

THE TREATMENT OF ARTERIAL INSUFFICIENCY OF THE LOWER LIMBS

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Severe arterial insufficiency of the lower limbs, which is the result of large-scale and complete obstruction of main arteries, may lead to extensive peripheral gangrene, necessitating amputation of the limb. On the other hand, slight arterial insufficiency will cause minimal symptoms and signs, such as a cold foot and absent peripheral pulses. A patient with this degree of insufficiency will be able to do his normal work and is not in danger of losing his limb. Here the obstruction of the main artery is incomplete or the collateral circulation is excellent. This degree of arterial insufficiency is usually discovered accidentally and these patients do not require treatment. However, the majority of patients with arterial insufficiency of the lower limbs fall between the above two groups. In them the diminished arterial supply leads to threatened or limited gangrene or to severe intermittent claudication. These patients require treatment urgently, not only to save the limb, but also to make it a useful one. It is the treatment of these patients which will be discussed in this paper.

Atherosclerosis with secondary thrombosis is the most important cause of arterial obstruction in the lower limbs, and the treatment of arterial insufficiency is largely the treatment of this condition. Thromboangiitis obliterans (Buerger's disease) is a rare disease and is not an important consideration when these patients with arterial insufficiency are treated. Thrombosis following arterial trauma or embolism may come on gradually, simulating atherosclerotic obstruction, and it has to be considered, especially in younger patients. Here the arteries, other than the obstructed one, are usually normal.

Atherosclerosis is a general disease which also affects arteries elsewhere in the body, e.g. those supplying the brain and heart, and relief of arterial obstruction will not cure the patient of his disease. The treatment of these patients with arterial insufficiency is therefore nearly always palliative and not curative.

The sites of atherosclerotic obstruction in the arteries which supply the lower limbs are:

(i) The aorta bifurcation and iliac arteries: Unassociated with obstruction of the femoral and popliteal arteries, it occurs especially in relatively young men. This condition has been discussed fairly recently in this *Journal*.¹ Patients belonging to this group are therefore not reported and discussed in this paper.

(ii) More commonly, the site of obstruction is in the femoral and popliteal arteries. These patients are usually older men in whom partial or complete obstruction of the iliac arteries may also be present.

Although atherosclerosis involves the arteries diffusely, symptoms of arterial insufficiency are brought on by thrombosis which occurs secondary to an atheromatous plaque. This occurs in the femoral artery, especially where it passes through the adductor magnus opening. From here the thrombosis may spread upwards to the femoral bifurcation and downwards to the popliteal artery (Fig. 1).

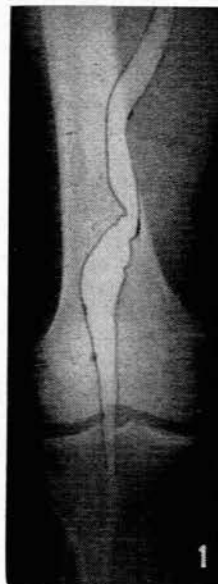


Fig. 1. Femoral arteriogram showing kinking of the femoral artery where it passes through the adductor hiatus. This is the site where thrombosis, secondary to atherosclerosis, starts in older persons.



Fig. 2. Femoral arteriogram showing obstruction of the popliteal artery. In younger persons thrombosis secondary to atherosclerosis often starts in the popliteal artery behind the knee-joint. The thrombosis may be precipitated by trauma to the artery.

In younger patients, in whom trauma may play a role, thrombosis starts in the popliteal artery behind the knee-joint (Fig. 2).

The treatment of patients with obstruction of the femoropopliteal artery can only be palliative since the patient cannot be cured of his atherosclerosis, but good results follow surgical relief of the obstructed artery. This can be achieved by an endarterectomy, where the thrombus and diseased intima are removed, or by the insertion of a graft bypassing the obstructed segment. To enable

one of these two operations to be done, the thrombosed segment must be limited in extent, and a patent and reasonably-sized artery must be present above and below the obstruction. If it is impossible to do an endarterectomy or to insert a bypass graft, two other surgical procedures have to be considered:

1. In patients with incapacitating symptoms, such as severe rest pain or ulceration, an above-knee amputation must be done.

