# Part VII

# Surgical treatments

# Extra-anatomic Bypass Surgery in Critical Lower Limb Ischemia

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Since the introduction in the early 1960 for management of infections or failure of previous graft (1,2), the use of extra-anatomic bypass has been increased in patients at high risk for aortobifemoral bypass or for those with limited disease not suitable for percutaneous angioplasty and/or stent (Table I) (3,4).

**TABLE I**
**Indications for extra-anatomic bypass surgery**

| | |
|---|---|
| 1) | "Hostile" intraabdominal pathologic features |
| 2) | Infected aortic graft (previous vascular surgery) |
| 3) | Aorto-enteric fistulas (previous vascular surgery) |
| 4) | High surgical risk of abdominal reconstruction in patients with visceral or systemic disease |

The extra-anatomic bypass implies avoidance of the anatomic pathway. Undoubtly, the most common types of extra-anatomic bypass are axillofemoral, axillobifemoral and femoro-femoral bypass.

In these surgical procedures, abdominal approach is avoided. This happens when there may be no reasonable surgical alternative or serious visceral and/or systemic disease, accepting a lesser degree and duration of benefit versus a lower mortality and morbidity rates.

Noretheless the patency rate of these alternative procedures is less than that of aortobifemoral bypass, and hemodynamic performance of extra-anatomic bypass grafts is often inferior (5).

Clearly results of extra-anatomic bypass should be not combined. Femoro-femoral bypass gives superiorly results in every aspect to axillounifemoral bypass. The combination of these procedures, the axillobifemoral bypass, holds an intermediate position.

However, the results of extra-anatomic grafts are different in patients with good versus poor run-off or when this procedures are performed as primary or secondary reconstruction for failure of previous grafts (6).

## Thoraco - iliofemoral bypass

The first thoracic aorta-to-femoral arteries bypass using homograft was performed by Sauvage in 1956 in a patient with history of intermittent claudication and a thrombosed aortoiliac graft. A transabdominal approach with a median sternotomy extending into the left fourth intercostals space was used and the graft was routed through the peritoneal cavity. Two preserved aortic homografts were anastomosed and interposed between the descending thoracic aorta and the femoral arteries. The graft remained patent for twenty months. This case report was published only in 1961 by Stevenson (7).

Blaisdell (8) reported in the same year the use of the descending aorta as an alternative inflow source for the treatment of aortoiliac occlusive disease. Sauvage operated to prevent certain limb loss after multiple failed abdominal grafts, and Blaisdell envisioned bypass around an infected abdominal aortic prosthesis.

He removed an infected aortoiliac polytetrafluoroethylene prosthesis and anastomosed a 14 mm Dacron graft to the descending thoracic aorta, through a low anterolateral thoracotomy, and using a retroperitoneal tunnel performed the distal anastomosis to the left femoral artery, with a suprapubic branch graft to the right femoral artery. The patient died four weeks later of intraabdominal sepsis.

The bypass from descending thoracic aorta to the femoral artery is only rarely performed in the surgery of the aortoiliac arterial occlusive disease.

No surgical center has performed a large number of this type of surgical procedure, above all in comparison of axillofemoral bypass. However, the published surgical series and case reports document a positive outcome (9,10,11). Infact, when abdominal aortic surgery is undesiderable because of severe disease at the inflow site, previous abdominal surgery, abdominal sepsis, axillofemoral bypass is often the most common performed procedure.

More recent studies (12,13,14), have established a role for descending thoracic aorta-to-iliofemoral bypass grafting for secondary revascularization on the basis of low perioperative morbidity, mortality and patency rates (Figure 1).

