Part VII

Surgical treatments

Surgery of the Profunda Femoris Artery

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The profunda femoris artery functions primarily to provide blood supply to the tight.

When the superficial femoral artery is occluded, the profunda femoris artery is the most important collateral for the perfusion of the lower limb.

On the basis of the its particular anatomic relationships, the profunda femoris artery is an alternative vessel to the superficial femoris artery with the potential to vascularize the extremities.

The diffuse nature of the atherosclerotic disease suggests that in many patients the profunda femoris artery will also be diseased (1).

The most common lesion is a plaque extended from the posterior wall of the common femoral artery into origin of the profunda, producing a stenosis of the profunda ostium (2).

The proximal segment of the profunda femoris artery becomes involved in up to 74% of cases, but distal disease of the collateral branches is relatively uncommon (3).

The most common types of lesions of the profunda femoris artery and femoral carrefour are described in Figure 1.

Recognition that this pattern of disease was liable to surgical correction led the introduction of profundoplasty by Martin nel 1972 (2).

Initial enthusiasm for the procedure has softened with age following the success of bypass surgery wich isolated profundoplasty has been unable to match 4.

This has limited the widespread use of isolated profundoplasty despite the fact that the relief of rest pain and healing of ulcers has been demonstrated in selected patients (5,6).

In limbs with an occluded superficial femoral artery, the profunda femoris artery constitutes a vital link in the collateral chain between the aortoiliac system and the peripheral vascular bed of the calf and foot. Other equally vital links include the popliteal geniculate system and tibial peroneal arteries. Since these vessels are all in series, their resistance are additive.

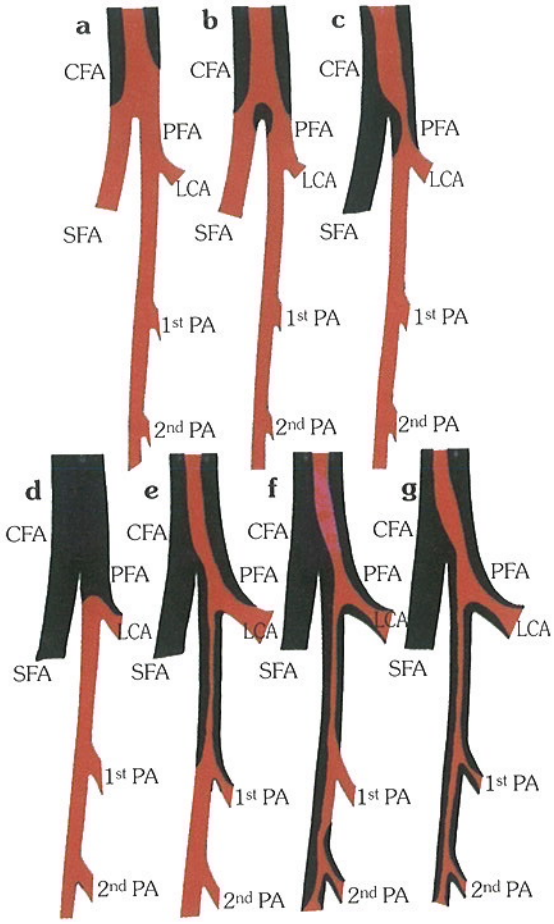

FIGURE 1

Type of lesions of profunda femoris artery (PFA)

a) *The profunda femoris artery and femoral carrefour is normal, the lesion is limited to the common femoral artery (CFA);*
b) *The stenosis is limited to the origin of the profunda femoris artery (orifice lesion);*
c) *The stenosis of the profunda femoris artery not involves the lateral circumflex artery (LCA);*
d) *The obstruction of the profunda femoris artery involves the lateral circumflex artery (LCA);*
e) *The stenosis of the profunda femoris artery involves the origin of perforator arteries (PA);*
f) *The stenosis involves all the profunda femoris artery and some of the perforator arteries;*
g) *The stenosis or obstruction of the profunda femoris artery involves all the perforator arteries.*

TABLE I
The Profunda femoris artery segments (7) (Figure 2)

1 - **Proximal portion:**	extends to the origin of the lateral femoral circumflex artery
2 - **Middle portion:**	reaches to the second perforating branch
3 - **Distal portion:**	extends form the second perforating branch to the artery's final division

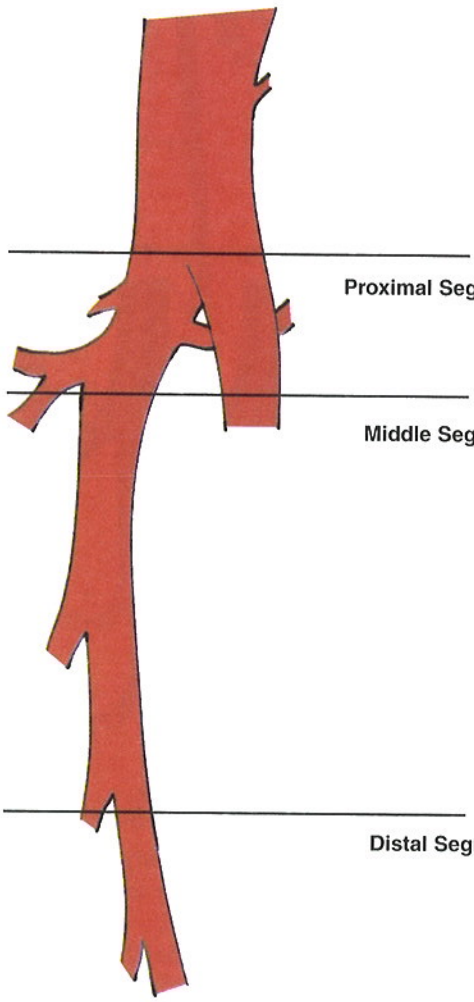

FIGURE 2
Segments and branches of profunda femoris artery

The lateral and medial circumflex femoral arteries, arising from the first segment of the profunda femoris artery, have multiple connections through the circumflex femoral branches to the gluteal and perineal arteries proximally to receive inflow from the iliac vessels (7).

