

From the Central Hospital of Kuopio, Finland.

RESULTS OF PERIPHERAL ARTERIAL SURGERY

By

L. W. F. LINDÉN

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INTRODUCTION

The importance of surgery depends on its outcome. Without positive results surgical measures are not justified. The role of surgery is to cure—to bring about a favourable physiological change by local instrumental manipulation. In recent years, new reconstructive methods have been developed, and in the case of arterial surgery, the results of reconstruction are becoming generally known.

The benefits of surgery differ in degree. A cure can be complete or partial in respect of time and function. Reconstruction can be either fully or partially successful.

Surgery has strengthened its position thanks to improved equipment, anaesthesiology, antibiotics, physiological methods, including fluid and electrolyte balance treatment and the use of respirators together with methods of examinations, such as arteriography and heart catheterization.

The improvement in the methods has enlarged the scope of surgery, particularly in the case of serious states and diseases. The surgical treatment of arteriosclerosis is a special branch. It comprises local surgical therapy of progressive disease of the arterial system. Surgery cannot cure systemic disease, but it can remedy local circulatory disorders caused by them. If the machinery has been worn down at several points, however, the renovation of a single part will not repair it or bring about any total improvement in its functioning. In arteriosclerotic surgery, the totality must always be borne in mind. There is little sense in treating a leg if the circulation of the heart, brain and kidneys is equally defective. However well the treatment succeeds, thanks to modern methods, the total position makes it meaningless. This factor is typical of arteriosclerotic surgery and should always be borne in mind in considering its feasibility.

Arteriosclerosis is a progressive disease. Beginning in the forties or fifties it spreads remorselessly and ends by crippling most of the older generation in their seventies or eighties. Not all its manifestations, however, lead to serious forms and symptoms. Occlusion of the arteries creates severe symptoms of peripheral ischemia and gangrene. The progressivity of the disease nullifies the permanence of surgical treatment. A part that has been opened is always liable to occlude again and occlusions can occur in new places.

The possibilities of surgery in the treatment of arteriosclerosis are limited and local. The systemic and progressive nature of the disease has a decisive effect on the formulation of indications and on the results.

ANALYSIS OF THE PROBLEM

The present methods of examination are not yet far enough advanced to reveal the extent to which arteriosclerotic changes have spread to different parts of the arterial system. Subjective symptoms are liable to misinterpretation, and should be confirmed by objective signs wherever possible. But bearing in mind our present inability to find clear signs of the extent to which the vessels of the heart and brain are affected in every case, there can be no justification for abandoning treatment of arterial occlusions of the extremities in such cases, especially if an extremity is in danger of being lost. Reconstructive surgery can and should be undertaken in the absence of clear signs of arteriosclerosis in the heart and brain. On the other hand, signs of cardiac and cerebral arteriosclerosis make reconstructive surgery out of the question for many patients.

Arteriography is still the most important method of elucidating the extent and localization of the changes. The equipment has been improved in recent years. Small mandrin needles, leading wires made of guitar string and teflon catheters, combined with automatic pressure injections, provide a neat and reliable technique. A general picture of the whole of the arterial system of the lower extremities is required. The catheter is therefore inserted from the femoral artery to the junction of the aorta, the dye is injected here and the whole arterial system of the lower extremities is photographed in one or more exposures. The total picture is important in planning surgery.

Subjective symptoms, palpation of the pulses, oscillometry and arteriography can be used in evaluating arteriosclerosis of the lower extremities and the results of reconstructive surgery. These enable the

circulation of the extremity to be examined with sufficient accuracy for conclusions to be drawn from the results of reconstructive surgery.

In defining the results of reconstructive surgery four phases stand out:

1. the initial degree of progression of the arteriosclerosis
2. the method of reconstruction
3. the primary result
4. the secondary result—*i.e.* the appearance of new symptoms during the period of observation.

These four variables together form the factors by which the surgical results of arteriosclerotic treatment should be evaluated.

The degree of progression of arteriosclerosis of the extremities is the first variable. To ascertain this, arteriography is indispensable.