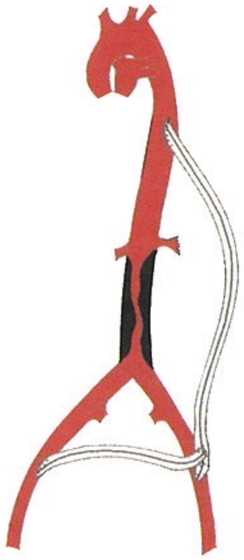

**FIGURE 1**
*Thoraco-femoral bypass*

**TABLE II**
**Thoraco-iliofemoral bypass versus axillofemoral bypass**

| |
|---|
| √ Shorter graft length |
| √ Better protection of the graft from infection |
| √ Better protection from mechanical trauma |
| √ Superior patency rates |
| √ No increased morbidity or mortality rates |

Descending thoracic aorta-to-iliofemoral artery bypass grafting must be considered a secondary procedure if performed in the presence of previous failed or infected aortofemoral or extra-anatomic bypass graft. Usually, descending thoracic aorta bypass is reserved for patients with aortic graft failure or infection or as alternative procedure when a direct transabdominal aortic approach isn't feasible (Table III).

**TABLE III**
**Descending thoracic aorta bypass: selection criteria as secondary procedure**

| |
|---|
| √ Failed axillofemoral bypass |
| √ Unsuitable axillary arteries |
| √ Aortic graft failure |
| √ Aortic graft infection |
| √ Abdominal septic source |
| √ Abdominal stomas |
| √ Previous abdominal radiation therapy |
| √ Multiple abdominal operations |

Although descending thoracic aorta-to-iliofemoral artery bypass grafting as secondary procedure is well established, its role as a primary procedure is controversial. However, some authors have expanded in the recent years the use of this surgical procedure to include selected patients in whom a primary aortofemoral isn't an optimal choice (15) (Table IV).

**TABLE IV**
**Selection criteria for primary descending thoracic aorto-to-iliofemoral bypass (15)**

| |
|---|
| √ Severe atherosclerotic disease or complete occlusion of the infrarenal aorta and controindications to direct aortic reconstruction; |
| √ Severe atherosclerothic disease or complete occlusion of the infrarenal aorta in which the descending aorta was preferred source of inflow on the basis of severity of aortoiliac disease. |

In their opinion, the use of descending thoracic aorta as an inflow source for primary aortoilio- femoral revascularization has several advantages respect abdominal aortofemoral bypass: the descending thoracic aorta has usually minimal atherosclerotic disease; the thoracic aortic clamp to perform the proximal anastomosis avoids spinal cord ischemia, mesenteric and renal ischemia; the retroperitoneal position of the graft avoids hostile abdomen and the placement of the proximal anastomosis in the chest eliminates the possibility of the aorto-enteric fistula (Table V).

Complete aortic occlusion occurs in 8% of patients admitted with atherosclerotic occlusive disease (16) and iuxtarenal aortic occlusion represents an advanced stage of disease (17).

**TABLE V**
**Advantages of descending thoracic aorta-to-iliofemoral bypass (20)**

| |
|---|
| √ Optimal inflow |
| √ Favorable hemodynamics |
| √ High patency rates |
| √ Avoid diseased aorta |
| √ Prevent aorto-enteric fistula |
| √ Avoid aortic cross-clamping |
| √ Reduce risk of operative embolization |
| √ Minimize splanchnic ischemia |
| √ Avoid transabdominal approach |
| √ Negligible risk of spinal cord ischemia |
| √ Excellent graft protection |
| √ Avoid sexual dysfuction |

The proposed pathophysiological mechanism for infrarenal aortic occlusion is that of iliac and distal aortic disease progression, with outflow to the renal arteries maintaining patency of the suprarenal aorta. Several reports have raised concern for proximal aortic thrombus propagation manifested as renal failure or mesenteric infarction (18).

Other reports has confirmed, on the other hand, that proximal thrombus progression rarely occurs when infrarenal aortic occlusion is accompanied by remote bypass grafting, except in the presence of renal or mesenteric lesions (19). However, the long term visceral ischemic complications in patients with juxtarenal aortic occlusion, undergoing thoracofemoral bypass, remain uncertain.