The more distal perforator branches have variable origins, and their ramifications form an arcade to connect with genicular and recurrent tibial arteries around the knee to fill patent segments of the popliteal-tibial network to supply the leg and the foot (7,8) (Figure 3).

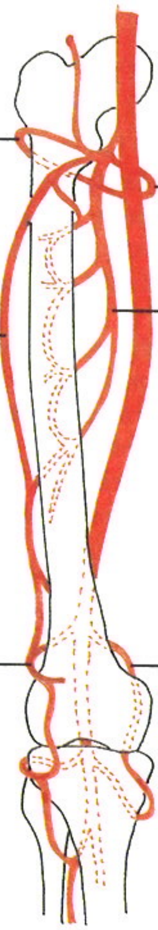

FIGURE 3
Profunda femoris artery branch network

In the case of occlusion or stenosis of the superficial femoris artery the blood supply to the distal limb depends mainly on the collateral inflow via profunda femoris artery.

Flow in the profunda is frequently compromised by inflow occlusive disease, or disease of the profunda itself. When the profunda femoris artery is affected by atherosclerosis, stenosis is often confined to the ostium (2,9).

Geometrical measurements have revealed that, where occlusion of the superficial femoris artery is present, the normal orifice of the profunda femoris artery already represents a relative stenosis of the 50%, interposed between the common femoral artery and the collateral circuit of the profunda femoris artery (10).

Restoring flow to the lower limb using profunda femoris artery is possible with a surgical inflow procedure combined with profundoplasty 11,12,13,14, with profundoplasty alone in selected cases (5,6,9,15,16), with profunda femoris artery as inflow site for infrainguinal revascularization (17) (Table II).

TABLE II
Profunda femoris artery surgical procedures

1	Isolated profundoplasty
2	Profundoplasty combined with infrainguinal revascularization
3	Combined aorto-femoral and profunda femoris artery reconstruction
4	Profunda femoris artery – popliteal bypass

Trans-Atlantic Intersociety Consensus on Management of Peripheral Arterial Disease (PAD) (18) suggests that "...the role of profundoplasty is well accepted as an adjunt to inflow procedures to maintain graft patency and reduce the need for subsequent or simultaneous distal reconstruction. The role of isolated profudoplasty is more controversial. Clinical success with a such procedure has been achieved 49% of patients at 3 years. A review of the literature has suggested that requirements for success include:
1) excellent inflow;
2) a greater than 50% stenosis in the proximal third of the profunda, and
3) the presence of excellent collateral flow to the tibial vessels in continuity with a foot with no tissue loss. In attempt to evaluate collateral flow distal to the profundoplasty as a predictor of success, a high segmental limb pressure gradient across the knee (AK – BK pressure / AK pressure > 0.5) has been found to predict clinical failure. There are no other successful objective predictors of success of isolated profundoplasty".

Examination

The profunda femoris artery is located in a remote position and it is difficult to evaluate by clinical examination or segmental limb pressure for atherosclerotic obstruction within its lumen (8).

Thigh claudication may be due to combined superficial and profunda femoris artery obstruction or to inflow obstruction at the iliac or common femoral artery.

Adequate femoral inflow is determinated by physical examination, continuos wave Doppler and color duplex scan, angiography and in equivocal proximal lesions the aortofemoral pressure gradient can be determinated at the time of arteriography or intraoperatively.

Althought the profunda femoris artery isn't palpable, the presence of a groin bruit or decreased upper thight pressure in a patient with a full pulse in the common femoral artery may propose profunda femoris artery stenosis when the superficial femoris artery is occluded. Doppler segmental pressure measurements may suggest this site of the stenosis when the upper thigh pressure is low (19).

The segmental pressure mesasuraments are also useful for determining the functional capacity of the collateral connections between the profunda and the popliteal-tibial run-off vessels by applying a specific formula (19) (Table III).

TABLE III
Profunda Popliteal Collateral Index (PPCI)

$$\frac{\text{Above - Knee Systolic Pressure (AKSP)} - \text{Below - Knee Systolic Pressure (BKSP)}}{\text{Above - Knee Systolic Pressure (AKSP)}}$$

A low index, less than 0.25, indicates good collateral capacity to carry blood flow to the popliteal run-off beyond an superficial femoris artery obstruction (5).

Calculation of the profunda popliteal collateral index is a realiable predictor of success when this index is less than 0.25 (5,8,20,21).

The pressure decrease across each segment of the extremities, which represents the resistance of that collateral bed, can be calculated and expressed as a segmental pressure gradient index (Figure 4).