The best indications for operation are those of the first degree, in which the occlusion or narrowing is between the popliteal artery and the lower part of the aorta, and the disease is local and segmental, being limited proximally and distally to a healthy or nearly healthy artery. Physiologically, this means that the flow into and out of the segment to be reconstructed is good. First-degree symptoms also include cases of narrowing in one, two or three bifurcations, with possibly a thickened intima between them. In first-degree cases peripheral functional atrophy of the artery resulting from low blood pressure can be observed.

Group II—second-degree indications—includes cases in which arteriosclerotic changes have produced distal occlusion or narrowing. Occlusion in the region of the iliac artery thus involves occlusive disease in the area of the thigh and calf. Occlusion in the area of the thigh also involves arteriosclerosis of the calf. The part to be reconstructed is still segmental, but there is arteriosclerosis on the distal side. In such cases the initial indications for surgery are not optimal because the occlusion of the calf does not lend itself to reconstruction and the circulation will not be fully restored postoperatively, though the primary results will be better than the initial state.

Group III—third-degree indications—comprises cases in which the changes are diffuse and dispersed over wide areas. No segmental localization can be found. Rest pain and gangrene are frequent symptoms. Treatment may involve a choice between reconstruction and amputation.

Methods of surgical reconstruction constitute a second variable. At present three principal methods are being used in varying ways at different hospitals: vein autograft by-pass, endarterectomy, combinations of these two, and plastic prosthetic by-pass in the thigh (*Dale 1959, DeBackey et al. 1964, Szilagyi et al. 1964*). Endarterectomy and prosthesis are performed in the iliac artery and the lower part of the aorta (*Darling & Linton 1964, Hardin 1964*). Combinations and variation of these methods exist. Fascia lata tubes have been used in some hospitals (*Darling & Linton 1964*). Minor differences in technical details increase the variety to some extent. According to the present literature, plastic tube by-pass in the thigh is not so effective as the other methods (*DeBackey et al. 1964, Szilagyi et al. 1965*).

The primary result—the third variable—depends largely on the first two variables. Circulation can be almost entirely restored to the extremity provided that the occlusion has been eliminated and that there is none in any other part of the extremity (Group I). In Group II, the result depends not only upon the part opened up but also on the arteriosclerosis in the lower extremity (calf and foot). The primary result is a partial improvement in the circulation of the extremity. In Group III, the primary result may be preservation of the extremity, elimination of rest pain and healing of gangrene (*Lindén 1960*). In unsuccessful cases, the reconstructed area occludes again and the circulation of the limb may even deteriorate.

The secondary result—the fourth variable—is the final outcome of reconstructive surgery and is correlated to all the other variables. A good sign is preservation of the circulation in the extremities in the same condition as it was as a primary result. The absence of symptoms and the time during which circulation is preserved provide the proof of the importance and utility of the operation performed. Reocclusion can be noted, and its cause can be discovered by means of a fresh arteriography.

MATERIAL AND METHODS

The material comprised 81 cases of arteriosclerosis treated operatively at the Kuopio Central Hospital. All the patients were men, except one. Their ages varied from 38 to 68—average 56.4 years. Seventeen displayed signs of cardiosclerosis, four of earlier cardiac infarction, ten of arterial hypertony (under 200 mmHg), and two of diabetes. The operations were performed between 1959–1964.

In the earlier operations, the methods employed were the vein by-pass method (VBP) and endarterectomy for short local occlusions in the thigh. Where necessary,

VBP was supplemented by proximal endarterectomy (removal of intima). In the later cases, longer endarterectomy of the thigh was practised and VBP was used only in cases where endarterectomy was found to be technically impossible. Endarterectomy was also practised in the region of the iliac artery and lower aorta. The method was applied equally to partial occlusions with a cleaning operation for the bifurcations. The teflon by-pass method was only used in a few cases.

The methods were adapted to the state of progression. These (Groups I, II and III) have been described above and represent the extent of the disease and the severity of the symptoms in the extremity. The relation between the methods of operation and the degree of severity can be seen from the actual numbers of each shown in the following table:

Degree of severity	VBF	FE	A-I E	TP	
I	14	12	29	—	: 55
II	6	5	6	—	: 17
III	1	3	2	3	: 9
Total	21	20	37	3	81

Thus the principal indications of operation (55/81) were local occlusions in the thigh and iliac artery. The interpretations of arteriography were confirmed by the operative findings. This class also includes cases in which mild thickenings of the intima were observed outside the reconstructed part, though there was no sclerosing and narrowing disease. Cleaning operations are also included in this class, even when the disease appeared at two or three bifurcations. Reconstructive methods were used in 17 out of 81 cases, almost a quarter of the material, representing the second degree of severity. In these cases, there was occlusive disease in the peripheral side of the area operated in the thigh or calf. Certain cases with severe symptoms (3rd degree), rest pain, incipient gangrene and occlusive arterosclerosis over a wide area were treated operatively. These numbered 9 and in three of them teflon prostheses were used.