2. In younger patients with distal (popliteal artery) obstruction, a lumbar sympathectomy may give worth-while improvement.

Conservative Treatment

Conservative therapy is carried out on all patients not requiring or not suitable for surgery and it consists of:

(i) The use of anticoagulants, which are very important in the treatment of arterial insufficiency of the lower limbs. They prevent extension of the original thrombus, which would have blocked the origins of collateral vessels, and they tend to prevent the occurrence of another thrombus at a different site, which would have further decreased the blood supply of the limb. They also lower the viscosity of the blood and therefore decrease the peripheral resistance. This results in bigger pressure gradients in the collateral arteries and, therefore, greater dilatation of these vessels.

(ii) The local care of the skin and its appendices must always receive proper attention and minor injuries must be treated immediately.

(iii) The general care of the body must not be neglected. Diabetes has to be controlled, and conditions which tend to induce vasospasm, such as smoking and exposure to cold, must be prevented.

(iv) Walking exercises are an important aspect of conservative therapy. The patient walks daily until intermittent claudication appears, and he soon discovers that the claudication distance increases from day to day. Exercise leads to vasodilatation and, therefore, a lower pressure in the small

arteries. The resultant larger pressure gradients in collateral vessels stimulate dilatation of these vessels and the development of the collateral circulation.

Antispasmodics

Antispasmodic agents do not have a place in the treatment of atherosclerotic arterial insufficiency because the diminished flow to the limb is the result of organic obstruction and not of arterial spasm. In addition, spasm of collateral vessels probably does not occur. Antispasmodic agents may induce peripheral vasodilatation and thus a larger pressure gradient in the collateral vessels which will dilate these vessels, but they cannot induce the same degree of vasodilatation that tissue metabolites cause and, therefore, are not as effective as regular daily exercise.

Thrombolytic Agents

Thrombolytic agents, such as plasmin or fibrinolysin, may have a place immediately after the onset of thrombosis when the thrombus can still be lysed. They are not of value in the chronic type of arterial obstruction discussed in this paper.

Surgical Procedures

The two surgical procedures that may be of dramatic help to the patient are an endarterectomy and a bypass graft operation. A good arteriogram is essential to determine if these operations can be done and it must show:

(i) The site and length of obstruction and the collateral arteries.

(ii) The inflow of blood from above, i.e. it must demonstrate the aorta bifurcation, the iliac and femoral arteries down to the obstructed segment.

(iii) The outflow of blood to the leg, i.e. whether the popliteal artery and its branches are patent (Fig. 3). The speed of blood flow in these arteries is also important because the outflow may be poor, although the arteries are patent,

in the presence of additional more peripheral obstruction. Sometimes a good outflow is provided by an excellent collateral circulation in spite of distal popliteal artery occlusion.

Experimentally almost any type of arterial replacement will remain patent if it is of moderate size and if it carries a large, fast flow of blood. Therefore, after an endarterectomy or a bypass operation, the flow of blood through the new segment must be good. Thrombosis of the graft or of the endarterectomized seg-