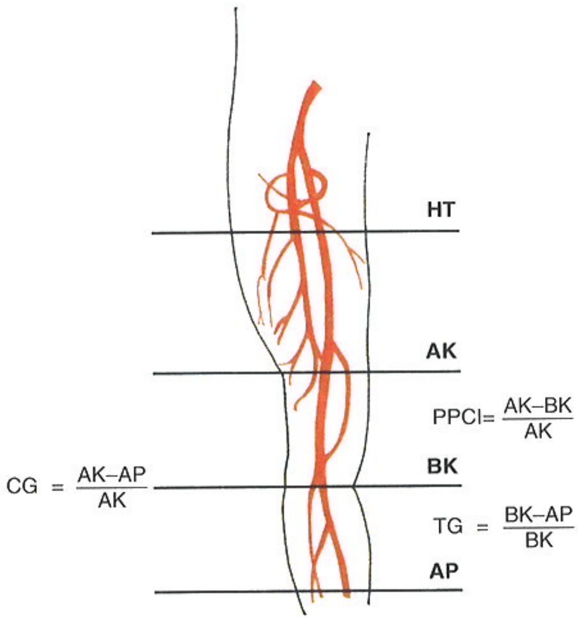

FIGURE 4
Segmental pressure gradient indices

Legend: HT = high tigh
AK = above-knee pressure
BK = below-knee pressure
AP = ankle pressure
PPCI = profunda-popliteal collateral index
TG = tibial gradient index
CG = combined gradient index

The combined gradient pressure index (PCGI) is equal to the total fractional pressure decrease from above the knee to the ankle and is express as follow:
(Above Knee – Ankle pressure) / Above Knee.

The popliteal gradient index, which will subsequently be referred to as the profunda-popliteal collateral index (PPCI), is expressed as the fractional pressure drop across the knee:
(Above Knee – Below Knee) / Above Knee.

The tibial gradient (TG) index is similarly expressed as follow:
(Below Knee – Ankle Pressure) / Below Knee.

These segmental pressure gradient indices in each category of profundoplasty can be compared and correlated with early results (19).

A reliable indicator of the amount of resistance of any vascular bed is the pressure decreased that occurs across the vessels themselves.

Boren (19) demonstrated that the profunda-collateral gradient index (PCGI) is an important prognostic indicator in cases of isolated profundoplasty.

A PCGI over 0.50 was never associated with functional success.

He found (19) that segmental pressure indexes were less valuable in cases of profundoplasty performed in association with an inflow operation.

Brewster (22) proposed intraoperative pulse volume recording (PVR), Garrett (23) suggested intraoperative ankle/brachial index (ABI) recordings.

All these methods are able to determine which patients does not require distal bypass, but they should be inaccurate in predicting which patients need it. Color-duplex scan examination can successfully show the status of the profunda femoris origin and its proximal segment; additional anatomical and physiological information can be acquired 24,25.

Strandness (24) defines a grater than 50% arterial stenosis at any level in the lower limb by the criteria in Table IV.

TABLE IV
Strandness's Criteria (24)

1) Local increase of more than 100% in peak systolic velocity (PSV) (with a normal of 65 cm./sec.) within the narrowed area;
2) Loss of reverse flow;
3) Marked spectral broadening.

These criteria have showed, when applied to the profunda, an 86 % of sensitivity and 100% of specificity for more than 50% stenosis when compared with angiography (26,27).

Appropriate preoperative arteriography study however is essential component of successful vascular surgery in the lower limbs.

The importance of concomitant iliac disease must be clarified by multiple oblique projections and withdrawn arterial pressures before and after administration of papaverine.

Beales (1) described in detail the proper radiologic assessment of the profunda femoris artery. In his experience 68% of significant profunda femoris artery ostium lesions were evident only on oblique projections, that is, standard anteroposterior views understimate the presence and significance of profunda femoris artery orifice disease.

Intraoperative flow measurements were obtained in the Boren's experience after profundoplasty with an electromagnetic flowmeter. The flow probe was placed directly over the common femoral artery or on the limb of the prosthetic graft. Mean baseline flow was measured and expressed in millimeters per minute.

Papaverine hydrocloride, 10 or 20 mmg, was administrated intra-arterially and flow measurements were compared. Results of flow measurements in each category (isolated profundoplasty, profundoplasty combined with inflow procedures) was compared.

Mean baseline flow after inflow procedure and profundoplaty was 238 ml./min., in contrast with 162 ml./min. after profundoplasty alone, with statistically significant difference ($p < .05$).

After administration of papaverine, flow increased to 499 ml./min. in the inflow procedure and profundoplasty group and 427 ml./min. after profudoplasty alone (not significant).

Operative flow measurement after reconstruction and segmental pressure gradient indices provide interesting physiologic correlations. The volume of flow after an inflow procedure and profundoplasty was higher than that after profudoplasty alone (19,28).

The difference in the segmental pressure gradient indices resulted greatest for tibial segment. This confirm the widely held belief that the difference in the results between the inflow procedures plus profundoplasty and profundoplasty alone group consists in the severity of the tibial disesase present in the group undergoing profundoplasty alone. The blood flow infact is greater and results are better in inflow procedures required in addition to the profundoplasty, because the degree of tibial occlusive disease is less than in patients selected for isolated profundoplasty.