The operative technique vary among authors (Table VI). Most prefers an antero-lateral thoracotomy with posterior tunnelling beneath the crus of the left diaphragm (21,22). A bifurcate graft is brought to the left groin an then one limb tunnelled to the right groin. A left flank incision is often performed to facilitate the tunnelling. Anterior thoracotomy and retroperitoneal tunnel of the graft along the anterior axillary line is also performed, the right femoral artery is reached by subcutaneous suprapubic tunnel as a femoro-femoral bypass (12). In some case has been described a thoracoabdominal approaches (Table VII).

**TABLE VI**
**Surgical approaches to descending thoracic aorta for thoraco-iliofemoral bypass**

| |
|---|
| Anterolateral thoracotomy (eighth intercostal space) |
| Posterolateral thoracotomy (eighth-ninth intercostal space) |
| Thoracoabdominal incision |

## Thoracic aorta - transobturator - popliteal bypass

The most commonly used procedure in aortic graft infections remains the complete removal of the aortic graft and extra-anatomic reconstruction by axillofemoral bypass grafting (29,30,31).

The cumulative patency rate at 3 years for axillofemoral bypass grafting is inferior to 60% (32). It is still worse in patients who have infrainguinal occlusive disease and compromised outflow, in whom patency is reduced to a cumulative 2-years secondary rate of 38% (32,33).

Recurrent infection of the axillofemoral bypass grafting increases the likelihood of major amputation (34).

All these adverse factors resulted in recurrent axillofemoral graft failure and acute lower limb ischemia. In such cases, conversion of the axillofemoral bypass graft to a more durable reconstruction is mandatory.

To avoid dissection in the abdomen, the revascularization procedure is based on the lower thoracic aorta as inflow site and to avoid the infected groin area is used the obturator route.

Both obturator foramina in the pelvis are close, and obturator bypass graft that is inserted has a shorter transverse segment within the pelvis behind the urinary bladder.

The graft that originates in the thoracic aorta terminates in this transverse portion of the obturator bypass.

The graft remains in a posterior position throughout the course in the thorax, retroperitoneum and pelvis. A potential drawback of this placement of the graft is the difficulty to performing a thrombectomy or revision when required.

**TABLE VII**
**Reports on descending thoracic aorta-to-iliofemoral bypass**

| Author | Year | Patients (n°) | Type of indication | | | Operative mortality | Follow-up (mean length in months) |
|---|---|---|---|---|---|---|---|
| | | | AGF | AGI | Other | | |
| Feldhaus (23) | 1985 | 18 | 12 | 3 | 3 | 1 | 40 |
| Haas (24) | 1985 | 3 | - | - | - | 1 | 16 |
| Mc Charty (25) | 1986 | 13 | 5 | 7 | 1 | 0 | 22 |
| Hussain (26) | 1988 | 8 | 2 | - | 6 | 0 | 36 |
| Schellack (27) | 1988 | 3 | - | - | - | 0 | 21 |
| Bowes (28) | 1990 | 26 | 9 | 1 | 16 | 1 | 53 |
| Branchereau (10) | 1991 | 10 | 9 | - | 1 | 1 | 14 |
| Criado (20) | 1992 | 16 | 6 | - | 10 | 2 | 48 |
| Mc Charty (12) | 1993 | 21 | 5 | 12 | 4 | 0 | 44 |
| Passman (15) | 1999 | 50* | 17 | 2 | - | 0 | 39 |

** 31 cases performed as primary procedures*
*Legend: AGF = aortic graft failure, AGI = aortic graft infection*

## Axillo - femoral bypass

Aortobifemoral bypass yeld uniformly good results and has therefore become the standard operation against wich other treatment for aortoiliac occlusive disease should be compared.

Lewis in 1962 was the first to use an upper extremity artery as the inflow donor for a lower extremity bypass graft. A nylon graft was placed from the left subclavian artery to the abdominal aorta. The graft was tunnelled subcutaneously along the chest wall, gaining an intraperitoneal location at the xiphoid (34).

Altough Lewis performed the first axillofemoral bypass, Blaisdell published the first description of the bypass technique one month after Lewis (35) (Figure 2).