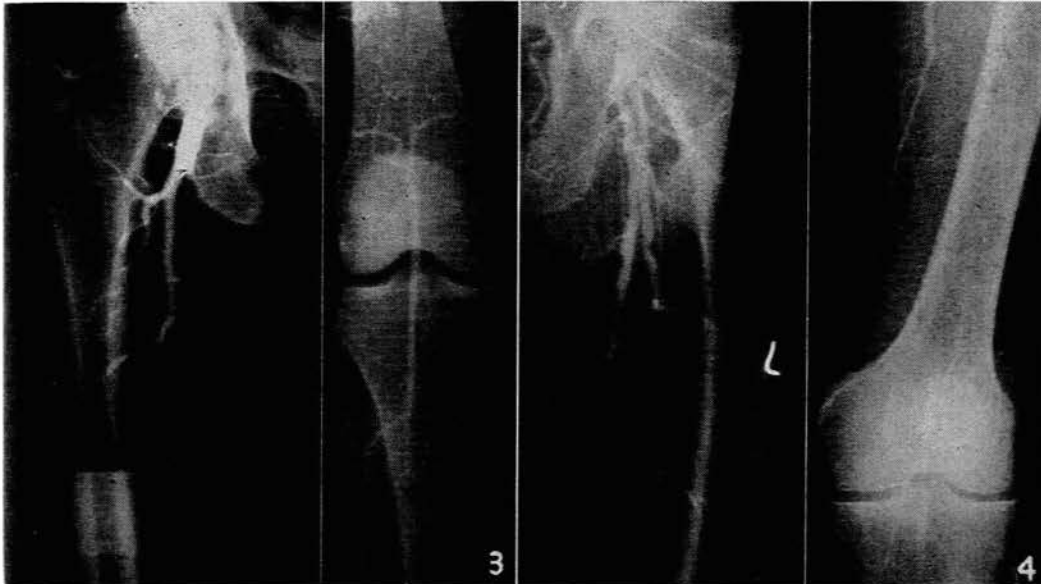


Fig. 3. Femoral arteriogram showing complete obstruction of the femoral artery at its bifurcation. The profunda femoral artery appears normal. The obstruction extends down to the origin of the popliteal artery. The arteriogram shows that this artery and its branches are patent. It suggests that there is a good outflow to the lower leg in this patient.

Fig. 4. Femoral arteriogram indicating obstruction of the femoral artery in the lower third of the thigh. The femoral artery is patent up to the origin of the descending genicular artery. Both the femoral artery and the profunda femoris show severe atherosclerotic changes, indicated by the irregularity of their outline. The popliteal artery is patent, but there is not a good outflow to the lower leg.

ment is likely to occur if either the inflow or the outflow of blood is poor (Fig. 4).

Clinical Observations

Observations were made on 88 patients who underwent surgery for femoropopliteal artery obstruction in the Karl Bremer Hospital since it was opened in 1956. Patients with proximal aorta and iliac artery obstruction and the large group of patients who were treated conservatively, are excluded. The operations carried out in this group of 88 patients are divided into 2 periods, and are shown in Fig. 5.

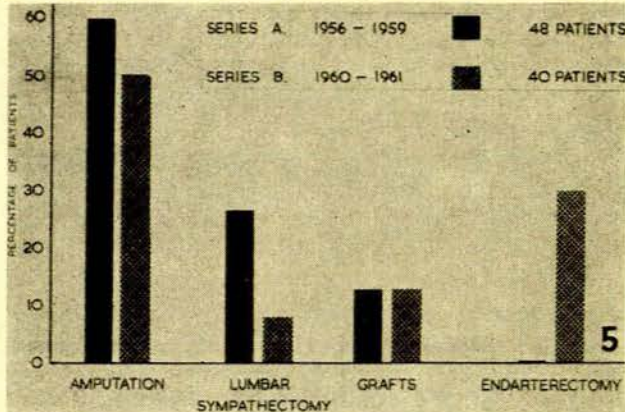


Fig. 5. Histogram indicating the types of operations done in 88 patients who presented with arterial insufficiency of the lower limbs and who have had femoral and/or popliteal artery obstruction. The operations have been divided into 2 periods to indicate the trend in operative treatment. There has been a slight decrease in the number of amputations; lumbar sympathectomy is done less frequently; there has been a marked increase in the number of patients subjected to endarterectomy, and the incidence of bypass-graft operations has remained the same. Those patients treated conservatively and those presenting with aortoiliac obstruction are not included in this group of 88 patients.

DISCUSSION

Certain aspects of the treatment of the patients mentioned above merit discussion:

The Arterial Blood Pressure and its Relation to Operation

A good blood pressure is necessary to keep a graft or an endarterectomized segment open in the postoperative period, since a temporary fall in blood pressure may lead to thrombosis. A high blood pressure may help to keep the endarterectomized segment or graft open, but may also put an excessive strain on the suture lines, especially when a graft is used. In one patient in this series in whom a bypass graft from the aorta to the popliteal artery, with a lateral anastomosis to the femoral artery, was used, the tension at the suture lines at operation was dangerously high because the patient had a blood pressure of 220/110 mm.Hg. The anastomosis between the graft and femoral artery separated 7 days after operation and a false aneurysm developed. After re-exploration, infection of the graft occurred. This led to fatal secondary haemorrhage a few weeks later. The danger of disruption of the suture lines in the hypertensive patient must be kept in mind when a decision is made regarding operative treatment.

