THE STORAGE AND USE OF ARTERIAL GRAFTS

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The problem of arterial repair and reconstruction has interested surgeons for many years, for as long ago as 1894 Murphy successfully repaired a damaged femoral artery by end-to-end anastomosis, and in 1907 Carrel described animal experiments in which free venous grafts were used to bridge arterial defects. He speculated upon the clinical possibilities of arterial grafting, but although there have been sporadic attempts to introduce arterial grafting into clinical surgery it is only in recent years that a high rate of success has been achieved and that methods of artery banking have been developed.

Bank Storage.—The first satisfactory arterial bank was that of Gross et al. (1949). In this bank grafts were stored in 10 per cent. homologous serum at 4 °C. They had a life of up to six weeks, and because of this there was a high rate of wastage. More recently Hufnagel (1947) and Hufnagel and Eastcott (1952) described the technique of freezing and storage at low temperature and Marrangoni and Cechini (1951) introduced the method of freeze-drying. Rob (1954) has also described the use of lyophylised grafts in this country. Both these methods have the advantage that the grafts may be stored for very long periods without deterioration, and the method of freeze-drying has the additional advantage that the storage is at room temperature and the grafts are easily transported. On the other hand, the process is a complicated one and the practical advantages of simplicity enjoyed by the alternative technique is a considerable one. The grafts which have been used in the cases described in this paper were all prepared by freezing and were stored at −79 °C.

Grafts may be autogenous, homologous, or heterologous. Autogenous venous grafts may be used to bridge peripheral arterial defects, the only practical vein being the long saphenous. Such vein grafts are difficult to suture because of spasm which makes their lumen small. They are of particular value in cases of traumatic arterial obstruction, in which the host is not diseased and the ready availability of the graft in the leg is an additional advantage.

Heterologous grafts were used successfully in animals by Carrel (1908), but their use in man is still in an experimental phase. Hufnagel (1954) has recently reported the successful use of such grafts sterilised in liquid ethylene oxide and then frozen and dehydrated. If such a technique can be shown to be safe, the availability of suitable grafts will be vastly increased and the task of keeping an ample stock of grafts in the bank will be eased.

Other materials such as nylon taffeta and orlon are being currently tried as substitutes for homologous grafts. It appears probable that they will be satisfactory for major arterial reconstruction, but it is still questionable whether they will survive without thrombosis in arteries as small as the femoral.

Homologous arterial grafts are taken in the mortuary from a subject under 40 years of age who has died free of transmissible disease, usually the result of an accident. The grafts are taken within twelve hours of death with full aseptic
precautions. They are cut into suitable lengths, placed in sterile pyrex tubes, and a rubber bung is inserted. The sterile part of the operation is now completed. A freezing mixture is prepared by adding CO₂ snow to methylated spirit until a temperature of about -70°C is recorded on an alcohol thermometer. The pyrex tubes are inserted into this mixture in turn for about three minutes. At the end of the three minutes the grafts are transferred to the bank for permanent storage. This may consist of a commercial deep freeze operating at about -20°C, as used by Deterling et al. (1951). An alternative is an insulated box kept cold with blocks of CO₂ snow, which need to be replaced about twice a week to maintain a temperature of -79°C. This has the advantage that it is not dependent on a constant electrical supply and will not warm slowly in the event of a power failure.

When a graft is required, the selected tube is taken to the theatre. The bung is removed and the tube filled with saline at 100°F. As the graft floats free it is poured into a bowl of warm saline. It is immediately ready for ligation of its branches and insertion into the defect. If it is necessary to transport a frozen graft to another hospital it can be done in a wide-mouthed vacuum flask packed with CO₂ snow.

Operative Technique.—A good exposure is necessary, and it is essential that the minimum number of collateral vessels be damaged. In particular those at the upper and lower limits of the block should be controlled with encircling ligatures. If free sacrifice of the collaterals were followed by thrombosis in the graft a disastrous result might follow.

When the obstructed segment is a short one it may be excised, but in blocks of more than 2 in. the graft is placed alongside the blocked vessel. This saves time and, in addition, avoids dissection alongside the adjacent vein which predisposes to its thrombosis.

The graft is inserted by a continuous everting suture using ooooo paraffined silk (Fig. 1). Heparin is not used as the danger of bleeding outweighs its advantage.
Once the clamps are taken off, any leaks at the suture line must be closed without reapplication of the clamps, for there is a distinct danger of immediate thrombosis if blood is left stagnant in the graft. Success depends on getting an accurate suture line and a good flow of blood. Grafts in the iliac arteries are therefore more likely to be successful than those in the popliteal.

**INDICATIONS**

Arterial grafting has now been used in a variety of circumstances in which arterial reconstruction is indicated. These include certain cases of trauma to the femoral or popliteal arteries, after resection of aneurysms or tumours, and in some cases of primary arterial thrombosis. The majority of segmental arterial obstructions are due to atheroma, and although the majority of these cases are unsuitable for surgery the remainder provide the main field for peripheral artery grafting.

