THE SURGERY OF ARTERIAL DISEASE AND INJURY*

BY

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The early diagnosis and treatment of arterial injuries have been well described in the Medical Research Council's War Memorandum No. 13, but with the end of the war the problems of peripheral vascular disease will again become the more important, and therefore I intend to consider them first. I would like to make it clear from the start that they are not so intricate that only the specialist, working with a highly trained team at a special centre, can hope to understand them and to undertake the treatment of vascular disease. It should be the duty of those occupied in clinical research to correlate the results of their elaborate investigations with clinical methods of observation, so that the practitioner may be able to form a pretty accurate estimate of the nature and extent of the disease he has to treat. The surgical specialist should aim at simplification and standardization of technique, so that it may be easy for others to follow his lead, and thus the advances in surgical treatment may become widely known and practised.

Difficulties must arise when unusual features present themselves, and it is under such circumstances that the experience and judgment of the specialist are required in the selection of the patients who are likely to benefit from surgical treatment.

Raynaud's Disease

It is now customary to refer to any condition in which coldness and cyanosis of the digits occur on exposure to a moderately low temperature as the " Raynaud phenomenon." It may be seen in association with any form of obliterative or degenerative arteritis, it may be secondary to pressure by a cervical rib, or it may follow frost-bite or injury from the use of vibrating tools. It is unfortunate that Raynaud himself did not describe a single clinical entity, yet there is a clearly defined condition to which the term Raynaud's disease should be limited. It is characterized by colour changes in the digits produced by cold, occurring in attacks which show a rapid onset and recovery, and affecting the extremities symmetrically. The peripheral pulses are preserved, and if there is any loss of tissue it is never more than shallow ulceration close to the finger-tips: true gangrene is extremely rare. The disease is seen almost exclusively in the female sex—in fact, if a male patient presents a similar picture it is likely to be an early stage of obliterative arteritis and not Raynaud's disease.

A patient who suffers from Raynaud's disease in this country will be relieved of her symptoms by going to live in a warm climate, and even a change of occupation so as to avoid local exposure to cold will produce some improvement. We have not found emotion to be a common exciting cause of attacks ; neither is excessive sweating of the extremities at all frequent in our experience. For these and other reasons we follow Lewis's teaching that the disease is due to a local fault in the small arteries, and not to a central affection of the sympathetic nervous system. Furthermore, it must be pointed out that by the term " local fault " Lewis did not mean that even in mild Raynaud's disease there is some structural change in the vessels ; the fault is an abnormal sensitivity to local cooling.

On the other hand, it can be shown that the more severe forms of Raynaud's disease are complicated by structural changes in the arteries—obliterative arteritis and thrombosis—and this is the most important of the factors determining whether a patient is likely to benefit from surgical treatment. In the mildest form there are only colour changes in the digits, and the arteries are still able to dilate rapidly and completely as the attack passes off. There is an intermediate group of moderate severity complicated by shallow ulceration of the finger-tips, in which vasodilatation occurs more slowly and is incomplete. In the most severe group, which shows sclerodactyly or hypodermolithiasis in addition to the other manifestations of Raynaud's disease, structural changes in the small arteries may prevent vasodilatation, so that the response to vasomotor inhibition or paralysis may be identical with that seen in advanced arteriosclerosis.

In Raynaud's disease the stimulus of cold almost obliterates the lumen of the digital arteries. After section of the vasomotor nerves their lumen is permanently increased, so that the same stimulus, while still reducing it greatly, does not arrest the circulation completely. The very different response to cold after sympathectomy in a person with normal vessels and in a patient with Raynaud's disease is further evidence in favour of the view that the vessels themselves are peculiarly susceptible to stimulation by cold.

It is clear, however, that unless sympathetic denervation is complete, vasodilatation will be inadequate, and the possibility of the obliteration of the artery by cold will persist. The importance of this factor is demonstrated by patients who show a good result in one hand and a poor result in the other after what were intended to be identical operations on the two sides. Anatomical variations in the origin and distribution of sympathetic rami are well known, and it is therefore essential to plan our operations so that there is the least possible risk of missing a few of them. It must not be forgotten that nerve impulses are mediated by chemical substances liberated at nerve endings, and widespread contraction of muscle may therefore result from the sparing of single nerve filaments.

