. Fig. 6 is an arteriogram of such a case. A graft was inserted with success (Figs. 7, 8, and 9), though the patient has since had to undergo amputation, presumably from advancing disease, for at the time of amputation the graft was patent.

Arrangement of the Graft

A graft may be anastomosed either end to end or end to side to the host vessel. In arterial injuries the results of resection and end-to-end grafting are good because usually the vessel is healthy.

In atherosclerosis of the limb vessels, however, the results of resection and end-to-end grafting have been disappointing, with a high incidence of immediate or early post-operative thrombosis. There are several factors predisposing to failure. In arterial thrombosis the artery distally may be so small that an efficient end-to-end anastomosis with a graft is difficult to construct. Furthermore, every method of suture causes some narrowing of the stoma, and to this is added the inevitable oedema which accompanies healing. Reduction in the size of the stoma is of little consequence in large vessels such as the aorta or common iliac artery, but in smaller vessels, such as the popliteal, especially when there is a thickened intima, an adequate stoma is difficult to fashion. Resection of the thrombosed segment is unnecessary; it can be difficult, tedious, and harmful, as during exposure of the artery important collaterals may have to be sacrificed, and, should the graft thrombose, more harm than good would result. Also the artery is often adherent to the adjacent vein, which is liable to injury and subsequent post-operative thrombosis. Lastly, the long skin incisions required for excision of the thrombosed arteries heal slowly and mild wound infections are not uncommon.

Dissatisfaction with the results of resection and end-to-end grafting in peripheral obliterative arterial disease has led us to adopt the bypass type of operation described by Kunlin *et al.* (1951). In this procedure the thrombosed artery is left *in situ* and a bypass graft inserted and anastomosed end to side to the host artery proximal and distal to the affected segment. There are many advantages of this method. Few if any collaterals are disturbed; in fact, the graft acts as an additional collateral, and should subsequent thrombosis occur no harm will have resulted. The size of the anastomosis is not limited by the diameter of the host artery, and the most suitable area free of calcification can be chosen.

The end-to-side technique has been criticized on the grounds that this type of anastomosis causes turbulence and thus predisposes to thrombosis (Rob and Eastcott, 1953). It is difficult to refute this contention, but it could as justifiably be argued that such turbulence would retard thrombosis rather than initiate it.

Factors conducive to intravascular thrombosis are slowing of the blood stream and intimal irregularity. In a streamlined vessel the periphery of the blood stream is almost stationary, and in the presence of any intimal abnormality, such as that produced by an anastomosis, thrombosis is apt to follow. If turbulence is present this sluggish zone of blood does not exist, and it would therefore appear that thrombosis might be retarded or prevented. The proponents of the "turbulence-thrombosis" theory may express the view that turbulence resulting from an end-to-side anastomosis injures the intima and that this initiates thrombosis. But throughout the circulation arteries originate as natural end-to-side "anastomoses," and at the origin of the great vessels from the aortic arch, where the angle of branching is acute and where blood is delivered at high pressure, turbulence should be pronounced. The stresses imposed at these sites might be thought to produce intimal

FIG. 6.—Femoral arteriogram showing extensive thrombosis. Most of the popliteal artery is thrombosed and the peroneal artery is the only patent artery in the leg. A graft was inserted from the common femoral artery to the small segment of popliteal artery indicated (P).

damage and thus predispose to thrombosis. In fact, the incidence of thrombosis here is far less than that at the femoro-popliteal junction, where the blood flow is laminar. To add further support to the contention that turbulence retards clot formation one may draw an analogy with clot formation *in vitro*: blood in a container will clot less readily if agitated than if left undisturbed.

It has also been said that after end-to-side anastomosis the altered haemodynamics results in a reduced blood flow through the graft, varying with the angle of branching and amounting to 10–30% (Szilagyi *et al.*, 1956).

The theoretical disadvantages of the end-to-side anastomosis have not been borne out by results and appear to be outweighed by the practical disadvantages of the end-to-end anastomosis.