Techniques: in the VBP method, a loose prepared long saphenous vein was turned upside down. An anastomosis, an oblique end to side was made in the artery distally above or below the knee. A proximal anastomosis was made in the upper part of the superficial femoral artery or in the common femoral artery. Where necessary, the femoral bifurcation and common femoral artery were cleaned by means of endarterectomy. 50 mg of heparine was injected in a single dose. 5-0 silk was used to close the anastomosis (Lindén 1960).

Endarterectomy of the femoral artery was performed by the semi-closed method with blunt ring strippers, using 2-4 arteriotomic incisions. In the earlier operations, the arteriotomy was closed without patches, but in the later ones we used vein or teflon patches in the femoral artery. Thickened intima were fixed with stitches in the wall of the artery at the lower part of the endarterectomy. In the iliac part we used 4-0 silk and in the common iliac and aorta double continuous stitching. After the calcification had been removed, the artery was found to be strong enough pro-

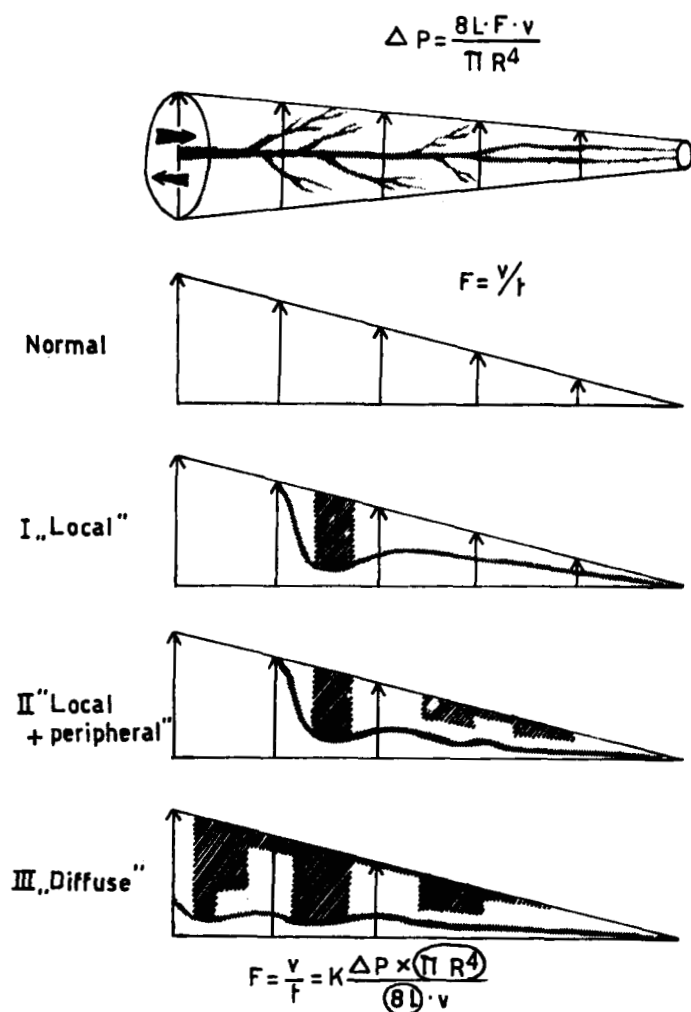


Figure 1.

vided the lamina elastica externa remained. There were no post-operative arterial ruptures. Only in a few cases were teflon reinforcement patches required. Where spot leaks appeared, "surgice" was used successfully to coagulate the blood. Sympathectomy of the 4th-5th lumbar ganglia was combined with iliac endarterectomy, especially when the disease was also peripheral. In these cases, anticoagulation was continued post-operatively with phenindion (Lindén 1962).