Murmurs Over the Femoral Arteries

A murmur over the femoral artery in the groin suggests incomplete arterial obstruction at a higher level. It must be kept in mind that a murmur can be produced artificially by excessive pressure with the stethoscope. A murmur over the femoral artery does not indicate the degree of proximal obstruction. In the presence of obstruction distally in the femoral artery, obstruction may be present proximally without a murmur. The reason is that the distal obstruction allows only a small flow of blood in the femoral artery. In 3 patients in this series murmurs were heard in the lower half of the thigh over the femoral artery. In all 3, incomplete obstruction of the artery was present at the site of maximal intensity of the murmur (Fig. 6).

Spasm of Arteries

A narrowed artery, shown on an arteriogram, is often said to be in spasm. Although localized spasm of an artery is seen, it is unlikely that diffuse spasm ever occurs. The diameter of an artery, which is a hollow-muscular organ, depends to some extent on the arterial pressure, and, if this falls, the artery becomes narrower. Therefore a diffusely narrowed artery seen on an arteriogram may not mean that the artery is in spasm, but that partial obstruction is present at its origin (Fig. 7).

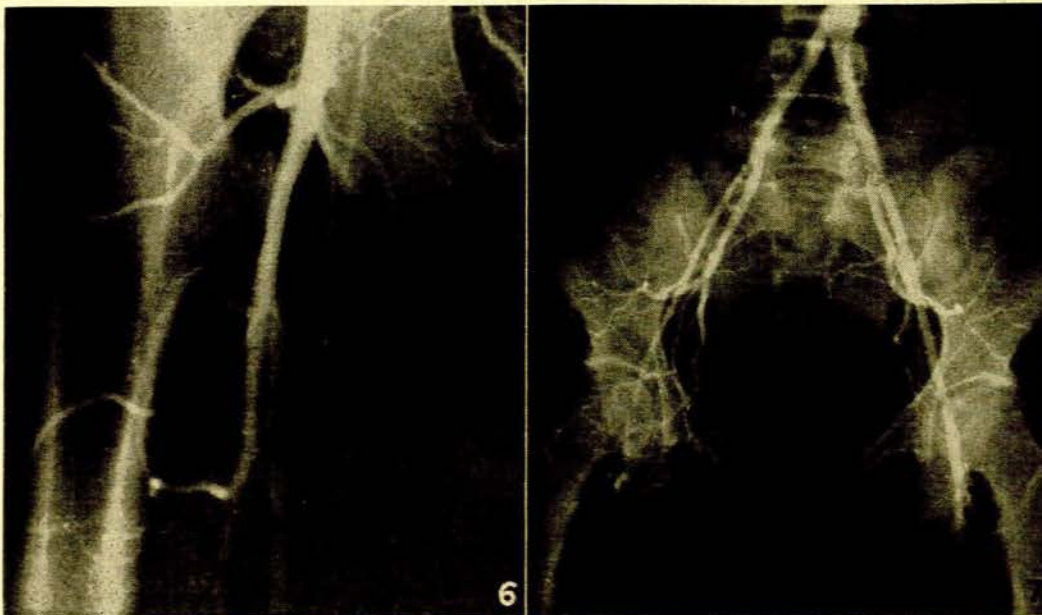


Fig. 6. Femoral arteriogram indicating partial obstruction of the femoral artery just below its bifurcation. A murmur was present in this patient, with its maximal intensity at the site of arterial narrowing.

Fig. 7. Aortogram showing obstruction of the right femoral artery where it lies over the femoral head. The right external iliac artery is smaller than the left one. This is not due to spasm of the artery, but to incomplete obstruction at its origin from the common iliac artery. Diffuse spasm of an artery probably does not occur.

Amputation

The incidence of amputation in the 88 patients reported in this paper is shown in Fig. 5. In series A, covering the period 1956-1959, the incidence of amputation was 60%, and in series B, covering the period 1960-1961, it was 50%. This high incidence of amputation stresses the seriousness of atherosclerotic arterial obstruction. When a patient presents with gangrene, even if limited, an amputation is usually required. In this series of 88 patients the operations of endarterectomy and bypass grafting saved the limbs of 20% of patients presenting with gangrene and severe rest pain. One patient in particular, who suffered from gangrene of the whole big toe, responded so well to an endarterectomy of a long segment of the femoral artery that he had, for practical purposes, a normal limb after the gangrenous toe was amputated.