The segmental pressure measurements may provide hemodynamic data not available from the arteriogram and may be employed in the selection of patients undergoing profundoplasty.

The PPCI allows improved patients selection, doesn't guarantee the success (19).

Finally, the measure of toe pressures and photopletismography may provide additional insight into the quality of the run-off bed.

Surgical Techniques

Isolated profundoplasty

With the exception of a few isolated case reports, surgical repair of the profunda femoris artery for primary intrinsic pathology, when the femoro-popliteal segment is patent, is very rare indication because this vessel is generally healthy and infrequently the site of isolated atherosclerosis.

Significant atherosclerotic obstruction, primary aneurysms or fibromuscolar dysplasia of the distal portion of the profundis femoral artery, occurs infrequently usually in patients with diabetes and rarely in the absence of concomitant involvement of the superficial femoral or popliteal artery (29,30).

Profundoplasty is an effective and time-tested surgical procedure for the management of the lower extremities ischemia.

In selected patients with superficial femoral artery occlusion, relief of stenosis in the proximal segment of the profunda is associated with an increase in lower extremity blood flow and resolution of ischemic symptoms (16,28,31,32).

Guidelines for primary use of profundoplasty were suggested by Rollins (5), who recommended that isolated surgery of the profunda femoris artery, as the primary procedure, should be reserved for limbs meeting the criteria showed in Table V.

TABLE V
Guidelines for profundoplasty by Rollins (5)

1) No hemodinamically significant inflow stenosis at the aorto – iliac area;
2) The Profunda femoris artery with diameter stenosis greater than 50%;
3) Atherosclerosis limited to the proximal one-third of the vessel with an essential normal vessel distally.

The most significant factor for predicting a satisfactory long-term result is the presence of good run-off from profunda branches into the tibial arteries in continuity with one o more tibial vessels to the foot (5,15,20,21,33-36).

Profundoplasty may be an alternative to distal bypass in selected patients and the operative morbidity and mortality in high risk patients is lower (37,38).

There is considerable diversity of opinion, however, with respect to the efficacy of profundoplasty in the severely ischemic limb. Some reports document clinical improvement 5,6,9,15,38, other reports are less favourable 39,40.

However, poor results are to be expected if profundoplasty is used only as a last resort, when other vascular reconstructions are excluded.

Rutledge (41), for example, admitted that patients were not considered for primary profundoplasty if femoral distal bypass was possible. This indication undoubtedly influences the results against profundoplasty.

Fugger (36) found no relationship between a patent popliteal artery and clinical success, whereas the number of patent crural arteries had significant predictive value.

Mitchell (42) observed a relation between clinical outcome and both the presence of a patent popliteal artery and the presence of at least patent crural arteries and he reported that the arteriographic features that are associated with success include the criteria in Table VI.

TABLE VI
Mitchell's arteriographic criteria for sussessfull profundoplasty (42)

1 minimal occlusive disease of the distal profunda femoris artery
2 well developed profunda femoris artery collateral system,
3 patent popliteal artery,
4 minimally tibial artery diseases.

Mitchell (42) moreover found that all the extremities with less than 50% orifice stenosis resulted in a failure of the isolated profundoplasty, compared to only 40% of the patients with more than 50% stenosis.

Miksic (15) found a significant association between clinical success and the presence of at least one crural artery with good collaterals and patent pedal arch. In particular in diabetic patient, an additional determinant may be the amount of pedal occlusive disease that is not reflected in the segmental pressure indices.

Circulation will be improved to increase the claudication distance, relieve the rest pain, and will permit healing of superficial ulcers or minimal gangrene of toe tips.

Limbs with frank gangrene should not be expected to respond to isolated profundoplasty and in this case is indicates a direct bypass to the popliteal – tibial vessels to salvage the limb (33,43).

A potential benefit of isolated profundoplasty may be to lower amputation from above the knee to belove the knee.

Kazmer (44) reported that with a below - knee pressure greater than 60 mmHg, healing of a below-knee amputation was nearly certain, with lower pressures an above - knee amputation was frequently required.

The primary purpose in these clinical conditions is to support a below - knee amputation level with improved potential for prosthetic ambulation (5,15,33,43).

However, isolated profundoplasty still has a clear place in vascular surgery practice when limb revascularization in elderly patients is considered at high risk and when is impossible below knee vascular reconstruction.

The profundoplasty procedure can be classified as showed in Table VII.

TABLE VII
Length of profundoplasty (19)

Short:	< 2cm.
Standard:	8 cm., or beyond the lateral circumflex branch to the first perforator
Extended:	> 8 cm., or beyond the first perforator