From a study of more than 300 arteriograms of the lower extremities affected by atherosclerosis we have been impressed by the relative infrequency with which thrombosis affects the common femoral and distal half of the popliteal arteries as compared with the superficial femoral and proximal half of the popliteal arteries. So vulnerable are the superficial femoral and proximal popliteal arteries to thrombosis that any reconstruction limited to this segment of artery, though at first successful, is liable to subsequent failure from thrombosis elsewhere in the vessel. For this reason we believe that when any part of the femoro-popliteal artery is thrombosed, in however short a length, the minimal graft to be used should extend from the common femoral artery above to the distal popliteal artery below if this is patent, as it usually is (Martin, 1957). Incidentally, and fortunately, at both these sites access to the host artery is easy.

Operation

Age is no contraindication to grafting provided there are no complicating medical conditions. If the patient will tolerate a major amputation he will tolerate a grafting operation.

Anaesthetic.—It matters little what anaesthetic is used provided no significant fall in blood pressure occurs during or after the operation. A fall in blood pressure may precipitate thrombosis, not only in the diseased vessels of the affected leg but also in the coronary or cerebral arteries or in the contralateral limb, so often themselves the site of atherosclerosis. A severe fall in blood pressure may occur when the circulation is restored after completion of the anastomosis. This may result from three factors—blood loss from the anastomosis, reactive hyperaemia in the limb, and the entry of metabolites into the general circulation, causing a vasodepressor action. The anaesthetist should be prepared to replace any blood lost by rapid transfusion, if necessary using a transfusion pump.

Operative Technique

The operation can be done as a synchronous combined procedure, thus considerably reducing the operating time (Owen and Rob, 1956). The patient is placed in the lateral position with the affected limb uppermost. The lower limb is kept straight and the patient's position is maintained by sandbags placed on either side of the abdomen and straps. The affected leg is elevated on a wooden table placed on the operating table over the contralateral limb.

The skin is prepared from the umbilicus to the ankle. One surgeon faces the inguinal region and the other the popliteal fossa, each with his own assistant on the same side. Having applied skin towels to isolate the operative fields, one surgeon first exposes the popliteal artery through a longitudinal incision centred over the popliteal fossa. The artery is palpated for patency and suitability for end-to-side anastomosis and is tested for evidence of retrograde blood flow. When this has been determined the other surgeon exposes the common femoral artery through a longitudinal skin incision and similarly palpates the vessel for the presence of atheromatous plaques and patency. The arteriogram will of course give a strong lead to the best site for anastomosis, but palpation of the vessel is the most accurate guide. In the inguinal incision the common femoral, superficial

femoral, and profunda femoris arteries are exposed and all their branches are preserved; in the popliteal incision the distal half of the popliteal artery and its branches are similarly treated.

While the dissection is proceeding an assistant prepares the graft. Although on occasion we have used autogenous saphenous vein, we prefer a freeze-dried arterial homograft. Inclusion of the external iliac artery in the donor graft provides a larger vessel and one of sufficient length, and in end-to-side anastomosis the disparity in size between the diameter of the graft and host artery is not of importance. The graft is soaked in water for 20 minutes to reconstitute its physical properties, for it may easily be fractured if it is manipulated before it is properly softened. All branches are ligated at their origin with fine silk, but if some branches have been cut flush, leaving no stump to tie, a stitch passed through the adventitia and media will control subsequent bleeding. A solution of heparin in saline (1 in 1,000) is then injected into the graft to test for leakage.

A tunnel in which the graft will subsequently lie is then made between the upper and lower incisions along the course of the femoral artery. The index finger of one hand is carefully insinuated in a downward direction through the inguinal incision and deep to the sartorius muscle, where there is a good plane of cleavage, and the index finger of the other hand is passed upwards through the adductor hiatus. Each finger is advanced as far as possible along the course of the femoral artery, but they will not meet. The intervening distance is tunnelled by means of an adult-sized bronchoscope that is long enough to extend from the proximal to the distal incision.