For this reason we now favour the posterior approach to the upper thoracic sympathetic trunk as modified by White and Smithwick (1942). Though the anterior approach as modified by Telford (1935) can achieve the same object in skilled hands, the less experienced are likely to find the posterior approach a simpler operation, and resection of the medial ends of the second and third intercostal nerves is a good safeguard against sparing any anatomically abnormal filaments.

It will be noted that these operations are designed to make a preganglionic section of the vasomotor supply to the arm. Removal of the second, third, and fourth lumbar ganglia, the usual operation for sympathetic denervation of the lower extremity, is a purely preganglionic section for the foot. It is well known that the sensitization of sympathetic nerve endings to adrenaline is less after preganglionic than after postganglionic section ; and as this sensitization plays a part in restoring a degree of vasoconstriction and so producing " recurrences " after operation for Raynaud's disease, the importance of planning a preganglionic operation is manifest. The uniformly better results obtained by operation for Raynaud's disease of the feet are often accounted for entirely on the ground that the lumbar operation is preganglionic, whereas in the thoracic operation some postganglionic elements also may be damaged. But it must be remembered that the disease

is never as severe in the foot as in the hand. Ulceration and sclerodactyly of the toes are almost unknown.

It is often said that sympathectomy is effective only for a few months or a year, suggesting either that nerve regeneration is the rule or that the peripheral remnants of the sympathetic can function independently. But the sympathetic denervation following a well-planned and correctly executed operation is permanent, as shown by sweating tests in addition to vasomotor reactions. In progressive structural disease symptoms may persist and increase in severity ; certain organs may be capable of acting without nervous control ; but these manifestations must not be misinterpreted as evidence of failure of sympathectomy. They show that there may have been an error of judgment in selecting patients for operation, and so far as Raynaud's disease is concerned the predominant consideration must be the severity of the disease. Milder forms react favourably to sympathectomy: the operation is often futile in the presence of complications, especially sclerodermia.

Obliterative Arteritis

Structural disease in the arteries of the leg is of many varieties with many different causes, ranging from injury to thrombo-angiitis and arteriosclerosis—presenile, senile, and diabetic. But whatever may be the aetiology, it is the level of the block in the arterial tree which determines the clinical picture and the value of sympathectomy in its treatment. This important fact was demonstrated arteriographically by Boyd in 1938, yet it is still commonly taught that in any form of obliterative arteritis the disease runs a progressive course characterized by intermittent claudication in the early stages, followed later by rest pain.

Actually three clinical groups may be recognized. In one a main vessel such as the femoral or more commonly the popliteal artery is thrombosed and the presenting symptom is intermittent claudication in the calf muscles. Though the foot may be appreciably colder than the other—for the disease is often unilateral—the nutrition of the skin of the foot remains good and gangrene does not occur, since the proximal vessels alone are involved and an adequate collateral circulation develops to keep the distal vessels supplied. It must be noted that if the posterior tibial artery is blocked in this way intermittent claudication in the muscles of the sole of the foot is the result, but may be mistaken for " foot strain."

When the popliteal artery is thrombosed the sural arteries supplying the gastrocnemii are likely to be permanently blocked, causing irreparable damage because of the poor anastomosis within the muscle itself. It is therefore not surprising that sympathectomy is of little or no value for claudication arising in this way. If, however, the block is in the external iliac or femoral arteries the outlook is much better, since the post-operative improvement in the collateral circulation at the level of the block provides a considerable increase in the blood flow to the calf and we have had enough experience to convince us of the great value of sympathectomy in these more proximal blocks.

The diagnosis can be made by anyone who has learnt to feel the pulse in the popliteal artery. This is too often regarded as a difficult examination and is therefore neglected. All the pulses in the leg—femoral, popliteal, posterior tibial, and dorsalis pedis—must be felt for as a routine examination. More accurate information is obtained by oscillometry, but this is rarely required for diagnosis: it is of much value in assessing the severity of the disease, and is therefore useful for prognosis.

The intensity of postural colour changes in the foot, and the rate 'at which superficial veins refill after they have been emptied by elevating the limb, are helpful in indicating the degree of arterial obstruction.