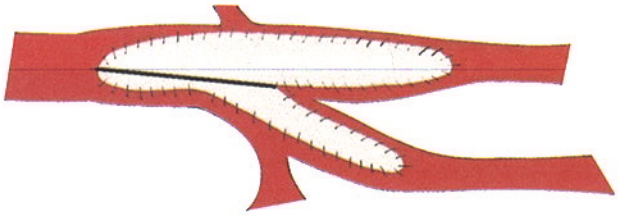

FIGURE 5
Angioplasty of femoral carrefour: bifurcated patch

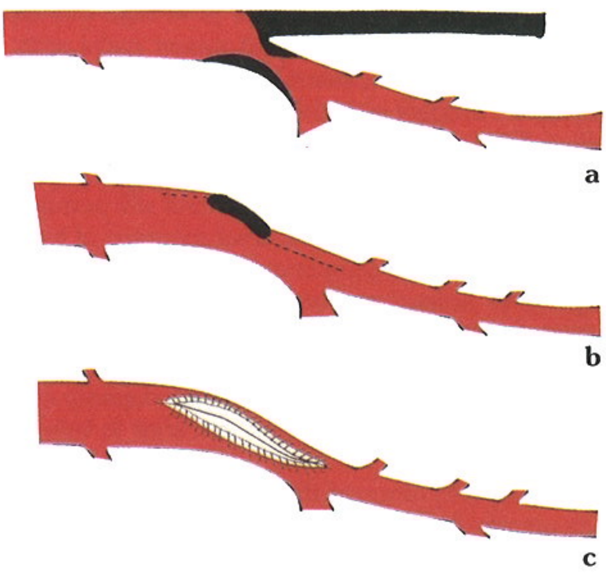

FIGURE 6
Angioplasty of profunda femoris artery:
a) – obstruction of superficial femoral artery, stenosis of profunda femoris artery
b) – section of superficial femoral artery and short arteriotomy
c) – angioplasty with patch

Angioplasty

The lesions of the femoral bifurcation can be treated with an angioplasty with patch (Figure 5) that could not be satisfying for the morphology of the vessel.

In fact, hardly ever it is possible to obtain a femoral bifurcation with normal calibre and with a hemodynamic optimum level.

The indications are limited to the cases with stenosis of the origin of profunda femoris artery and obstruction of superficial femoral artery (Figure 6).

Endarterectomy and angioplasty with patch

The most frequent surgical technique for the reconstruction of profunda femoris artery is endarterectomy and angioplasty with patch (5,21,33,35,36,45) (Figure 7).

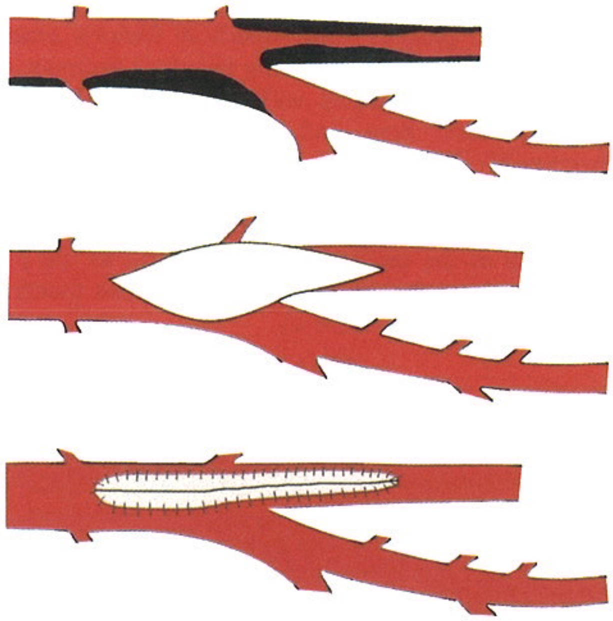

FIGURE 7
Endarterectomy and angioplasty with patch

The attention must be similar to that of a carotid endarterectomy. Endarterctomy with autogenous tissue patch is recommended for extended profundoplasty (38).

Technical variants:
1) Arterial patch (Figure 8)
2) Waibel's technique (46) (Figure 9)
3) Eversion endarterectomy of superficial femoral artery and end-to-side anastomosis to profunda femoris artery (Feldhaus' technique) (47) (Figure 10).

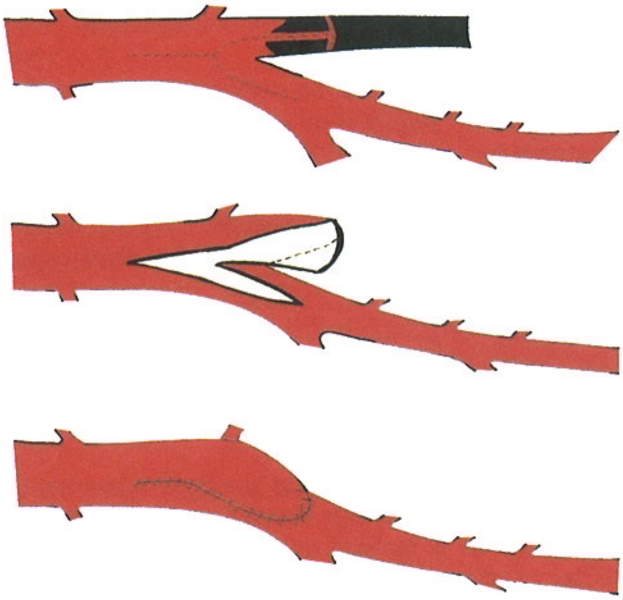

FIGURE 8
"Arterial patch": endarterectomy and suture of superficial femoral patch to the profunda femoris artery