Each patient's post-operative circulation was examined with oscillometry and pulse palpation. His condition was reexamined at intervals of 1-6 months. In many cases of renewed occlusion, a fresh arteriograph was performed. In general, the signs and symptoms remained consistent.

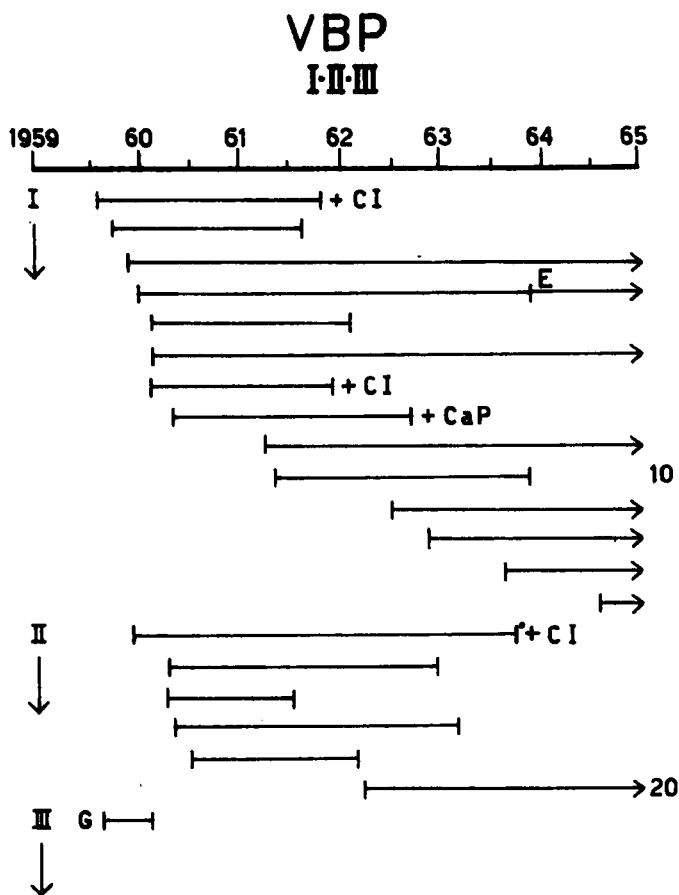


Figure 2.

RESULTS

The results obtained with the different methods are shown in the accompanying tables. Figures 2, 3 and 4 indicate the methods used in Groups I, II and III (degrees of progression) together with the primary results and the secondary results—the time the vessels remained open. Figure 2 shows the vein by-pass (VBP) cases of the thigh, Figure 3 the femoral endarterectomies (FE) and teflon prostheses (TP), and Figure 4 the aorta-iliac endarterectomies (A-I E). Thus the tables give all four variables in summarized form.

It can be seen that most of the VBP cases were followed for almost five years. In the first-degree cases, the circulation of 14 patients was