These simple clinical methods usually provide all the information required to make a decision for or against sympathectomy, but brief reference must be made to the more complicated tests with local or spinal analgesia, and to arteriography. Spinal analgesia produces vasomotor paralysis, but the local blocking of sympathetic trunks with procaine has the advantage that muscle power is preserved, and so it is possible to test the effect upon claudication by getting the patient to carry out repeated movement against resistance under controlled conditions before and after the injection.

The duration of the sympathetic paralysis in these tests is brief, and whereas a good response is an argument in favour of operation, a poor response should not be sufficient in itself to deny a patient any chance of relief by sympathectomy. The improvement in collateral circulation which accounts for any post-operative improvement in the limb is a gradual process, and this explains the well-known fact that the results of sympathectomy for obliterative arteritis are usually better than tests by temporary nerve-blocking might lead us to expect.

It is often said that it is only when spasm is an important factor in the disease that sympathectomy is worth while. But an improvement in the blood flow after spinal analgesia is not evidence that spasm has been relaxed, for it is the reaction produced in any normal individual. It really means that the arteries are capable of relaxing fully when vasoconstrictor impulses no longer reach them, and a poor response indicates that the structural changes of degeneration or inflammation interfere with this normal reaction. No doubt spasm does play a part in obliterative arteritis, but its importance has been greatly exaggerated.

Another disturbing dictum is that sympathectomy is contra-indicated for claudication because, if the operation is successful and the circulation in the skin is improved, there must necessarily be a corresponding impairment of the deep circulation to the muscles. There is experimental evidence that sympathetic impulses are vasodilator to the arteries of skeletal muscle, and this provides a strong theoretical argument against sympathectomy for claudication. We have enough practical experience, however, to show that the operation is often beneficial, and our disappointments are to be explained by the obliteration of certain important muscular branches. Arteriography is the only pre-operative examination which can give us information on this point, but it must not be assumed that this test is often necessary, as the decision about operation can usually be made without its aid.

In the second clinical group the distal arteries, of the size of the plantar arch and its digital branches, are principally affected, and the characteristic features are pain in the foot at rest, often worst in bed at night, and nutritional changes in the skin—discoloration, ulceration, and gangrene. When dependent the toes or the whole foot are of a reddish-blue colour, and they blanch when elevated above heart level. Permanent discoloration of the affected parts heralds the onset of gangrene. The pulse in the main vessels, at the knee and even at the ankle, may be present, and under such circumstances there is an abrupt drop in the surface temperature at the level of the arterial obstruction.

Sympathectomy can achieve a great deal in this distal group—the intense pain is often abolished, and if it persists it is because gangrene has already been established. The improvement in the circulation in the foot after two or three weeks may be sufficient to permit the successful local amputation of toes ; and if the stump fails to heal and pain recurs we know that a major amputation is necessary, though it may be done below the knee.

In the third group there is widespread narrowing of the lumen throughout the arterial tree. Rest pain follows closely upon intermittent claudication, and gangrene of the toes occurs with loss of the pulse in the main vessels at the knee or at the groin. Under such circumstances sympathectomy is useless, and amputation above the knee becomes inevitable.

Arterial Injuries : Early Treatment

For small lacerations simple suture may be effective, and if it is available fibrin foam is valuable in strengthening the repair. For more extensive wounds, in which suture would narrow the lumen unduly, complete division with axial anastomosis, or the re-establishment of the stream using a cannula or vein graft, is preferable to complete division and ligation of each end, though the last may be the only possibility under conditions of stress. It is unfortunate that so often the conditions under which the wound has to be treated preclude any long and delicate procedure requiring special apparatus. The attempt to restore the lumen, even if it succeeds only for a short period, may be of the greatest value if it gives time for the establishment of a collateral circulation before the vessel finally becomes blocked.

It must always be remembered that, if the artery has to be ligated, double ligation by itself is not enough—in fact, it is dangerous because the longitudinal tension in the artery increases the risk of secondary haemorrhage. The damaged segment must be excised, and not for this reason alone, since it may set up spasm in the peripheral arteries. Excision may be regarded as the most radical form of periarterial neurectomy, which explains the post-operative improvement in the colour and temperature of the limb.