The Choice Between a Bypass Graft Operation and an Endarterectomy

Both operations, if successful, will give good results and grateful patients. When a graft is used, the area of arterial obstruction is bypassed. When an endarterectomy is done, the obstructed artery is opened and the thrombus and intima are removed with special instruments (Fig. 8).

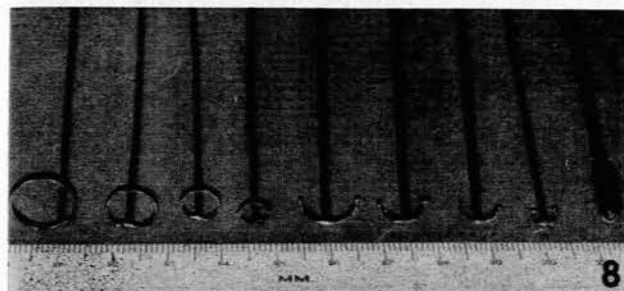


Fig. 8. Photograph of the special instruments used for the operation of endarterectomy at the Karl Bremer Hospital. These instruments were made in the Department of Surgery.

The adventitia and media are usually thickened and strong enough to withstand the arterial pressure. The internal surface is smooth and if the flow of blood is adequate, the segment will stay open. An endarterectomy, however, has the disadvantage of extensive dissection, and it is a more difficult operation than the insertion of a bypass graft. It is also difficult to know how far the endarterectomy must be carried distally since stripping of the intima can be done down to the bifurcation of the popliteal artery, but the posterior and anterior tibial arteries are too small. There is always a danger that the edge of the remaining intima will be folded inwards by the blood stream and thus cause obstruction. It is advisable to sew the intima to the outer layers at the lower end, but at the proximal end this is not necessary since the blood stream will press the intima against the outer layers.

The operation of endarterectomy also has certain advantages over a bypass-graft operation: (i) The danger of wound infection and secondary haemorrhage is smaller because a large foreign body is not inserted into the tissues, and (ii) if the operation is unsuccessful the thrombosis which occurs after an endarterectomy will be more limited than when a graft segments of the

main artery, which were open before operation, become thrombosed—the patient is much worse off than before operation and may lose his limb.

The Choice Between an Endarterectomy and a Bypass-Graft Operation in the Presence of Limited Gangrene

The presence of peripheral gangrene is usually an indication for amputation because it indicates a severe degree of arterial insufficiency, with the likelihood that the popliteal artery and its branches are occluded. In addition, the gangrene is usually infected, and perivascular lymphangiitis extends upwards along the main arteries so that any operation on these arteries will involve dissection of the infected lymphatic channels with the risk of infection and secondary haemorrhage. This is especially so when a large foreign body, such as a graft, is used. Limited gangrene of the toes is not necessarily a contraindication for an operative attempt to relieve the arterial obstruction, but the procedure of choice is an endarterectomy. In the series of patients reported in this paper, secondary haemorrhage, the result of infection of suture lines between the graft and artery, occurred in 4 instances. It was a very serious complication which led to amputation in 2 patients and was fatal in the other 2.

The Factors which Govern Arterial Outflow

A good flow of blood through an endarterectomized segment or through a graft, is essential to keep it open. There must not, therefore, be any severe obstruction in the branches of the popliteal artery, as shown by the arteriogram. However, the speed with which the blood flows through these arteries is also important, and this can be shown by taking serial X-ray photographs. The speed of flow through the peripheral parts of the limb

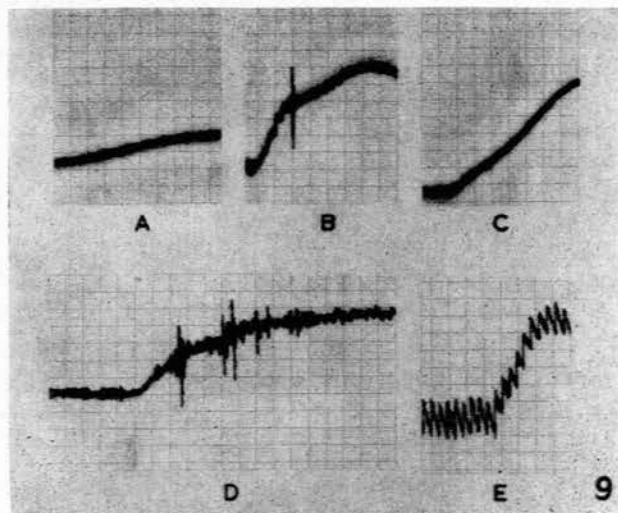


Fig. 9. Series of plethysmograms taken in the operating room and in the postoperative period on a patient on whom a successful endarterectomy operation had been done:

- Plethysmogram taken during operation, immediately after release of clamps on popliteal and femoral arteries. Venous occlusion shows a very poor inflow and there is a suggestion of a pulse.
- Plethysmogram taken a few minutes later; the venous-occlusion inflow has improved and the small pulse remains.
- Plethysmogram taken a few hours after operation. The venous-occlusion inflow is fair, but no pulse can be seen.
- Plethysmogram taken 1 day after operation. The venous-occlusion inflow is poor, but the pulse has increased slightly.
- Plethysmogram taken 2 days after operation. The venous-occlusion inflow is good and an excellent pulse is present.

can be increased by a lumbar sympathectomy, which is done at the same time as the operation on the obstructed artery. This decreases the resistance of the smaller arteries and therefore increases the flow through the graft or endarterectomized artery.

The tone of the peripheral arteries of a limb is increased as the temperature of an ischaemic limb falls when the limb is exposed to cool surroundings. Cooling of a limb is aggravated when the main arteries are clamped during operation and the foot may cool down to room temperature. After completion of the anastomosis and release of the arterial clamps, immediate spasm of the peripheral arteries may occur if the foot is cold. The resultant diminished peripheral flow may lead to thrombosis of the graft or endarterectomized segment. Serial plethysmography done during operation and in the immediate postoperative period, and correlated with the subcutaneous temperature of the foot, showed a good peripheral pulse and a good venous inflow immediately after release of the arterial clamps. When the foot had been allowed to cool to room temperature, the pulse and venous inflow diminished after a few minutes when tone in the small arteries returned and spasm was induced by the low temperature. If thrombosis did not take place during this phase, the blood flow gradually improved as the extremity warmed up (Fig. 9). This process might take several days (Fig. 10). This may explain why the anterior or posterior tibial pulse, which is felt immediately after a successful operation, sometimes disappears, only to reappear after a few days. It is possible to prevent this

spasm of the small arteries by keeping the patient and the extremity warm in the operating room.

Sometimes a syndrome analogous to the 'exposure foot' syndrome is seen in patients in whom severe ischaemia has been relieved by a successful operation. Redness, pain and swelling of the foot are present in the postoperative period. The foot is warmer than the opposite one. These changes are produced by the accumulation of metabolites. This syndrome is the result of severe pre-operative ischaemia, often made worse by cooling of the extremity during operation.

Arterial Pressures Measured at Operation to Determine Significant Inflow Obstruction

An arteriogram shows an artery in only one plane, and it may appear normal although the lumen of the artery is partly obstructed (Fig. 11). To exclude significant inflow

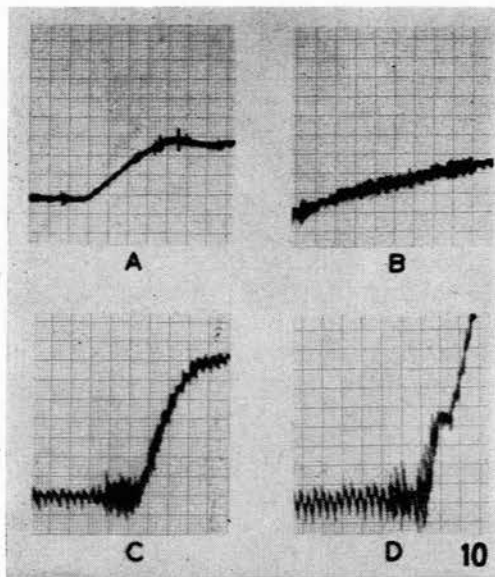


Fig. 10. Plethysmogram taken on a patient who had a successful bypass-graft operation:
A. Plethysmogram taken immediately after the graft had been inserted and the clamps had been taken off the femoral and popliteal arteries. No pulse is visible and the inflow on venous occlusion is poor.
B. Plethysmogram taken one day after operation. A small pulse is present, but the venous-occlusion inflow is still poor.
C. Plethysmogram taken 2 days after operation. A fairly good pulse can now be seen, and the venous-occlusion inflow is good.
D. Plethysmogram taken 4 days after operation. There is an excellent pulse and an equally good venous-occlusion inflow.