Moore in 1971 (36) reported an eight experience of 52 axillo-femoral bypass, including the three cases of Blaisdell (37). Schultz (38) introduced externally supported graft prostheses in 1978, and published in 1986 the results of a series of axillofemoral bypass grafting perfomed using the externally supported prosthesis. Externally supported PTFE graft became available in 1981 (Figure 3).

Since the introduction of axillofemoral bypass in 1962 its role in treatment of aortoiliac disease has remained controversial.

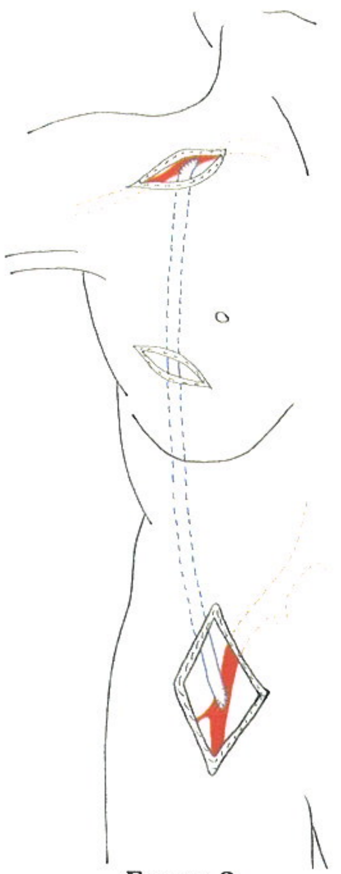

**FIGURE 2**
*Axillo unifemoral bypass graft*

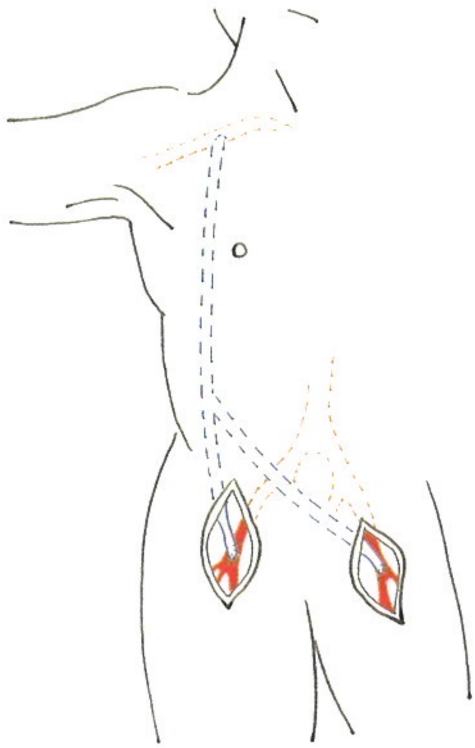

**FIGURE 3**
*Axillo bifemoral bypass graft*

The initial enthusiasm for a lower operative mortality rate respect to the standard aortofemoral surgery was soon stifled by lower patency rates. The primary patency of axillofemoral bypass is inferior to that of aortobifemoral bypass (Table VIII).

**TABLE VIII**
**Factors influencing patency rates**

| | |
|---|---|
| 1) | Configuration of the graft (axillounifemoral vs axillobifemoral) |
| 2) | Symptoms on presentation (claudication vs. threatening ischaemia) |
| 3) | Hemodynamic stenosis of the inflow site (subclavian - axillary axis) |
| 4) | Run-off |
| 5) | Diameter of the graft |
| 6) | Type of graft material (Dacron vs PTFE and external nonsupported vs external supported ) |

However, the patients undergoing axillofemoral bypass are significant older, are medically ill, and have more severe ischemia than patients undergoing aortobifemoral bypass.