These remarks also apply to contusion of an artery such as may follow a "near miss." It may be a difficult matter to determine whether an artery is constricted because it is bruised or merely because it is in spasm, from which, of course, it may recover within 24 hours. If there is much discoloration it is more than likely that intimal damage will cause thrombosis, and it will usually be wise to excise the damaged portion. If in such a case it is decided to postpone excision because blood is still, flowing through the constricted part of the artery the surgeon should be prepared to reopen the wound within 12 to 24 hours if there are no signs of improvement in the peripheral circulation. By this time the appearance of the vessel should indicate clearly what ought to be done.

When an artery has to be tied soon after an injury we would follow Makins's teaching and tie the companion vein. Reference will be made later to the inadvisability of tying the vein in the later stages.

Should sympathectomy be performed—or at least injection of the sympathetic supply with local analgesic solution or alcohol—to encourage collateral circulation after the sudden block of a large artery? There are animal experiments to show the value of sympathectomy under such circumstances, gangrene being greatly limited in extent or avoided altogether. There is also much clinical evidence of the value of sympathectomy as a preliminary to ligation of a main vessel, such as the popliteal artery, which is known to carry a serious risk of gangrene. But the assessment of sympathectomy after wounding of a main artery is a different matter, and we must await the full report of the Army's forward surgical teams before drawing any conclusions. My own experience of a few patients upon whom sympathectomy or injection had been performed shortly after wounding was unfavourable, but there may have been many successfully treated at the front who were therefore never sent to a vascular centre at the base.

There are, however, many other measures which should be taken to give the best chance of survival to a limb threatened with gangrene. The most simple, and perhaps the most important, is attention to the position of the limb. If it is too much elevated it will become pale and cold, because of the free drainage of blood out of a limb which has a very limited supply. If it is allowed to hang down it will become cold and blue from venous congestion. In both of these positions pain may be severe, but an optimum position may be found which is most comfortable, and in which the limb is warmest and of the best colour—it is usually with the limb extended at or just above heart level.

Reflex vasodilatation of collateral vessels may be brought about by heating the trunk and the healthy extremities, but the affected limb must be kept cool—either exposed to room temperature, or even cooled by a fan or ice packs. Warming a limb increases the local tissue metabolism and therefore the demand for blood ; cooling has the opposite effect, and thus tends to reduce the need for oxygen to approximate to the amount which can be supplied by the impaired circulation.

Rapid transfusion of a pint (473 c.cm) of blood may have the effect of forcing open collateral vessels, and is naturally especially valuable after severe blood loss.

Traumatic Aneurysm and Arteriovenous Fistula

In managing these later results of arterial injury it is most important to bear in mind that the safety of the limb depends upon delaying operation to provide time for an adequate collateral circulation to develop. As a rule there is no difficulty about waiting for three months or more when there is a fistula, since the force of the arterial pulse can diffuse easily into the open vein without much, if any, increase in the size of a false aneurysm sac. But with an injury which is purely arterial it

happens not infrequently that a steady increase in the size of the false sac, and in the severity of pain, necessitates intervention at an earlier date. In our own limited experience I have been forced to operate upon one brachial and three axillary false aneurysms within a month of wounding.

This experience has brought it home to me that the usual description of the production of a traumatic false aneurysm does not cover all of them. It is said that the haematoma which forms immediately upon the arterial wound becomes hollowed out like a cup, the original clot thus forming the wall of the sac. When this happens the wall must be fairly substantial, and when organized should provide a strong fibrous barrier against the arterial pressure. Fresh layers of clot would form within the sac, so that spontaneous cure of a small aneurysm may follow. I believe that I have seen this occur in two of our soldiers.

But the aneurysms which demanded early operation gave clinical signs of having thin walls which yielded alarmingly to the pulse beat, and when they were opened there was a central mass of blood-clot surrounded by fluid blood within the very thin and imperfect sac wall formed by the surrounding muscle and connective tissue. I wonder how frequently this may be the state of affairs in traumatic false aneurysms : I suspect more frequently than current teaching would lead us to expect.