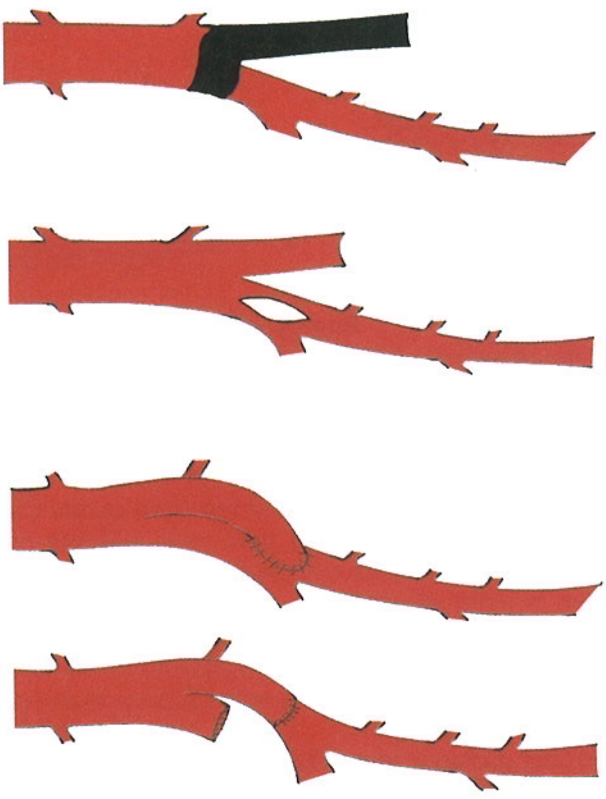

FIGURE 9
Waibel's technique: after endarterectomy of superficial femoral artery end-to-side or end-to-end anastomosis with profunda femoris artery

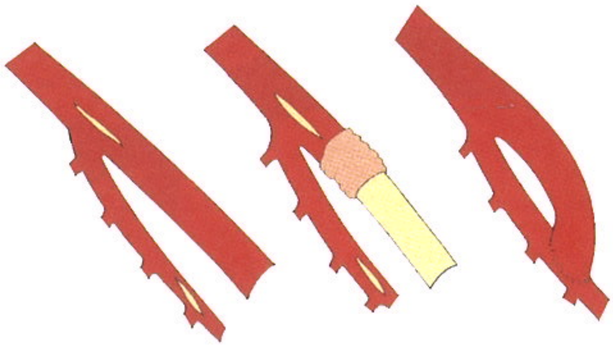

FIGURE 10
Feldhaus' technique

Bypass

1) Common femoral artery bypass (femoral carrefour is normal) (Figure 11).

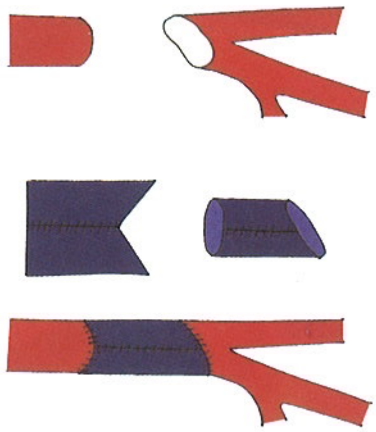

FIGURE 11
Common femoral artery bypass: interposition of a venous graft obtained with two venous graft sutured with each other

2) Profunda femoris artery bypass (superficial femoral artery is obstructed):
   a) Common femoral artery – profunda femoral artery bypass with end-to-end anastomosis (Figure 12a,b);
   b) Common femoral artery – profunda femoral artery bypass with proximal end-to-end anastomosis and distal end-to-side anastomosis (Figure 13a);
   c) Common femoral artery – profunda femoral artery bypass with proximal end-to-side anastomosis and distal end-to-end anastomosis (Figure 13b);

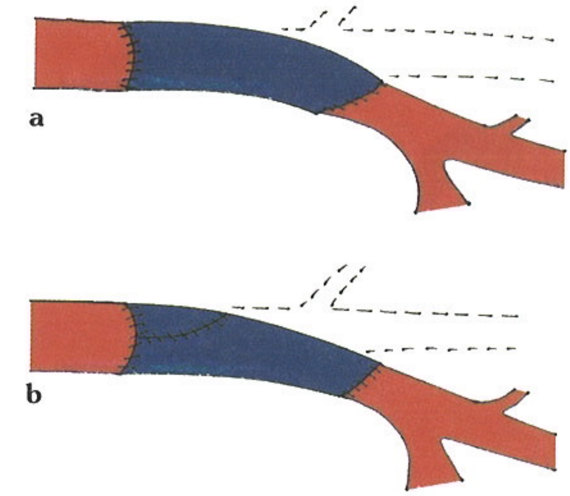

FIGURE 12
Profunda femoris artery bypass with simple venous graft (a) and with venous graft + broadening venous patch (b)

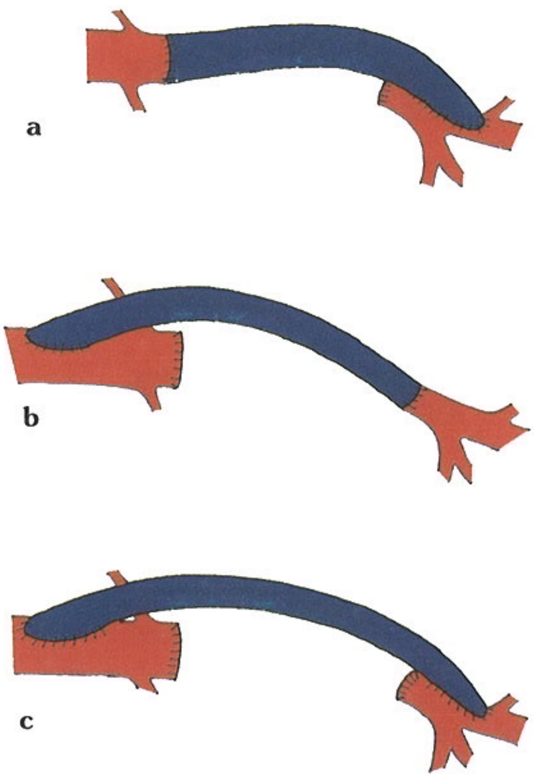

FIGURE 13
Different types of profunda femoris artery bypass

d) Common femoral artery – profunda femoral artery bypass with both end-to-side anastomosis (Figure 13c);

3) Double bypass with revascularization of both femoral arteries.