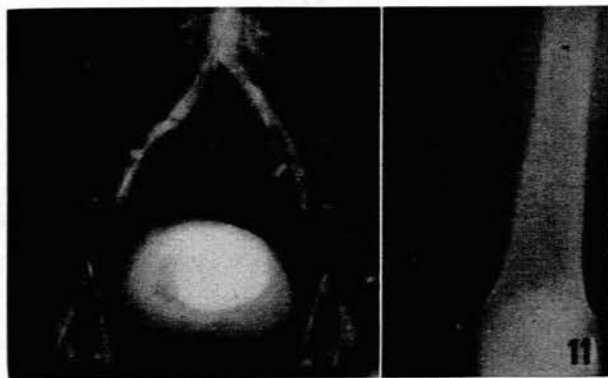


Fig. 11. Aortogram showing an incomplete obstruction of the femoral artery in the lower third of the thigh. In addition, there is a poorly visible filling defect at the origin of the right common iliac artery. Severe atherosclerosis was present in this situation and this resulted in thrombosis following an endarterectomy on the obstruction in the femoral artery.

obstruction a cardiac catheter (no. 6) is attached to a transducer and a recording apparatus, and inserted at operation through the femoral artery so that its tip lies in the aorta. It is then gradually withdrawn and the arterial pressure is registered. If significant obstruction is present, a pressure drop occurs as the catheter tip passes the obstruction (Fig. 12). A significant fall in blood

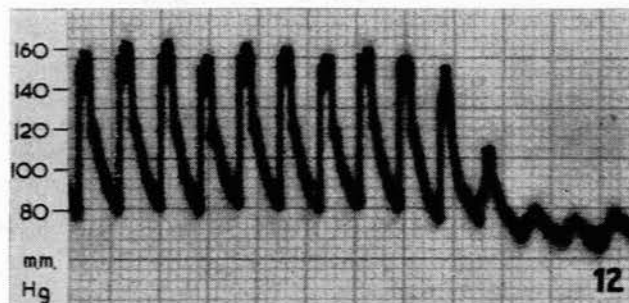


Fig. 12. Blood-pressure tracing taken during operation by means of a catheter inserted through the femoral artery so that its tip lies in the abdominal aorta. The catheter is attached to a transducer and recording apparatus and is gradually withdrawn. The tracing shows a sudden drop in systolic pressure. Such a sudden fall in arterial pressure more accurately indicates the severity of proximal obstruction than an arteriogram.

pressure is regarded as an indication for exploration of that area of the artery where the drop in pressure occurs,

and this site is determined by marking the catheter and measuring its length.

The Use of Anticoagulants in Arterial Insufficiency of the Lower Limbs

Anticoagulants are used, not to keep the graft or endarterectomized segment open, but to prevent thrombosis elsewhere. It is advisable to start the patient on anticoagulants soon after operation, but there is a risk when anticoagulants are administered too soon. Two patients in this series were heparinized in the operating room and both bled in the postoperative period. In one the wound was drained by means of a tube connected to a suction pump so that the amount of blood lost could be measured accurately and replaced. This patient lost 2 litres of blood in the first 8 hours postoperatively. He was then given protamine, and the bleeding stopped. In another patient in whom no drainage was provided, severe bleeding occurred in the tissues around a graft. He had an episode of hypotension and died 8 hours after operation from a myocardial infarction. It is interesting that in this patient heparinization did not prevent coronary-artery thrombosis.

An endarterectomized artery or a graft will thrombose in spite of the administration of anticoagulants if the inflow and outflow of blood is poor. This was well demonstrated in one patient in whom thrombosis of an endarterectomized artery occurred despite the administration of anticoagulants. He was re-operated on 14 days later and a more extensive endarterectomy was done. No anticoagulants were given after this second operation, but the artery remained open. Our routine procedure is not to give these patients any heparin, but to start them on coumadin 24 hours after operation.