Although most reports have favored the axillo-bifemoral configuration over the axillounifemoral bypass (6), other studies do not show a significant difference

**TABLE IX**
**Primary patency rates for axillounifemoral bypass for aortoiliac occlusive disease and CLI**

| Author | Patients (n°) | CLI % | Mortality (%) | Primary patency (%) | | |
|---|---|---|---|---|---|---|
| | | | | 1yr | 3yr | 5yr |
| Ascer (39) | 34 | 100 | 5 | - | - | 44 |
| Chang (58) | 23 | 100 | - | - | - | 33 |
| El Massry (44) | 50 | 62 | 5 | - | - | 79 |
| Naylor (59) | 17 | 100 | 11 | - | - | 50 |
| Rutherford (33) | 27 | 100 | 13 | 48 | 19 | 19 |

**TABLE X**
**Primary patency rates for axillo-bifemoral bypass for aortoliliac occlusive disease and CLI**

| Author | Patients (n°) | CLI % | Mortality (%) | Primary patency (%) | | |
|---|---|---|---|---|---|---|
| | | | | 1yr | 3yr | 5yr |
| Ascer (39) | 22 | 100 | 5 | - | - | 50 |
| Naylor (59) | 17 | 100 | 11 | - | - | 68 |
| Passman (60) | 108 | 80 | 3.4 | 90 | 74 | 74 |
| Rutherford (33) | 15 | 81 | 11 | 78 | 62 | 62 |

between the primary patency rates of both groups (39). Several authors have suggest that long term patency is significantly better with axillobifemoral bypass when compared with axillofemoral bypass (40,41), others do not support this result (42).

The reported primary patency rates for patients with claudication is higher than for those patients who require limb salvage (43,44) (Table IX,X).

Hemodynamically significant axillosubclavian arterial occlusive disease, undetectable bilateral measurement of brachial blood pressure, may be present from 16 % to 25 % of patients undergoing axillofemoral bypass (45).

This high incidence of inflow artery stenosis in patients with no symptom in the upper extremities is greater than expected since reconstructive surgery for upper limbs is only 1-2% of all vascular procedures (46).

The explanation is the development of collateral vessels of the subclavian-axillary axis that accounts for lack of upper extremity ischemic symptoms and the low number of vascular procedures.

**TABLE XI**
**Why inflow arteries are not routinely investigated in axillofemoral bypass?**

1) Low incidence of severe atherosclerotic disease affecting these arteries
2) Preferential choice of right axillary artery as an inflow source because of the widespread belief that there is a lower incidence of stenosis of the right side inflow arteries compared to the left
3) Reliance on pulse examination and non invasive studies to identify inflow artery stenosis
4) Possible added morbidity of inflow arteriography

The subclavian - axillary artery cannot be assumed to be free of significant disease (Table XI).

The subclavian - axillary left axis stenosis seems to be more frequently than stenosis on the right side (47), but other reports documented only a slight predominance of the left-side lesions (48).

Noninvasive arm arterial pressure measurement have been classically accepted as the standard method to evaluate the arteries as a donor sites for an axillofemoral bypass (49).

This method isn't a reliable test. Crawford (50) described that was no difference between upper limb pressures in 27% of patients with ischemic symptoms and significant brachiocefalic stenosis. Whelan (51) has demonstrated that non invasive arterial pressure measurement isn't accurate to identify stenosis of the subclavian - axillary axis.

The high rate of axillofemoral bypass failure has also blamed from some authors on occlusion of the superficial femoral artery (33,40). In other reports (39,44) the patency of the superficial femoral artery did not significantly influence either operative flow rates of the primary patency of the graft. These findings underlined the importance of the profunda femoris artery and the profunda - popliteal collateral vessels.

The bypass itself may produce significant resistance at the increased rates of flow, such as occurs during exercise. An 8 mm. diameter and 60 cm. long axillofemoral graft probably adds resistance to the system in a normal sized individual with an average flow rate of 600 ml/min.

However, use of a larger diameter graft might predispose to thrombosis by diminution in flow velocity (4).

Graft diameter selection is a compromise between adequate resting velocity and adequate flow capacity.

No prospective trials comparing Dacron and PTFE have been performed. The retrospective trials reports have show not difference in patency rates between these two types of graft (52).