A long pair of biopsy forceps is then passed through the bronchoscope. The jaws of the forceps grasp one end of the graft, which is then pulled through the bronchoscope, taking care to avoid rotation. The bronchoscope is then withdrawn, leaving the graft in position. When suitable sites of anastomosis have been determined, the graft is put under slight tension and the surplus is excised to prevent subsequent tortuosity. Each end of the graft is then prepared for anastomosis in the following manner.

The adventitia is carefully and completely removed for a distance of about 1 in. (2.5 cm.). This is important, for, during the suturing, threads of adventitia may be drawn into the lumen and predispose to thrombosis. It is not necessary to remove the adventitia of the host artery, because the suturing is always done from the graft to the host artery so that the diseased intima is pushed against the media by the point of the suture needle and not separated from it, as it may easily be if the needle is passed in the opposite direction. The removal of the adventitia of the host artery, too, may result in excessive bleeding from the anastomosis. The end of the graft is cut longitudinally with scissors for about $\frac{1}{4}$ in. (2 cm.), is splayed open, and the corners are trimmed. Arterial clamps are then applied to the host artery above and below the site chosen for anastomosis and to branches arising from the excluded segment. Haemostasis must be perfect, and bulldog clamps are ideal. If a bulldog clamp is not adequate for control of the common femoral artery, then a Crafoord clamp applied as lightly as is consistent with haemostasis may be used, or, alternatively, a soft rubber tourniquet. A longitudinal incision about $\frac{1}{4}$ in. (2 cm.) long is then made in the host artery, started by scalpel and completed by fine straight scissors. It is not necessary to excise an ellipse of artery. Occasionally a calcified plaque is encountered or a piece of intima becomes partially detached. Both can be removed, apparently with impunity. The lumen is then intermittently irrigated with heparin while the anastomosis proceeds.

Two sutures of 00000 arterial silk are inserted close to each other through the apex of the graft, the ends being tied on its outer aspect (Fig. 7). Each needle is then inserted from within out through the host vessel at the corresponding end of the incision and tied. The base of the graft is sutured to the host vessel in a similar manner (Fig. 8). An over-and-over continuous everting suture on both sides, beginning at the

base of the graft, completes the anastomosis (Fig. 9). The suturing should always begin at the base, as this is the only difficult part of the anastomosis. Before the final stitch is tied heparin solution is injected into the graft to displace any contained air which might conceivably produce air embolism when the clamps are released.

FIG. 7.—Two everting mattress sutures are inserted at base and apex of graft. Needles are inserted from graft to host artery so that diseased intima, if present, is pushed against the media and not separated from it as might occur if needle is passed in opposite direction.

FIG. 8.—Mattress suture at apex of graft should be tied before the continuous suture is begun. This step has been omitted for sake of clarity.

FIG. 9.—Anastomosis has been completed by tying the continuous everting suture to the corresponding end of the apical mattress stitch. The bulge or "cobra head" effect in graft is a usual finding when clamps are released after end-to-side anastomosis.

When the anastomosis has been completed the anaesthetist prepares for a rapid blood transfusion. The clamps are then released one by one, first those on the smaller branches, and then those on the distal popliteal artery, proximal popliteal artery, the profunda femoris artery, the superficial femoral artery, and finally the common femoral artery. This allows a gradual rise of arterial pressure within the graft, and the haemorrhage from the suture line is much reduced. Leakage will almost certainly occur but should not be arrested by immediate suture. A swab placed firmly over the anastomosis for three to five minutes and kept in position by temporary approximation of the skin will generally produce complete haemostasis. If this fails, a stitch or two tied over a small free muscle graft will seal any remaining leaks.

When all bleeding has stopped and the blood pressure is satisfactory, the wound is closed by stitching deep fascia and skin separately.

Post-operative care.

All patients are given phenindione, starting on the day of operation and continuing for three weeks. The prothrombin index is maintained at about 50%. Penicillin and streptomycin are administered for five days. The patient is allowed out of bed on the fourteenth day.

Results and Discussion

The conclusions which form the basis of this paper are derived from two series of cases—one early series of 20 patients operated on between 1946 and 1955, and a later series of 31 cases started early in 1956. The results have been very different in the two series.