It may be asked if an operation can be done on an obstructed artery while the patient is receiving anticoagulants. Operations on the heart, e.g. a mitral valvotomy, can be done in spite of anticoagulant therapy, provided the prothrombin index is above 50. A number of patients with arterial insufficiency of the lower limbs have had a coronary thrombosis and are on long-term anticoagulant therapy. There is a definite risk of an increased tendency to arterial thrombosis if they are taken off anticoagulants, and in them an operation on the obstructed artery can be done without discontinuing the anticoagulant therapy. It is probably inadvisable to use a long bypass graft when a patient is on anticoagulant therapy, since there is danger of bleeding into the tunnel around the graft. An endarterectomy, therefore, may be a safer operation.

All patients with arterial insufficiency of the lower limbs should receive long-term anticoagulant therapy, whether they are operated on or not. Anticoagulants in these patients will also help to prevent arterial thrombosis elsewhere in the body, e.g. in the coronary or cerebral arteries. With permanent anticoagulant therapy, occlusion of a graft or an endarterectomized artery one or more years after a successful operation, may be prevented. At the Karl Bremer Hospital long-term anticoagulant therapy for these patients has been in use for 18 months only and although the immediate results are promising, this period is too short for evaluation.

CONCLUSIONS

The main indications for a bypass-graft operation or for an endarterectomy on an obstructed femoral or popliteal artery, are:

(i) Ischaemia with threatened gangrene of the limb, severe rest pain, limited gangrene or ulceration.

(ii) Intermittent claudication so severe that the patient cannot do his work, even if he changes his occupation.

(iii) Arterial obstruction from thrombosis which follows embolism or trauma, where an arteriogram shows that the rest of the arterial tree is normal. In these patients severe symptoms do not necessarily have to be present to indicate an operation, and the operative results are usually good.

Permanent anticoagulant therapy in patients with arteriosclerotic arterial obstruction is essential.

Although a bypass-graft operation, or an endarterectomy, is done on the artery of a limb, it is an operative procedure not to be undertaken lightly. Atherosclerosis is a generalized disease and there is a risk of occlusion of the arteries to the heart and brain during and immediately after the operation. In addition, the operation is often associated with a significant blood loss. It is wrong to state that not much harm is done if the operation fails. These operations should only be done if the surgeon is experienced, if the general condition of the patient is satisfactory, and if definite indications for relief of the obstructed artery are present.

SUMMARY

1. Patients with severe arterial insufficiency of the lower limbs require amputation, whereas those with minimal symptoms and signs do not require any treatment. The great majority of patients, however, fall between these two groups, and the treatment of these patients is discussed. They can be helped greatly by an endarterectomy or a bypass-graft operation. If these operations are not possible the other methods of treatment are amputation, lumbar sympathectomy, and conservative therapy. The importance of anticoagulants and walking exercises in conservative therapy is stressed.

2. The clinical observations on 88 patients with femoral and popliteal artery obstruction, who were treated surgically at the Karl Bremer Hospital during the last 5 years, are discussed. It is pointed out that an endarterectomy is probably a safer operation than a bypass-graft procedure, because the danger of infection is less and, if infection occurs, secondary haemorrhage is less likely. If the operation fails thrombosis is more limited in the patient who has had an endarterectomy and he is not necessarily worse off after his operation.

3. A syndrome analogous to the exposure-foot syndrome may occur if cooling of the extremity is allowed to take place in the operating room or if the ischaemia of the limb has been severe before operation. This syndrome is discussed with reference to serial plethysmography. The use of anticoagulants in the postoperative period and long-term anticoagulant therapy in patients operated on, are discussed.

4. It is pointed out that these operations on obstructed femoral and popliteal arteries should not be undertaken if the surgeon is not experienced and if the patient's general condition is not satisfactory. Definite indications for the relief of the obstructed artery must be present. These are: ischaemia with threatened gangrene, severe rest pain, limited gangrene or ulceration, and severe intermittent claudication.

REFERENCE

1. Louw, J. H. and Roberts, W. M. (1961): *S. Afr. Med. J.*, **35**, 346.