Further Considerations on the Indications for and Limitations of Direct Surgery in Arteriosclerosis

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Segmental obstruction due to arteriosclerosis may occur in peripheral arteries. Further experience in resection of these obstructed segments and their replacement by vein grafts is reported. Replacement of segments of the femoral artery has been accomplished in 30 patients. The proper selection of patients is essential for success. The various causes of failure and the limitations of the procedure are emphasized.

The application of the principles of thromboendarterectomy and vein or arterial graft replacement for segmental obstruction in arteriosclerosis is not new. In earlier communications\(^1\), \(^2\), \(^3\) we have briefly summarized the history of the efforts in this field. In these papers we have reported additional experience of our own, attempting to define indications for such procedures, limitations of their application and recording details of technique.

The purpose of this paper is to report our subsequent experience in the field, to re-emphasize certain principles laid down earlier and, particularly, to analyze the failures in an effort to discover the causes for unfavorable results.

We have, at the writing of this paper, replaced an obstructed segment of the femoral artery in 30 patients (bilaterally in 1). Of these 31 grafts, 16 were successful\(^*\) and 15 failed. Both grafts were successful in the one patient who had both femoral arteries operated upon. Among the successful cases there were 4 saphenous homografts, 2 femoral autografts and 10 saphenous autografts (2 in one patient). The oldest of the autografts is 23 months, of the homografts 17 months. There have been 15 patients in whom femoral grafts have failed. Of these three have been homografts. One of them was not completed because of technical difficulties, but is grouped with the failures. The other two remained patent and functional postoperatively but closed at two and four months respectively. The remaining 13 failed immediately or shortly following implantation and were never functional. Except the two homografts mentioned above, none of the grafts has closed once its patency was definitely established postoperatively.

This paper does not include our experience with replacement of aortic bifurcation\(^3\) or thromboendarterectomy.\(^1\), \(^2\), \(^3\) The latter has been abandoned as a definitive procedure in favor of vein auto- or homograft in the femoral system and has been retained only for use in the iliac arteries.

Selection of Patients

Among the large number of individuals suffering from arteriosclerosis, candidates for segmental resection represent a relatively small group. The incidence of such cases is difficult to estimate. Robb\(^4\) from “the study of a large number of arteriograms and anatomical dissections... over a period of years,” concludes that “fully 66 per cent of all patients with intermittent claudication or gangrene of the toes have a lesion in their arteries which is anatomical.
cally suitable for an artery graft. In actual fact, less than 20 per cent of these patients are suitable, the majority being rendered unsuitable by the manifestations of arterial disease such as involvement of the coronary or cerebral arteries, etc.” He would undoubtedly include in this group patients in whom the pathology is so severe and so generally distributed that even though localized obstruction in main arterial channels is present the vessels distal to such areas are too narrow to carry sufficient blood for normal function of the extremity.

Candidates for therapy of this type are patients who suffer primarily from claudication. It is this symptom which prompts them to seek medical attention and, as will be seen later, if other symptoms are present the likelihood of success is markedly diminished. In an effort to determine the limits of this form of surgical therapy we have operated upon a number of patients who were definitely in a borderline category. Our series is still small and certainly no statistically significant conclusions can be drawn from it. Even at this point, however, certain definite indications and particularly contraindications would appear to stand out. There is one basic finding common to all candidates for superficial femoral artery resection; namely, the presence of a femoral pulse and the absence of one at the popliteal level. This does not necessarily mean that the obstruction is limited to the superficial femoral artery, but it is the broad base for the beginning of the selection of possible candidates for this type of surgery.

The age of the patient appears to be of little importance. Arteriosclerosis, particularly atherosclerosis, is not necessarily a disease of the aged. Those patients in which the grafts were successful ranged in age from 36 to 54 years, the average being 52. Among those in whom the grafts failed, the ages ranged from 33 to 66 years, the average age being 51.

Rest pain is considered to be a most important factor. Of the patients in whom the grafts were successful none had this symptom, while 7 of the 15 failures were in patients who complained of rest pain. The ischemic pain of arteriosclerosis in most instances denotes an involvement of a large number of arterioles, and rapid flow of blood through the vein graft, which is necessary for its continued patency, is not likely to occur. At this point in our study rest pain is considered a contraindication to femoral artery resection.

Trophic changes, such as ulceration or gangrene of a toe or other portion of the foot, are in the same category as rest pain. In none of the patients with successful femoral grafts were trophic changes present, while in four of the patients in whom the grafts failed there was an ulcer of one toe.