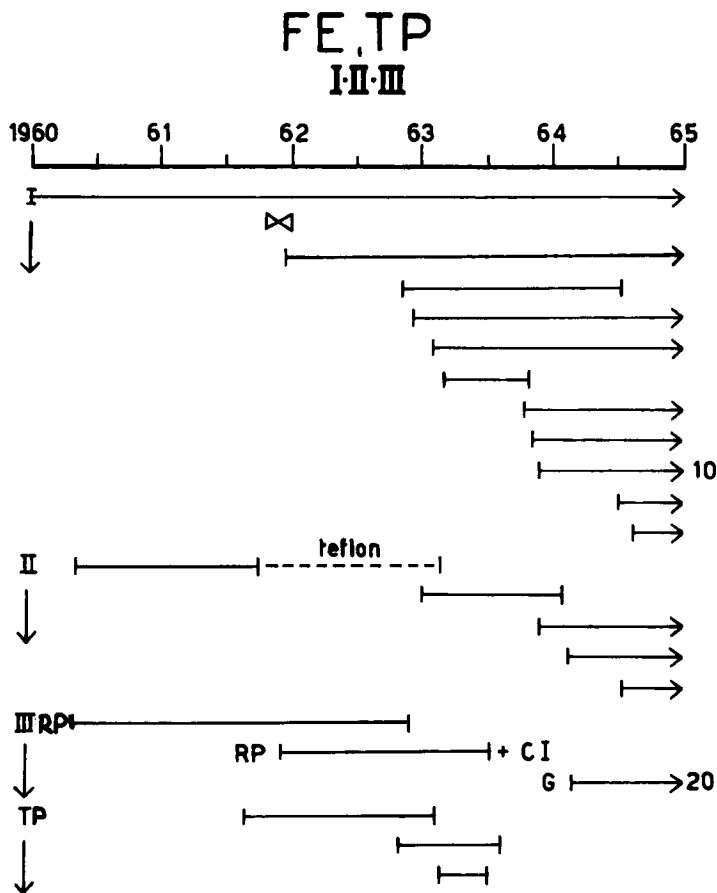


Figure 3.

good, the grafts of 8 remained open, 3 died and in 3 there was renewed occlusion. Of the 10 cases followed for an average of 4–5 years, 3 died, and in 3 there was reocclusion; of the 7 of these patients who remained alive, the circulation of 4 stayed open—giving an overall result of roughly 50–60 per cent. Of the second degree cases the vessels of 6 remained open for an average of approximately three years, one died, and in one there was renewed occlusion. The third-degree gangrene patient had to be amputated some six months after reconstruction.

The femoral endarterectomy cases were followed for a shorter time—average 1.7 years. Of the 12 first-degree cases, four suffered renewed occlusion—one of them as a primary result—and one underwent another endarterectomy. Of the 7 first-degree cases followed up for an

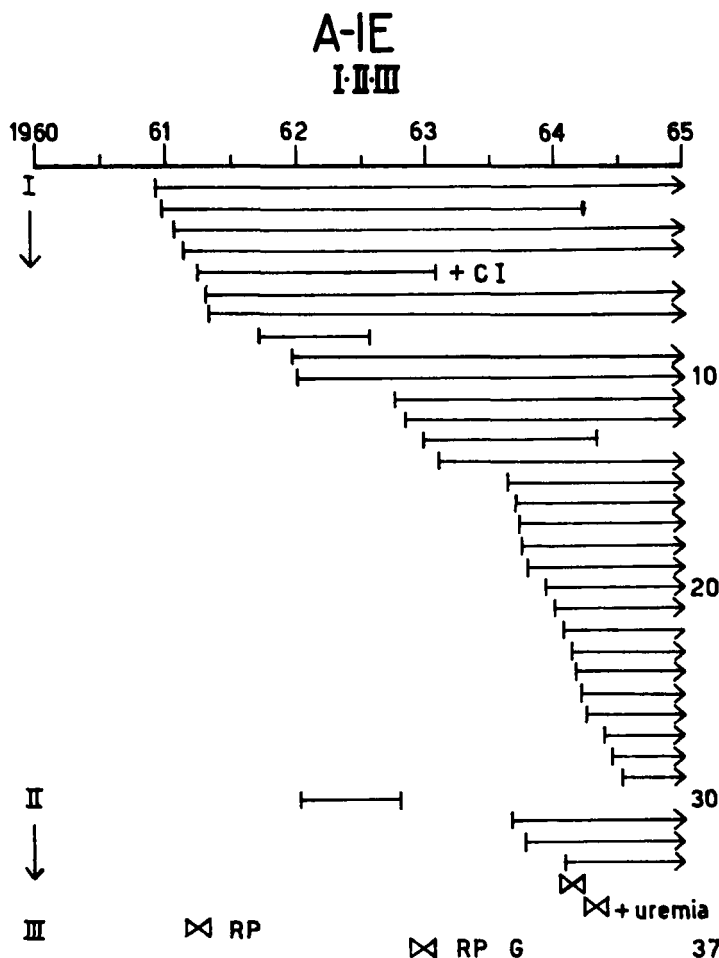


Figure 4.

average of over two years, 4 remained open. Thus the duration of positive results (50–60 per cent) was less than it was in the VBP material. In the 2 occluded cases among the second-degree patients, the average open time was a little over one year. A better result was obtained in the three third-degree cases: the extremity was preserved for an average of over two years and the rest pain and gangrene were cured. Teflon prostheses were used in the third-degree cases and the open time averaged nine months. The one case that remained open for over a year was a common iliac-common femoral by-pass.