Since the introduction in the 1988 of the concept of the externally supported grafts there seems to be a preference for the use of externally supported grafts in axillofemoral bypass (52). Supported graft provides a flat flow surface, resists kink formation and provides more resistance against externally applied pressure than non supported graft. Harris (55) reported 76 externally supported PTFE axillofemoral grafts with primary patency rates respectively of 93% and 85% at 1 and 4 years.

Clinically it has been recognized that frequently axillobifemoral graft occlusions are described during the sleep (40). The proposed mechanisms are the decrease in cardiac output during sleep and compression from the body positioning.

Jarowenko (54) studied six axillobifemoral grafts, revealing the ankle and calf brachial indexes by pulse volume recordings. These parameters were not altered by body weight external compression. On the contrary, Cavallaro (55) has obtained different results. Eight patients underwent pulse volume recordings and ankle – brachial index from 11.5% to 54% at five minutes, and from 16% to 40% at ten minutes are reported. External compression decreased the ankle-brachial index from 11.5% to 54% at five minutes, and from 16% to 40% at ten minutes compared to the baseline compression. The pulse volume recording amplitude also decreased after five and ten minutes of external compression. All hemodynamical changes were statistically different.

Axillofemoral bypass grafts are associated with increased risk of infection. The incidence of this complication is described from 4% to 29% (43,44).

However, hemodynamic results after axillofemoral bypass are inferior to aortobifemoral bypass graft. It is possible that this is due to inadequate axillosubclavian inflow, graft resistance or both (56).

Therefore, axillofemoral bypass remains an acceptable alternative to aortobifemoral bypass in patients at high risk with limited life time expectancy.

## Modified technique for performing axillobifemoral bypass (Rutherford's tecnique)

The "classic inverted c" configuration has the advantage of carrying the higher flow rate that exists in that segment of the axillofemoral graft that supplies both legs all the way down to the ipsilateral femoral artery. A disadvantage of this approach is the need of a second, retrograde end-to-side anastomosis.

The "lazy S" configuration (Figure 4), although leaving a distal segment of the axillofemoral stem with a lower flow rate, and thus unprotected, has several advantages (57):

1) avoid the fourth anastomosis;
2) reduce the amount of prosthetic material;
3) provide for forward angle outflow through all anastomoses;
4) preserve the higher flow rate all the way to the anastomosis to the ipsilateral femoral artery.

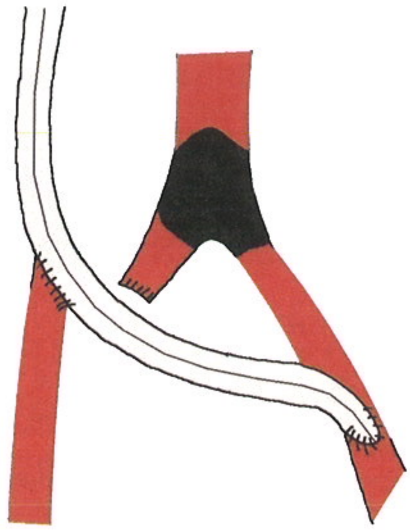

**FIGURE 4**
*Axillobifemoral bypass (Modified tecnique)*

## Axillo - popliteal bypass

Veith (62) first initiated the use of axillopopliteal bypass grafting. In 1977 Smith (65) reported the axillopopliteal bypass in a patient who had graft infection after bypass of a femoral artery aneurysm.

In 1978, Veith (62) reported fourteen axillopopliteal bypass graft and noted the patency in 12 of them after 14 months. Connolly (64) in 1984 reported additionally experience with this type of procedure. In 1989 Ascer (65) reported 55 axillopopliteal bypass graft in 50 patients. In 1992 Keller (66) described his experience with 41 axillopopliteal bypass that were done for limb salvage.