The definitive treatment of a traumatic aneurysm is extirpation of the sac whenever this is possible, but for the brachial aneurysm and two of the axillary aneurysms which required earlier operation I performed proximal ligation as close as possible to the aneurysm as a preliminary measure ("immediate proximal ligation"). This was done to reduce the size of the swelling, which threatened to rupture and also compressed neighbouring collateral vessels, to give further time for the development of a collateral circulation, and to facilitate the direct approach to the aneurysm itself three or four weeks later. For one of them—an aneurysm of the third part of the axillary artery—I combined the preliminary ligation with upper thoracic sympathectomy. The nutrition of the limb did not suffer, nor was the second stage of the operation rendered more difficult by the first stage of this double procedure.

Before deciding upon proximal ligation, however, it must be clearly established that the lesion is purely arterial, for this operation carried out on an arteriovenous fistula is fraught with grave danger and may be disastrous, because the ligature interferes seriously with the developing collateral circulation at the level of the fistula, without impeding in any way the too easy return flow of blood into the veins. The danger was well illustrated by a patient transferred to us after ligation of the external iliac artery for a large varicose aneurysm of the femoral artery which also involved the origin of the profunda. As soon as he had recovered from the anaesthetic he was found to have an external popliteal nerve palsy and a cold painful foot which showed all the manifestations of severe ischaemia, though gangrene fortunately never became fully developed.

Diagnosis of Arteriovenous Fistula

An arteriovenous fistula can be recognized by the character of the bruit which is heard over it and is conducted for great distances proximal and distal to it. It is a continuous whirring clattering sound with a systolic crescendo, and well deserves its common designation of "machinery murmur." This should be sufficient in itself to distinguish a fistula from an arterial aneurysm with its systolic bruit.

There are many other associated signs, of which tachycardia and an increase in pulse pressure, owing to a drop in the diastolic blood pressure, are usually the first to be recognizable. The increase in pulse rate may not be noticed until the remarkable slowing of the pulse which follows obliteration of the fistula by digital compression has been observed. Only one of our 34 arteriovenous fistulae was associated with a cardiac murmur, and overfilling of superficial veins was rarely seen : these would appear to be later developments. All of our patients showed some degree of enlargement of the heart. though very few were reported by the radiologist to be beyond the normal limits ; the heart decreased in size in every one after closure of the fistula, yet it is clear that the diagnosis cannot be made by this method. The blood volume also was less after

closure of the fistula in every patient thus examined; but although it is possible in the end to say that the blood volume was shown to be increased on the average by about 15%, as the "normal" blood volume of a given individual is not known the pre-operative figure can scarcely be expected to provide evidence of a fistula.

It is much more difficult to decide where the fistula is and what vessels are involved. The loudness of the bruit is deceptive, and the determination of the point where pressure will abolish it may not be an accurate guide, because compression of the main vessel proximal to the fistula can give the same result. Arteriography, which is a great help when a main vessel is obstructed, usually fails to give a clear picture of a fistula, especially if it is large enough to allow the opaque material to diffuse rapidly into the vein. The track of the missile as shown by a through-and-through wound or a retained foreign body is often the best guide. But the decision usually has to be made by guesswork, and over and over again one has felt that the whole undertaking would have been so much simpler had one started with the information which has to be gathered in the course of the operation.

Treatment of Arteriovenous Fistula

We learnt that for safety it is necessary first to pass controlling tapes round the artery and vein involved as near as possible above and below the fistula without opening into it. In a bullet wound this may be comparatively simple, but as most of the wounds were caused by fragments of mortar shell or bomb, and as there had clearly been widespread haemorrhage with subsequent scarring inside and outside the vessel sheath, it was often a tedious dissection to clear the required length of the artery without damaging branches which were needed as collaterals. For the same reason it is often difficult to find healthy enough vessel wall to hold sutures, especially with varicose aneurysms, and I often felt humiliated by my lack of enterprise, for we were commonly reduced to quadruple ligation instead of carrying out the various forms of arterial reconstruction which we had hoped to attempt. On the other hand, it must be admitted that the results obtained by this "old-fashioned" method were not unsatisfactory.