Among the aorta-iliac and iliac cases, ten of the older ones were

followed-up for about 4 years. Of these, two reoccluded and there was one death, so 80 per cent remained open. Of all the 29 such cases with first-degree indications, three reoccluded and one died. Thus the result was relatively good: about 90 per cent. One of the six second-degree cases died, one suffered primary reocclusion, one reoccluded secondarily and three remained open. The death was due to uremia. The primary reocclusion was due to a long endarterectomy which extended along the whole iliac artery. Half of the cases were still open a year after operation. In both of the third-degree cases, reocclusion was a primary result. Owing to their rest pain and gangrene, they had to be amputated.

On comparing the results, VBP in the area of the thigh proved to be somewhat better than endarterectomy, though the difference is not statistically significant. The follow-up time for the endarterectomy cases was shorter. It is impossible to state definitely which is the best method. For the second-degree cases the VBP method proved to be somewhat better, but in the third degree cases endarterectomy produced notably better results and teflon prostheses were ineffective.

The best results in the whole material were achieved by endarterectomy in the aorta-iliac occlusions. During the whole follow-up time, 80–90 per cent of the cases observed for an average of 3.5 years remained open. The corresponding percentage achieved simultaneously by femoral VBP was 50–60 per cent. Operation proved to be beneficial in the second-degree cases, but only slightly so in the third-degree cases.

A comparison between the operative results of the first, second and third-degree cases confirms that the higher the degree of severity, the worse are the results. The results were still positive in the second-degree cases. In Group III the results did not last long, though when we performed endarterectomy, it did save the extremity in some cases.

One of our patients died during the operation owing to bleeding from the vena cava, and one died post-operatively from uremia. Six died during the follow-up time. In five of these the cause of death was cardiac infarction and in one lung cancer (Cl, CaP).

DISCUSSION

Indications for surgical treatment of arteriosclerosis in the extremities are still a subject of wide discussion. At all events, the result is clearly correlated to the degree of progression of the disease and the localization of the occlusion in the extremity. Where the changes have spread

to a large area, the circulation can be improved in part of the extremity, but the latter does not fully regain its normal function even if, in some cases, it can be saved from amputation. Therapy is unable to keep pace with progression and, as the years go by, a large part of the extremity will become diseased again. As the case is followed, new localizations are found and the disease appears in the other extremity. Surgery provides no final cure for arteriosclerosis.

One indication for operation is a limb beset by rest pain and gangrene that seems to call for amputation. It must not be amputated without an arteriography. In some cases, local reconstruction of the blood vessel can improve the circulation to such an extent that the symptoms cease, despite the diffusion of the changes, and the limb saved—for a time, at least. Rest pain is a case at point. It does not in itself indicate amputation, but obviously something must be done to relieve severe pain.

In cases in which the disease is diffuse or peripherally occlusive (Groups III and II), a functional disproportion remains in the circulation after the operation. There is a scarcity of bloodflow to and from the reconstructed area. This means that the flow (volume velocity) does not decrease in the normal ratio, and the artery is always predisposed to thrombosis. The greater this physiological disproportion, the greater the danger of an unsuccessful operation. Post-operative anti-coagulation may prevent the onset of thrombosis to some extent.

Primary failure of operation is very seldom due to technical errors. In some cases the vessels have become so defective that endarterectomy cannot be performed. In addition, the saphenous vein may be too narrow. An arteriotomic suture of the femoral artery without a patch gives rise to narrowing, which in its turn accelerates renewed occlusion. The iliac vessels are usually wider than normal after an endarterectomy and do not require patches for arteriotomy. During an endarterectomy, every effort should be made to remove the thickened intima and media as completely as possible, as well as the calcification. In my experience, the common iliac artery holds out against the blood pressure provided the outer part of the media (lamina elastica externa) is preserved. In this case, too, the result of the operation is more permanent. Part of the arterial wall can be replaced by teflon patches. In not one case in our material has an artery ruptured after endarterectomy.

An investigation of the reasons for post-operative occlusion, comprising 15 arteriographies, indicated the following: the most important reason was arteriosclerotic progression—i.e. new narrowings on the

distal or proximal side of the area operated. Owing to the physiological disproportion this had caused in the circulation, the point of reconstruction had become reoccluded. Progressive arteriosclerosis was also responsible for the poorer results and eventual reocclusion among the second and third-degree cases. Technical errors were responsible for only a very few reocclusions.