In the first series, autogenous vein grafts were used exclusively. In 15 patients the anastomosis was end to end above and below, and in five either end to side above and below or end to end above and end to side below. In none of these cases did the graft extend from the common femoral artery above to the distal half of the popliteal artery below; in all a short segment of thrombosed vessel was either excised or bypassed. Further, in the end-to-side anastomoses the technique employed did not allow of such a wide stoma as that described above and used in the second series. All

the patients were suffering from atherosclerosis and all were male. Their ages ranged from 46 to 72 years. Of these 20 patients, only eight (40%) were discharged from hospital with patent grafts. Three grafts (15%) were patent at the end of one year and only one remained patent after three years.

In the early part of 1956 it appeared to us that bypass grafts by an end-to-side technique should only be used to leave the thrombosed vessel intact and to preserve collaterals. At the same time it was decided that the shortest, and in fact the only, bypass graft to be used would be one extending from the common femoral artery above to the distal half of the popliteal artery below, because of the less frequent involvement of these arterial segments by atherosclerosis; the superficial femoral artery and proximal half of the popliteal artery are so prone to progressive thrombosis that we felt that this part of the arterial tree should always be excluded even if the thrombosis is limited. In this latter series 88 bypass grafts were inserted in 50 patients. Polyvinyl alcohol sponge prostheses were used in six patients, autogenous vein grafts in five, and arterial homografts in 47. All were performed for atherosclerosis. Thirty patients were male and one female. The ages ranged from 49 to 79.

Thirty operations were performed for intermittent claudication and 28 for incipient gangrene. Of the six polyvinyl alcohol prostheses, only one remained patent six months after operation. Two thrombosed before discharge from hospital and one six weeks later. In two patients secondary haemorrhage occurred—one from infection and the other from an undetermined cause. In the first case, that of a man aged 68 in whom a bypass operation had been performed between the common femoral and popliteal arteries, a secondary haemorrhage occurred on the fifth post-operative day at the proximal anastomosis. *Staphylococcus aureus* was cultured from the wound. The defect in the anastomosis was sutured, but two days later a further haemorrhage followed which necessitated ligation of the external iliac artery. The leg became gangrenous, and the patient rapidly deteriorated and died. The graft was patent at post-mortem examination. In the second patient, a man aged 38, haemorrhage occurred at the proximal anastomosis a month after discharge from hospital. Armed with the experience of the former case, no attempt was made to suture the leak, but the entire prosthesis was removed and successfully replaced by an arterial homograft.

Of the 58 arterial homografts used two thrombosed immediately after operation, probably from technical errors, four thrombosed before hospital discharge, and four between ten weeks and eight months later. Forty-eight grafts were patent two to eight months after operation.

Of the five autogenous vein grafts inserted, three were patent six to eight months after operation. One thrombosed before hospital discharge and the other six weeks after discharge. In the patient in whom the early thrombosis occurred an arterial homograft was inserted at a later date. This graft, too, thrombosed before hospital discharge, possibly indicating a marked immunological reaction in the host.

Although the follow-up period is short a comparison can nevertheless be made between the end-to-end and end-to-side anastomoses. In the first series 60% thrombosed before hospital discharge and in the second series only 24%. In the second series, in which long bypass grafts only were inserted, 82% were patent two to eight months after operation. Owing to the small number of autogenous vein grafts used in this series it is not possible to make a comparison with the arterial homografts, but we have no reason to believe that they are inferior.

In the assessment of patency of the grafts subjective evidence was not taken into consideration, because many patients with arterial thrombosis may improve with bed rest alone. Patency was assessed mainly by the presence of pedal pulses. In a few cases these were not palpable because of pre-existing thrombosis between the graft and the ankle. In such cases patency was confirmed either by

palpating the pulsating graft in the femoral triangle and in the popliteal fossa or by arteriography. Arteriography was used in only four cases.