We carried out lumbar ganglionectomy two to three weeks before all our operations for arteriovenous fistula in the lower extremity, with the single exception of a fistula between the peroneal artery and vein. We did this partly because our series was intended to link up with that of Lieut.-Col. A. M. Boyd, and I understood that this was also his practice; partly because, even in spite of waiting for a collateral circulation to form, damage might be done to it in the course of the dissection of the lesion, and the best possible collateral circulation therefore seemed to be desirable; and partly also because I knew that at other centres these fistulae were being treated without sympathectomy and I hoped our series might form part of an interesting controlled experiment. It may yet appear that we were unnecessarily over-cautious, but we never saw anything approaching gangrene of a toe. It would be wrong to draw conclusions from our small numbers—1 common femoral, 3 superficial femoral, 5 profunda femoris, and 7 popliteal lesions—but they all recovered with good function. The most critical was in the man who had already had his external iliac tied in continuity for a common femoral arteriovenous fistula: after a preliminary lumbar ganglionectomy I was forced to do a "triple arterial" ligation of his common, superficial, and deep femoral arteries, yet six months later he was able to walk four miles without pain, his residual disability being due to the ischaemic palsy of the external popliteal nerve, which was steadily recovering.

While quadruple ligation was in our experience the usual treatment for arteriovenous aneurysm, it may be possible to vary the procedure for aneurysmal varix. The scarring is less as a rule—no doubt the direct opening of the artery into the vein serves to limit the amount of blood extravasated into the surrounding tissues—and the dissection of the lesion is more straightforward. In two popliteal fistulae after the vein had been tied above and below the fistula it was possible to narrow down the communication till it could be safely ligated as though it were a branch of the artery, and thus the artery itself was spared.

Syndrome of Venous Obstruction

We were rather surprised, however, to note that these patients whose popliteal artery was preserved at the cost of the vein were less comfortable than those who had had both vessels blocked by quadruple ligation. They complained of aching pain and a bursting feeling in the lower leg, ankle, and foot produced by lowering the leg, which was more severe in the standing than in the sitting position, though sitting in one position for an hour or so may be almost intolerable. The pain may be relieved by walking for a short distance, but the quickest and most effective method of easing the pain is by lying down with the legs raised above "heart level." Swelling round the ankle may accompany the pain.

We came to recognize these symptoms of venous obstruction in many patients after injury or operation, but we also noticed that they are more marked when the arterial supply is unimpaired. Being persuaded that when ligating an artery immediately after an injury simultaneous ligation of its companion vein is advisable or is at least harmless, it took us a long time to realize that the different conditions under which ligation is undertaken at a later stage may call for different treatment. We had thought, with others, that in the treatment of an arteriovenous fistula, while immediate proximal and distal ligation of the artery would be sufficient to stop the vicious circulation, the additional ligation of the vein would be better (Maybury, 1945).

But the recognition of these symptoms as those of venous obstruction made us think again, and we were able to put the matter to the test in two fistulae—one between the profunda femoris artery and the common femoral vein, and the other between the superficial femoral artery and vein. For both of these we ligated the artery as close as possible above and below the fistula but left the vein intact. Neither of the patients complained of any of the symptoms of venous obstruction, and both had an adequate peripheral arterial supply. It is therefore our impression that the collateral circulation resulting from an arteriovenous fistula safeguards the arterial flow to the limb after ligation of the artery, and that it is a distinct advantage to preserve the vein whenever this is possible.

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OBSERVATIONS ON CASES OF STARVATION AT BELSEN*

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Belsen was a detention and not an extermination camp— that is to say, not a camp where organized extermination was carried out. Originally devised for perhaps a few thousand people, it became progressively more overcrowded in the early part of 1945 as the Allied armies closed in from west and east and forced the Germans to evacuate other concentration camps. At its peak it is said to have contained over 66,000 persons. The majority of these were Jews of Polish or Hungarian origin, but almost all countries and religions were represented. Many of the patients had spent only short periods in Belsen, having previously been interned in other concentration camps, such as the notorious one at Auschwitz. However, the following notes, based on information given by a Hungarian woman doctor who was in Belsen for four months, convey some idea of the diet on which they had existed before the liberation of the camp.

In Jan., 1945, there was already very little food, but the quality was not so bad. Each person got one-sixth of a loaf a day (the loaf was black and weighed about 1.4 kg.), and sometimes potatoes and pieces of meat. For instance, there was occasionally a thin slice of sausage for supper and a little meat in the soup. On Sundays tinned meat was distributed; 12 persons shared one tin. By February everybody was getting

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