On comparing VBP and endarterectomy as methods of treating femoral occlusions, it must be remembered that the material presented here does not permit clear statistical conclusions to be drawn. It is evident, however, that in the case of local atheroma (first-degree arteriosclerosis) endarterectomy is the better method. As the changes due to the disease increase and the occlusion becomes longer, the advantages of VBP grow: it produces a better blood vessel than a long endarterectomized artery. The post-operative danger of thrombosis is smaller if second-degree cases are treated with VBP. On the other hand, endarterectomy is technically easier. Personally, I prefer vein by-pass to endarterectomy in long femoral occlusions and in cases of narrowing arteriosclerosis in the region of the calf. In treating diffuse third-degree arteriosclerosis by means of local reconstruction, endarterectomy is the better method.

On the whole, many year's experience has shown that the new reconstructive methods of arterial surgery have established their position as a useful, productive measure, particularly when the indications are right. To give the maximum benefit, cases must be brought for treatment at an early stage, for in the end, the fight against arteriosclerotic progression is doomed to defeat.

S U M M A R Y

81 cases of occlusive arteriosclerosis of the lower extremity was operated by reconstructive surgery.

In the thigh, vein autograft by-pass (VBP) and endarterectomy (FE) were performed. The methods applied in the aorta-iliac artery were endarterectomy (A-I E) and, in a very few cases, teflon prosthesis by-pass (TP). (21 + 20 + 37 + 3 = 81).

The degree of arteriosclerotic progression in the extremity was determined by arteriography and from the operative findings. The material was then divided into three groups according to the extent of the disease. First-degree cases—the "local" group—were those in which the changes and occlusion were segmental, and the proximal and

peripheral artery was almost healthy. Second-degree cases were those with peripheral changes in addition—the “local and peripheral” group. In the third-degree cases, the disease had extended over large areas of the extremity: these comprised the “diffuse-changes” group ($55 \text{ (I)} + 17 \text{ (II)} + 9 \text{ (III)} = 81$).

Of the first-degree cases in which the thigh was affected, 50–60 per cent remained open for 4–5 years after VBP and 2 years after endarterectomy. In the aorta and iliac cases, the result was 80–90 per cent for a follow-up time 3–4 years.

Among the second-degree cases, those treated by VBP remained open for 2–3 years, those treated by endarterectomy 1–2 years.

In the third-degree cases, endarterectomy saved the extremity for an average of 1–2 years in optimal cases. Rest pain and gangrene were eliminated. One patient died during the operation, one post-operatively (2.5 per cent).

RESUME

81 cas d'artériosclérose occlusive de l'extrémité inférieure ont été opérés par chirurgie reconstructive.

Dans la cuisse, un by-pass d'autogreffe de veine (VBP) et une endartérectomie (FE) ont été pratiquées. Les méthodes appliquées aux aortes-iliaques ont été l'endartérectomie (A-I E) et dans quelques cas, le by-pass par prothèse teflon (TP). ($21 + 20 + 37 + 3 = 81$).

Le degré de progression artériosclérotique de l'extrémité a été déterminé par artériographie et par les trouvailles opératoires. Le matériel est divisé en trois groupes selon l'extension de la maladie. Les cas du premier degré – le groupe « local » – ont été ceux chez lesquels les modifications et l'occlusion étaient segmentaires, l'artère proximale et périphérique étant pratiquement en bon état. Les cas du deuxième degré sont ceux chez lesquels il y avait, en plus, des modifications périphériques – groupe « local et périphérique ». Dans les cas du troisième degré, la maladie s'était étendue sur une large partie de l'extrémité: ceux-ci comprenaient le groupe des « altérations diffuses » ($55 \text{ (I)} + 17 \text{ (II)} + 9 \text{ (III)} = 81$).

Dans les cas du premier degré chez lesquels la cuisse était atteinte, 50 à 60 pour cent restèrent ouverts pendant 4–5 ans après le VBP et 2 ans après l'endartérectomie. Dans les cas aortes-iliaques, les résultats ont été 80–90 pour cent pour une période d'observation de 3 à 4 ans.

Parmi les cas du deuxième degré, ceux traités par VBP sont restés ouverts pendant 2–3 ans, ceux traités par endartérectomie 1–2 ans.