Arteriography has been one of the most reliable aids in the selection of patients for femoral grafting. In some instances, however, the favorable appearance of the vessels in x-ray films has lead us to attempt surgery against our better judgment; that is, when rest pain and/or trophic changes were present in the foot (fig. 1). For the most part, the presence of a channel distal to the obstructed segment has been considered a prerequisite to surgery. Not
all of our early cases showed this distal segment, but we believe this to be due in some instances to errors in techniques such as (1) the insertion of the needle into the profunda femoris artery, (2) the injection of insufficient contrast media, (3) slow injection and (4) exposure of the film before the media has reached the distal segment. At the present time we do not hesitate to repeat the arteriogram if the first one gives questionable information. In a number of cases, even though a distal segment was not visible

![Arteriogram showing heavy shadow of the profunda femoris as compared with that of the superficial femoral artery, partially blocked in this arteriogram. At surgery the latter vessel proximal and distal to the occluded segment, was found almost occluded by atheroma and having only a thin ribbon-like channel along one side.](image)

and in an effort to define the extreme limits of surgery for segmental block, exploration of the popliteal artery was carried out. Clinically unfavorable cases failing to show a distal channel arteriographically in no instance had an open channel on surgical exploration. In those clinically favorable, that is, without atrophic changes or rest pain, the distal channel at the time of exploration was usually open.

The degree of disease as shown by the arteriogram would appear to be of importance in the selection of patients. In the main this is true although some successful cases showed a fair extent of filling defects of the lumen above and below the site of obstruction. Of particular importance is the presence of reasonably normal vessels below the bifurcation of the popliteal artery. Because of technical inadequacies these vessels are not always visible, but when a distinct pattern is obtained and the vessels are "moth-eaten" and disappear in the upper portion of the lower leg the prognosis is poor.

Occasionally the profunda femoris will show a heavy white pattern and if the proximal and distal superficial femoral segments are visible they may be of a uniformly pale quality (fig. 2). At surgery these segments may prove to be almost occluded by atheroma, each having only a thin ribbon-like channel along one side which, when seen en face in the x-ray, appears to be a good channel. We have referred to this phenomenon as "ribbon channels." The outlook in such instances is unfavorable.

Occasionally the profunda femoris will show signs of extensive disease. In our experience this vessel remains healthy in most instances longer than does the superficial branch, and any real degree of disease in the profunda is considered a contraindication to superficial femoral artery surgery.

It is interesting that calcification, per se, is not a uniformly satisfactory guide. One would hesitate to operate upon a patient with moderate to severe calcium deposits in the vessels in question, but a number of our successful cases showed such calcification. One patient with marked calcification of the abdominal aorta and somewhat less calcium in his pelvic and femoral vessels (fig. 3) had a successful iliac thromboendarterectomy on one side and a homologous vein graft in the opposite femoral artery. The one patient with bilaterally successful femoral grafts had a moderate amount of calcium in both superficial femoral arteries. By the same token, an absence of calcium is not necessarily a hopeful sign. Calcification was not particularly prominent in any of the failures, and in some there was none to be seen roentgenologically.

The factor of the number and size of collateral vessels has been included in this study.
The absence of trophic changes and rest pain and the presence of an open distal channel are obviously dependent upon an adequate collateral circulation. Whether the character of the appearance of the collateral vessels arteriographically can be used to any degree, however, in the selection of patients for surgery is questionable. One point of interest during the surgical procedure has been the backflow from the distal segment. The presence of backflow does not necessarily mean open tibial vessels. A good collateral artery entering just distal to the lower point of section of the femoral artery may well provide a substantial backflow. It is important not to injure a sizable collateral vessel coming into the distal segment (fig. 4), since in the event of failure of the graft the intact collateral vessels may mean the difference between the maintenance of the preoperative clinical state and a worsening of it. In one of our cases in which a large collateral vessel was sacrificed subsequent amputation was necessary. In some cases it has seemed desirable and even necessary to extend thromboendarterectomy past the lumen of such collateral vessels in order to complete a graft. We have done this successfully, recognizing at the time the possibilities of subsequent thrombosis, a risk present in all instances of thromboendarterectomy.

**Technical Details of Surgery**

The second group of factors bearing directly on the outcome of blood vessel replacement has to do with the technical details of surgery.

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**Fig. 3.** Roentgenograms showing marked calcification of the aorta (a) and similar though less extensive calcium deposits in the femoral artery (b). These findings would ordinarily deter the operator from surgery on such vessels. This patient, however, had an intimectomy of one common iliac artery and graft replacement of the femoral artery of the opposite side. Both vessels are open 9 and 16 months later.

Among these factors the type of graft stands out in importance. Certainly, where possible the patient’s own tissue should be used, but unfortunately such a graft is not always available. In recent years the increased interest in vascular surgery has provided many types of substitutes for blood vessels, but because in this series of cases we have used only vein grafts, other types of substitutions will not be considered. The first two grafts were autogenous superficial femoral vein segments, measuring 10 and 8 cm. respectively. These were
successful and the patients are asymptomatic 23 and 22 months respectively. This type of graft is considered less desirable than the saphenous vein for two reasons: (1) A vein, regardless of the site, under arterial pressure will usually dilate to twice the size of the concomitant artery. This makes for turbulence of blood flow at the change of luminal diameters and as shown experimentally by Schmitz has appeared to promote clotting. (2) Depending on the length of vein segment used and the collateral venous return, stasis may result from the excision of a vein segment. Though neither of these complications occurred in our cases the hazards must be recognized. The saphenous autograft on the other hand, dilates to approximately the size of the superficial femoral artery and at this site, where it is supported by muscle and fascia, becomes an ideal graft. Where, because of previous thrombosis or stripping, it is not available, a homologous saphenous vein may be used. In our series such a graft, taken by stripping just prior to implantation, has been used in six instances. Four of these are still open and functioning, the oldest, 25 cm. in length, now in situ for 17 months. A seventh included in this group as a failure was never implanted. Because of extreme friability of the host’s vessels the graft had to be taken down after implantation and the proximal and distal host segments ligated. Two functioned originally and then closed at two and four months respectively following implantation. The second was removed six months postopera-