Profundoplasty and distal reconstruction

Profundoplasty should be performed in association with a femoro - popliteal or tibial bypass to relieve an accompanying severe profunda femoris artery stenosis, if the lesion is relatively short and discrete, is immediately adjacent to the area of expected common femoral artery anastomosis, and not prolongs the distal bypass procedure.

Combined aorto-femoral bypass and profunda femoris artery reconstruction

Aorto-femoral bypass is the standard operation for relief of aortoiliac occlusive disease and usually the distal anastomosis is realized on common femoral artery and has excellent results with patency rates > 85% at 5 years (48) (Figure 14).

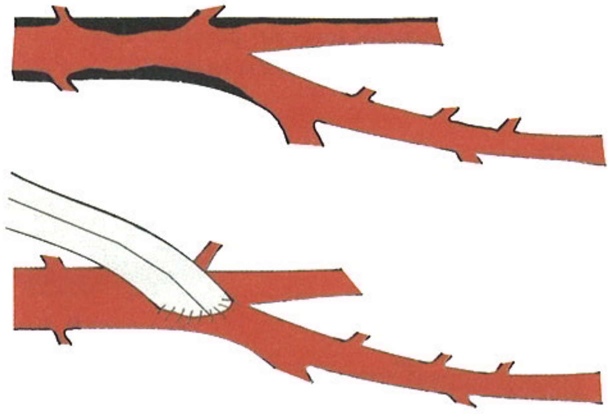

FIGURE 14
Distal anastomosis on common femoral artery of an aorto-femoral bypass

Establishment of an adeguate graft outflow at the level of the femoral anastomosis has been clearly documented to be important for both early and late graft patency and for the hemodynamic results of revascularization in terms of symptoms' relief (22,49).

A requisite for the hemodynamic and anatomical success of the aorto-femoral reconstruction is the restoration of pulsatile flow and normal pressure to the profunda femoris artery.

In the presence of coexisting aortoiliac occlusive disease and common femoral artery outflow obstruction, using profunda femoris artery as outflow vessel in aorto-femoral bypass can optimize the collateral circulation and may reduce the need for distal bypass (Figure 15 and 16).

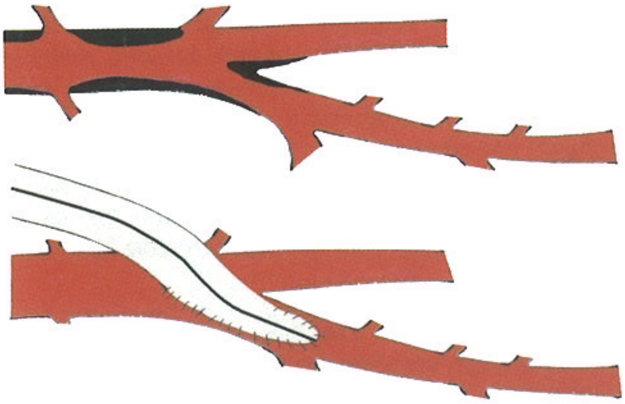

FIGURE 15
Distal end-to-side anastomosis of an aorto-femoral bypass to profunda femoris artery

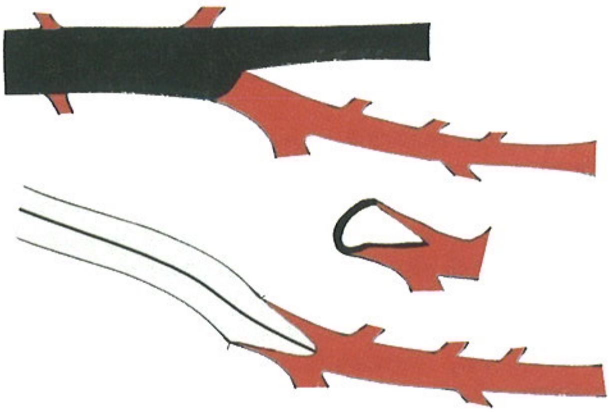

FIGURE 16
Distal end-to-end anastomosis of an aorto-femoral bypass to profunda femoris artery

When the ateroma exists beyond the origin of the profunda femoris artery it may be necessary to perfom a more distal bypass in the mid or distal portion of the profunda femoris artery.

Hemodynamically, blood flow throught the profunda femoris artery is equal to that throught the common femoral artery (50), when both the superficial and profunda femoris artery are patent, and is twice that throught a femoro-popliteal vein graft (51).