Failure to improve after grafting procedures, or failure to maintain improvement, may be ascribed to two causes. Either the graft or the host artery may thrombose. Early failure which occurs immediately or a few hours after operation may be due to technical error, one of these being inadequate washing with heparin solution so that a clot is swept onwards after restoration of blood flow to lodge distally. Late failure may be the result of thrombosis in the graft or in the host vessel. Fig. 3 is an example of the occurrence of thrombosis in a graft two months after the operation. Most of the graft is occluded and only the proximal and distal portions are patent. We cannot determine the reason for the late graft thrombosis, but it may be that immunological reactions are responsible in some instances. There is little doubt that most of the late failures are due to thrombosis of the host vessels: atherosclerosis is a progressive disease.

We have one clear instance of the failure of a graft because of thrombosis in the host vessel. A graft was inserted in a man aged 74 for incipient gangrene. The clinical improvement was remarkable, but five weeks later gangrene set in and an above-knee amputation was performed. Fig. 10 shows the graft to be patent and the host vessel thrombosed.

FIG. 10.—Photomicrograph of the popliteal artery (P) and arterial homograft (G) in an amputated leg. The graft is patent, but the popliteal artery is occluded by both recent and old thrombosis. (H. and E. $\times 3\frac{1}{2}$.)

Because of the progressive nature of atherosclerosis grafting procedures are palliative rather than curative, but there is no doubt that the palliation achieved is far greater than that afforded by any other method of treatment. Although the series of cases presented is small, and the follow-up period is short, the results indicate that when possible bypass grafting, using the end-to-side anastomosis, should be carried out when other simpler methods of treatment have failed.

Summary

The materials available for peripheral artery grafting are discussed, and, of these, autogenous vein or human artery has proved to be superior to any synthetic substance. In atherosclerosis autogenous vein of sufficient length and diameter is rarely available, and so the latter is now used by us exclusively.

Grafting should be considered in all patients suffering rest pain or incipient gangrene, and also in those who are incapacitated by intermittent claudication. Coronary disease may make the operation a risky one, but this risk is probably no greater than that of an amputation.

The end-to-side graft is best in our hands, the reason being possibly because of the turbulence of blood flow

induced at the site of anastomosis. The graft should always extend from the common femoral artery above to the distal part of the popliteal artery below, even if the length of femoro-popliteal artery obstructed is minimal. No other graft is now considered.

The results show a success rate of over 80% for periods up to 18 months, and in the state of our present knowledge the operation seems well worth while.

Failure may occur from extension of disease in the host arteries, from clotting in the graft, or sometimes from clotting at the site of anastomosis. An operation for grafting is described in detail.

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LIQUOR AMNII STUDIES IN THE PREDICTION OF HAEMOLYTIC DISEASE OF THE NEWBORN

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In a review of the deaths from haemolytic disease of the newborn in England and Wales during 1953 and 1955 Walker and Mollison (1957) stated: "It is suggested that, if all cases of haemolytic disease of the newborn (due to anti-Rh(D)) were predicted antenatally and were treated when necessary by early adequate exchange transfusion, the present death rate could be greatly reduced. Each year, in England and Wales, more than 150 infants would be saved."

The following preliminary report on liquor amnii studies shows that it is possible to predict haemolytic disease of the newborn antenatally.

Bevis (1956) described his investigations on liquor amnii carried out during and after his tenure of a Leverhulme Research Scholarship from the Royal College of Obstetricians and Gynaecologists. In an effort to arrive at a prognosis for the baby yet to be born of a sensitized rhesus-negative woman, he obtained specimens of liquor by abdominal paracentesis, and using a spectrophotometer produced a spectral absorption curve for each specimen by plotting its optical density against the wavelength. It was Bevis's experience that when the baby was unaffected by haemolytic disease the graph of optical density at various wavelengths was virtually a straight line between 600 and 400 m μ . When the baby was the subject of haemolytic disease, Bevis noted a rather consistent deviation attributable to increased optical density at 450 m μ . This deviation is referred to hereafter by the somewhat colloquial term of "the bulge," and its appearance has been attributed by Bevis to the presence of bilirubin, the concentration of which it reflects quantitatively. He has also identified a less consistent deviation attributable