**Fig. 4.** Arteriogram showing the presence of a large collateral vessel just distal to the lower end of the obstructed segment. The injury or sacrifice of such a vessel may, in the event of failure of the graft, result in the loss of the patient's leg. This hazard may inhibit the surgeon in his effort to obtain a satisfactory distal segment for anastomosis.

**Fig. 5.** Photomierograph of a late occlusion (four months) of a saphenous homograft showing organizing thrombus in the lumen with thickened intima and fibrous media and adventitia.

tively and showed an organized clot within the lumen, a thickened intima with subintimal granulation and almost complete replacement by fibrous tissue of the media and adventitia. The signs of inflammation usually seen early in homografts were not present. It is assumed that the intima is that of the host. It is interesting to compare this with a saphenous autograft removed four months following implantation showing a well organized thrombus and intimal thickening. There was no inflammatory reaction. The remaining replacements, 22 in number, were saphenous autografts. Of these 13 failed and 9 were successful. The oldest of the latter grafts, 15 cm. in length, has functioned for 21 months. The longest successful
graft in this series is a 38 cm. saphenous auto-
graft and has been in situ for 16 months. We
have seen no correlation between the length of
a graft and success or failure. The diameter of
the graft in relation to the host vessel has been
mentioned earlier. In general, the saphenous
vein will dilate to the proper size for femoral
artery replacement, though one of our failures
was attributed to technical difficulties arising
from a saphenous vein being too small.

The character and disposition of the blocked
segment of femoral artery are of importance.
In some of our cases it has been removed and
the graft laid into its bed. In others it has been
left in situ and both ends ligated. Because of
the apparent complete obliteration of the lumen
in one instance the ends were left free, that is,
without ligature, and a hematoma developed
following surgery. On exploration, it was found
that the bleeding was coming from one of the
open ends of the blocked segment. It is assumed
that the increased flow of blood through the
collateral vessels resulting from the graft was
sufficient to force blood through the small
remaining lumen of the blocked segment.
Humphries\textsuperscript{8} states that such a segment, left in
situ, has been seen to fill in a postoperative
arteriogram.

In the anastomosis of blood vessels the sur-
geon is dealing with an unusually difficult group
of factors, the most uncertain being the clot-
ing hazard. With the advent of anticoagulants
it became possible to neutralize this hazard,
but at the same time the danger of bleeding
was increased and the balance between these
two extremes of too much clotting or too much
bleeding is still not easily controlled. In the 31
implantations of grafts reported here, anti-
coagulants were used in 23 instances. In some
cases heparin alone was used, in others it was
accompanied by either Dicumarol or Trom-
exan. Regional heparin was used in four
instances. Among those patients receiving anti-
coagulants the grafts were successful in 11 in-
stances. Failure occurred in 12 of the 23, hema-
toma formation being present in six of them
and considered a factor in the unfavorable out-
come. Of the 16 successful grafts, anticoagu-
lants were used in 11 cases. There were no
hematomas, though one patient developed a
transient hematuria. Of the 15 failures anti-
coagulants were omitted in only three instances.
The types of anticoagulants used and their
methods of control must be considered as vari-
ables, and it is difficult to appraise the role of
anticoagulant drugs in any study. It is still
more difficult where a variety of drugs is em-
ployed. In our series of cases anticoagulants do
not appear to have been an important factor in
the success or failure of the grafts.

**Summary**

1. In 30 patients having segmental blocks
in the superficial femoral arteries the obstruc-
ted segments have been resected and replaced with
venous grafts (bilaterally in one patient). Six-
teen of the grafts were successful, 15 failed.

2. The replacements included two femoral
vein autografts, 22 saphenous autografts and
seven saphenous homografts.

3. Factors possibly contributing to success
or failure of the grafts are grouped under two
main headings: (a) selection of patients and
(b) technical details of surgery. The impor-
tance of the proper selection of patients is em-
phasized, the outstanding contraindication be-
ing rest pain and trophic changes in the foot
of the extremity under consideration. Arteriog-
raphy is necessary to the proper selection of
patients but may be misleading as well as help-
ful. Technical details of surgery are important
in the outcome and various factors under this
heading are discussed.

**Sumario Español**

Obstrucción de segmentos de las arterias
periféricas puede ser causado por arterioescler-
osis. Se informa adicional experiencia en la
reseción de estos segmentos y substitución con
injertos de vena. Substitución de segmentos de
la arteria femoral se han efectuado en 30
pacientes. La propia selección de los pacientes
es esencial para el buen resultado. Las varias
causas de fracasos y la limitación del procedi-
miento se recalcan.

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