Therefore, the flow in a graft anastomosed directly to the profunda femoris artery, beyond the area of stenosis or occlusion, should equal flow in a graft to the common femoral artery when superficial femoral artery and profunda femoris artery are patent.

Concomitant aortofemoral and femoropopliteal bypass has been considered as surgery of choice for coexisting aortoiliac and femoropopliteal occlusive disease (52).

However, long prosthetic grafts, from aorta to popliteal or distal vessels result in poor long term patency and limb salvage (53).

The preoperative level of ABPI seems to be significantly correlated with the successful outcome of the reconstruction, altought no valid threshold is found 54. Patency of below-knee popliteal artery was found to be a favorable indicator.

Sequential aorto-common femoral artery bypass and profundoplasty have improved limb salvage in the critical limbs ischemia (14) (Table VIII).

TABLE VIII
Patency and limb salvage rates after sequential aorto-femoral bypass and profundoplasty

Author	Cumulative patency (%)	Limb salvage (%)	Follow – up (years)
Ouriel (20)	96	86	4
Heyden (53)	77	70	5
Prendville (55)	91	90	5

The results for bypass to the distal profunda femoris artery are similar to those for proximal profunda femoris artery bypass (20,55).

Though, it is possible to anticipate improvement following combined aortofemoral and extended profunda femoris artery reconstruction, the most important question is when the distal bypass is an absolute requirement.

In the presence of aortoiliac and femoropopliteal occlusive disease, aortofemoral bypass using profunda femoris artery as outflow vessel results in a good long-term patency.

Usually the exploration of the middle or distal segment of the profunda femoris artery, when the proximal portion is occluded, reveals a disease - free segment which is durable outflow vessel with the same result to the proximal segment (55).

Finally, combined aortofemoral bypass and profundoplasty isn't indicated when occurs the conditions showed in Table IX and femoro-distal bypass seems to be necessary.

TABLE IX
Indications for combined aorto-femoral and distal bypass

1) poorly developed profunda femoris artery collateral flow
2) severe ischemia or gangrene and /or an ABPI under 0.30
3) occlude or severely diseased below – knee popliteal artery

Profunda femoris artery as inflow source for infrainguinal revascularization

Despite a widespread appreciation of the profunda femoris artery as an outflow or collateral vessel, relatively little attention has been paid on the use of this artery as an inflow source for distal reconstructions.

The appropriateness of the profunda femoris artery as an important outflow site for inflow reconstruction is now recognised and accepted (56,57).

However, data are incomplete concerning the use of the profunda femoris artery as inflow site for infrainguinal reconstruction.

Farley (58) in 1964 was the first to describe profunda femoris artery – popliteal bypass.

Stabile (59) subsequently reported 14 bypasses with patency in 13 of 14 bypasses during a 1 to 3 years follow-up.

Nunez (57) described 5 cases in which the profunda femoris artery was used as inflow site.

Leather (60) reported the use of the profunda femoris artery as inflow site in 14 % of 1000 cases of in situ vein bypass graft.

Mills (61) described 56 cases originated from middle or distal segment of the profunda femoris artery. Relatively little attention has been addressed to this useful technique (Figure 17).

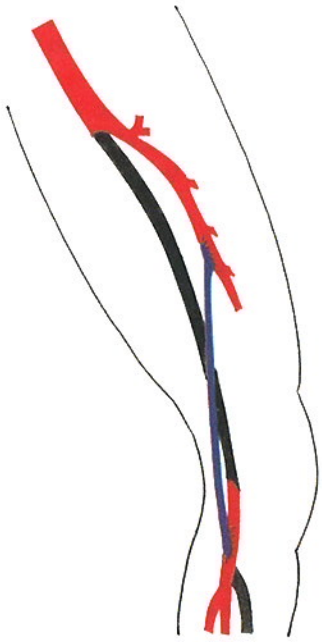

FIGURE 17
Profunda femoris artery as inflow site for infrainguinal reconstruction

Many vascular surgeons seemed to be averse to use of the distal segment of profunda femoris artery as inflow site either because of difficulty of surgical exposure or fear that progressive disease in the proximal profunda femoris artery may compromise the bypass.

The profunda femoris artery may be considered practical and durable inflow source when the patient presents the caratheristics described in table X.

TABLE X
Profunda femoris artery as inflow site: indications

1) groin scarring from previous inflow reconstruction or infection;
2) inadequate vein length and occlusive or stenotic disease in the superficial femoral artery or popliteal arteries precluding their use as an inflow site;
3) concomitant profundoplasty;
4) patients requiring simultaneous inflow and outflow reconstruction.

In patients requiring repeat distal revascularization without adequate ipsilateral saphena magna, the profunda femoris artery can be exposed directly, avoiding groin scar and shortening the length of ectopic vein from ipsilateral saphena parva, controlateral saphena magna or arm vein.

This tecnique is relevant to patients with patent aorto-femoral, femoro-femoral or axillo-femoral bypasses which required crural reconstruction in second istance.

In these cases, the risk of infection can be avoided by direct exposure of the distal segment of the profunda femoris artery and reducing time of surgery.

Finally, the complications of surgery of the profunda femoris artery are listed in Table XI.

TABLE XI
Complications in profunda femoris artery surgery

Thrombosis
Parietal complications
Lymphatic complications
Septic complications
Anastomotic or iuxta-anastomotic stenosis
False anastomotic aneurysm (pseudoaneurysm)

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