Dans les cas du troisième degré, l'endartérectomie a sauvé l'extrémité pour 1 à 2 ans en moyenne dans les cas optima. La douleur du repos et la gangrène ont été éliminés. Un malade est décédé en cours d'opération, l'autre après l'opération (2,5 pour cent).

ZUSAMMENFASSUNG

81 Fälle von obliterierender Arteriosklerose der unteren Gliedmassen wurden mittels rekonstruktiver Chirurgie operiert.

Am Oberschenkel wurden autogene Venenüberbrückungsoperationen (VBP) und Endarteriektomie (FE) ausgeführt. Die Methoden, welche an der Aorta-iliakal Arterie verwendet wurden waren Endarteriektomie (A-IE) und in einigen wenigen Fällen Teflonprothese-Überbrückung (TP). ($21 + 20 + 37 + 3 = 81$).

Der Grad der arteriosklerotischen Progression wurde mittels Arteriographie und aus den operativen Befunden bestimmt. Das Material wurde dann entsprechend der Ausdehnung der Erkrankung in drei Gruppen eingeteilt. Fälle des ersten Grades—die "lokale" Gruppe—waren jene, bei denen der Verschluss nur auf einen Abschnitt begrenzt und die proximale und distale Arterie beinahe gesund war. Fälle des zweiten Grades waren jene, die zusätzlich periphere Veränderungen aufwiesen—die "lokale und periphere" Gruppe. Bei den Fällen der dritten Gruppe hatte sich die Erkrankung über weite Gebiete der Gliedmasse ausgebreitet: Diese umfassten die "diffuse Veränderungsgruppe" (55 (I) + 17 (II) + 9 (III) = 81).

Von den Fällen der ersten Gruppe bei denen der Oberschenkel ergriffen war, blieben 50–60 pro zent offen für 4–5 Jahre nach VBP und zwei Jahre nach Endarteriektomie. Bei den Aorta-iliakal Fällen war das Ergebnis 80–90 pro zent für eine Nachuntersuchungszeit von 3–4 Jahren.

Von den Fällen der zweiten Gruppe blieben jene, die mittels VBP operiert waren 2–3 Jahre offen, jene, die mittels Endarteriektomie behandelt waren, 1–2 Jahre.

In den Fällen des dritten Grades bewahrte die Endarteriektomie die Extremität in den besten Fällen für einen Durchschnitt von 1–2 Jahren. Ruheschmerz und Gangren wurden ausgeschaltet. Ein Patient starb unter der Operation, ein anderer postoperativ (2,5 pro zent).

REFERENCES

- Cockett, F. B. (1964) Nine years survey of the results of direct arterial Surgery. *J. Cardiovasc. Surg.* **5**, 502.
- Dale, W. A. (1959) Autogenous vein grafts. Charles C. Thomas.
- Darling, R. & Linton, R. (1964) Aortoiliiofemoral endarterectomy for arteriosclerotic occlusive disease. *Surgery* **55**, 184.
- DeBakey, M., Crawford, K. S., Morris, G. C. Jr., Cooley, A. A. & Garret, H. E. (1964) Late results of vascular surgery in the treatment of arteriosclerosis. *J. Cardiovasc. Surgery.* **5**, 473.
- Hardin, C. A. (1964) Survival and complications in 134 surgically treated cases of aortoiliac thrombosis. *Surgery* **55**, 617.
- Lindén, L. W. F. (1960) Reconstructive surgery in peripheral occlusive arteriosclerosis. *Ann. Chir. Gynea. Fenn.* Suppl. 96.
- Thromboendarterectomy of the iliac abd femoral arteries by the semiclosed method (1962) *Ann. Chir. Gyneae. Fenn.* **51**, Suppl. 108.
- Szilagyi, D. E., Smith, R. F., Elmquist, T. J. G., Gontzales, A. & Elliot, J. P. (1965) Angioplasty in the treatment of peripheral occlusive arteriopathy. *Arch. Surg.* **90**, 617.
- Szilagyi, D. E., Smith, R. F. & Elliot, J. P. (1964) Venous autografts in femoropopliteal arterioplasty. *Arch. Surg.* **89**, 113.
- Symposia of the VI Congress of the International Cardiovascular Society (1964) *J. Cardiovasc. Surg.* **5**, No. 6.