**Trauma.**—Reports from Korea have shown that the prognosis of femoral and popliteal artery injuries has been immensely improved by grafting. But as with embolectomy, the flow must be re-established within eight to ten hours at most. Using grafts, and other methods of arterial repair, Jahnke and Seeley (1953) reduced the amputation rate following major arterial injury to 8.8 per cent. and Ziperman (1954) to 17 per cent. Both these figures compare very favourably with those of World Wars I and II.

In all cases of major arterial trauma the circulation is still further impaired by the presence of arterial spasm which prevents proper functioning of the collateral circulation. Kinmonth (1952) drew attention to the value of 2 per cent. papaverine applied locally to the artery, and in clinical practice tolazoline hydrochloride (Priscol) given intra-arterially proximal to the lesion is also valuable and its effect is more widely spread. This is in marked contrast to the effect of tolazoline hydrochloride given orally. Isaac Starr (1952), Lynch (1953), and others have pointed out that when this drug is given by mouth or intravenously it occasions a generalised vasodilatation, and a limb with an arterial obstruction has its blood supply still further reduced. In addition, the increased cardiac output which is required to meet the generalised vasodilatation may be an embarrassment to the heart, and elderly subjects with coronary atherosclerosis may be unable to meet the new demand.

If an arterial injury is associated with a fracture, the latter must be absolutely immobilised if an arterial graft is to be used.

**Aneurysm.**—Peripheral aneurysms may be due to trauma, syphilis, or atherosclerosis. They demand treatment on many grounds, but the greatest danger is from peripheral embolus from the clot which has formed in the sac. In the past many types of operation were designed in all of which the main artery was ligated to encourage complete clotting within the aneurysm. The use of an arterial graft makes radical treatment possible without detriment to the circulation.

_Case 1._—Bernard C., aged 69 years, came to hospital with a pulsating swelling in the popliteal fossa. Examination showed this to be a large aneurysm of the popliteal artery. Because of the danger of embolus the aneurysm was explored in April 1953. After the popliteal artery was controlled above and below the aneurysm with bulldog
clamps, it was incised and much loose clot evacuated. The artery was transected above and below the aneurysm, an arterial graft inserted, and the sac of the aneurysm was closed over the graft (Fig. 2). The peripheral pulses were felt at the end of the operation and the limb circulation has remained normal.

**Primary Arterial Thrombosis.**—This rare condition occurs in young adults. The aetiology is obscure, though it is probable that many cases are early manifestations of atheroma. The symptoms are usually incapacitating, for there is severe ischaemia with claudication in a young person otherwise in excellent health—an ideal combination of circumstances for grafting.

**Case 2.**—A patient, aged 38, came to hospital complaining of severe claudication of four months' duration. He was a merchant seaman and had been to a hospital in South America where a diagnosis of Buerger's disease had been made and a hopeless prognosis given. When his ship docked at Avonmouth he came to see Dr Cates, who realised that he might be a suitable case for grafting as the popliteal and distal pulses were absent. This was confirmed at arteriography (Fig. 3).

At operation in October 1953 the blocked segment was excised and grafted. There was an immediate return of peripheral pulses and he was discharged symptom-free.

**Tumour.**—A number of cases come to mind such as pelvic tumours and carotid body tumours in which resection of the neoplasm might require an arterial repair in the reconstruction. Fibrosarcoma of the thigh is probably the
most common tumour to involve vital blood-vessels. Stanford Cade (1951) has shown that local resection of the group of muscles in which the tumour takes origin gives as good prognosis as amputation and is therefore the operation of choice. If resection involves sacrifice of the femoral vessels, restoration of the arterial flow will ensure viability of the limb and indeed render its circulation normal.

Case 3.—Henry H., aged 63 years, had had a swelling of the left thigh for ten years. During the past year it had grown at a considerable speed and given rise to a feeling of numbness down the inner aspect of the leg and to oedema of the foot. Examination disclosed a large soft tissue tumour in the anterior and medial compartments of the thigh. The plain radiograph showed extensive medial sclerosis with calcification. The tumour was excised widely by Professor R. Milnes Walker, and it was necessary to include the femoral vessels in the resection (Fig. 4). The femoral vein was ligated and the arterial defect reconstructed with a 4 in. frozen graft. The medial calcification did not greatly add to the difficulties of the operation, this being in contradistinction to calcification of the intima which occurs in atheroma and renders operation almost impossible. Owing to the loss of elastic recoil in medial sclerosis the lumen is wider than normal, and in this case a frozen graft of external iliac artery was used.

Atheroma.—Atheroma is by far the most common cause of arterial obstruction, and in some cases reconstructive surgery will afford dramatic relief. Surgery to the main arteries of the leg is justifiable only when the disease is particularly severe in the limbs and spares the coronary and cerebral circulations.

Contraindications

It is obvious that no local surgery should be advised when the patient suffers from angina pectoris or the symptoms of cerebral atheroma. The slowing up occasioned by impaired blood supply to the legs is a natural safeguard for the heart.
Locally severe disease shown on the arteriogram adjacent to the length of complete block may render the operation too difficult to be worth while undertaking.

In addition, the presence of a second block a short distance below makes grafting unwise as the absence of flow will result in early thrombosis. Occasionally arteriography shows that the block extends distally into the small arteries, and grafting is not possible (Fig. 5).

Fig. 5
Contraindications to grafting in atheroma.
A, Extensive disease locally; excision to reasonable artery contraindicated in operations for claudication.
B, Double block.
C, Distal end of block extending into small vessels below popliteal.

Indications in Intermittent Claudication.—Surgery is considered in intermittent claudication only when the disability is severe enough to cause interference with work and, in fact, the proportion of cases suitable for operation is small. Bilateral obstructions are not normally suitable for surgery as this is an indication of widespread disease. Occasionally, however, after a successful operation on one leg the second will become blocked at a later date and require operation.

Case 4.—William M., aged 61 years, attended hospital incapacitated by intermittent claudication. He walked with a limp from the first step and had to stop at 50 to 60 yds. Arteriography disclosed a short block in the femoral artery in the region of the adductor hiatus. The posterior tibial artery was patent. Lumbar sympathectomy was performed but did not affect his disability. On 7th August 1952 the blocked segment was excised and grafted with a segment of frozen foetal aorta. The posterior tibial pulse returned immediately. His convalescence was impaired by venous oedema of the leg, but this did
not prove to be a serious disability. Fifteen months later, in November 1953, he reported the onset of claudication in his other leg. Arteriography showed that the graft was still patent (Fig. 6), though there was a significant narrowing due to advancing atheroma proximal to it. On the other side there was a 4 in. block from the origin of the profunda femoris artery. This was grafted in December 1953 and the posterior tibial pulse returned at once.

Case 4. Arteriograms before and fifteen months after an arterial graft. The graft is of good lumen throughout, but a new site of narrowing is present 1 cm. proximal to the graft.

Rest Pain.—These cases are often suitable for treatment by grafting and, indeed, they comprise a particularly satisfactory group, for the alternative is a major amputation. It is necessary only to observe the contraindications which have already been outlined.

Case 5.—William H., aged 52 years, complained of pain in the hip on walking for six years. He had received some treatment in the physiotherapy department, a common event with patients suffering from gluteal claudication. During the previous six weeks he had developed severe rest pain which prevented sleep. On examination the foot circulation was precarious and the femoral pulse absent. Aortography disclosed that the left common iliac artery was obstructed though the other vessels did not appear seriously
atheromatous. The left common iliac artery was grafted and there was an immediate return of the femoral pulse and, within twenty-four hours, of the posterior tibial and dorsalis pedis pulses (Fig. 7).

Gangrene.—Patients with gangrene usually have extensive and diffuse disease and are not suitable for treatment by grafting. In addition, there is a distinct risk of coronary thrombosis. In some cases of gangrene the reduced blood flow is due to an iliac and a femoral block. In such a case grafting the iliac artery gives a strong pulsatile flow to the profunda femoris, and this may be sufficient to maintain the foot through the anastomosis round the knee joint.

Case 5.—Jesse M., aged 63 years, had attended in 1951 with intermittent claudication. Two years later he suddenly developed painful gangrene of the fifth toe of the left foot (Fig. 8) and an above-knee amputation was thought to be an imminent necessity. Aortography (Fig. 9) showed extensive and bilateral atheroma, but the main obstructions to the circulation to the left foot were a short block (1 cm.) in the external iliac artery and a long block in the femoral artery beginning at the origin of the profunda femoris. The proximal block in the external iliac artery was grafted. There was an immediate improvement in the circulation to the foot, and after some months the area of necrosis separated. He now has no rest pain and is able to walk about a mile without claudication (Fig. 8).

In dealing with cases of atheroma there have naturally been disappointments and failures as a result of inexperience and of operating on cases that are now known to be unsuitable. Taking all cases, however, the immediate success rate is sixteen out of twenty-six cases (60 per cent.). Three patients have died—two with

Case 6. Aortogram before and after a graft of the external iliac artery for severe rest pain.
gangrene from coronary thrombosis and one, on heparin, from retroperitoneal haemorrhage after an iliac graft. In addition, there have been three late thromboses, but in only one of these was there a thrombosis of the graft alone.

The grafting of arteries is an operation which has a limited but now well-established place in surgery, though only time will tell what the late results of grafting will be. If disappointments are to be avoided, however, great care must be taken in the selection of atheromatous cases and the collateral circulation must never be interfered with.

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REFERENCES