The indications for axillopopliteal bypass grafting can be summarized as:

1. infection of previous aortofemoral or axillofemoral bypass graft;
2. occlusion of previous axillofemoral or aortofemoral graft, with extension of occlusive disease into superficial femoral artery and profunda femoris artery and densely scarring groin;

3. extensive aortoiliac and femoral artery occlusive disease in a patient with severe cardiac disease;
4. insufficient hemodynamic and clinical improvement after an axillofemoral bypass grafting;
5. sepsis of the groin in patients in whom performance of transobturator canal bypass isn't possible because of aortoiliac infection, cardiac risk factors or obesity.

The choice of the outflow site and the route of the tunnel for graft are dependent on whether or not infection or scarring are present and on location and quality of patent arterial segment (65).

The tunnel may be constructed from the axillary artery to the ipsilateral groin along the mid axillary line and then to popliteal artery via a subsartorial route. When the groin is infected or scarred, the tunnel may be placed lateral to antero-superior iliac spine, and then carries inferiorly along the lateral aspect of the tight. Here the tunnel curved toward the medial aspect of the lower tight and finally the tunnel follow the anatomic route of the popliteal artery.

If the approach to the popliteal artery isn't feasible, the above-knee and below knee popliteal artery may be exposed through a lateral approach, as described by Veith (65).

When the common femoral artery is severely diseased or the groin has been subject to multiple operations, may be used a direct approach to the distal profunda femoris artery (68). This approach may be used as a part of sequential axillopopliteal bypass grafting (65) (Table XII).

**TABLE XII**
**Types of axillo-popliteal bypass grafting**

| |
|---|
| Straight axillopopliteal bypass grafting |
| Sequential axillo - femoral to popliteal bypass grafting |
| Crossover axillopopliteal bypass grafting |

The rates of failure and repeated operations are not surprising in view of the advanced disease in patients selected for this procedure. In the Ascer's opinion limb ischemia could be reversed, in patients in whom the only possibility is an amputation, performing axillo-popliteal bypass (Table XIII).

## Obturator foramen bypass

Realized for the first time by Shaw (69) in 1962 in the management of the infected femoral grafts, this extra-anatomic bypass circumvents the femoral triangle utilizing a muscular tunnel deep to the adductor muscles. Obturator bypass grafting has been described as one method to supply perfusion to the lower extremity in case of a deep groin infection (69) (Figure 5).

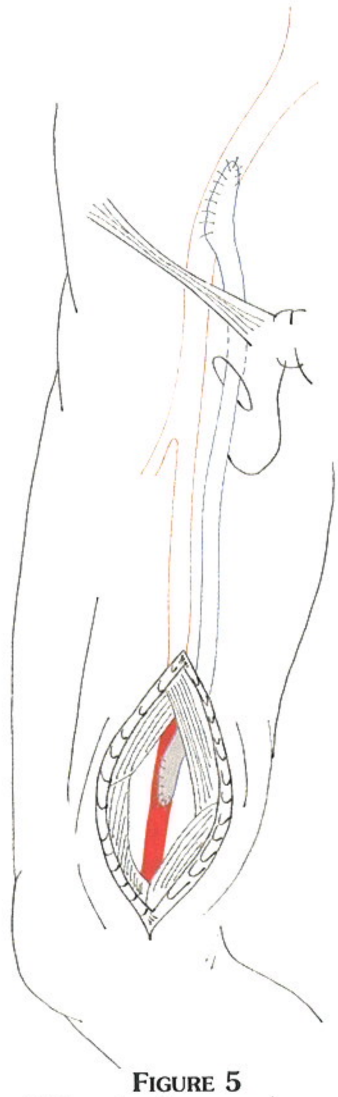

**FIGURE 5**
*Obturator foramen bypass*

**TABLE XIII**
**Primary patency rates for axillo-popliteal bypass for aortoiliac occlusive disease and CLI**

| Author | Patients (n°) | CLI % | Mortality (%) | Primary patency (%) 1yr | 3yr | 5yr |
|---|---|---|---|---|---|---|
| Ascer (65) | 55 | 100 | 8 | 58 | 45 | 40 |
| Keller (66) | 41 | 100 | 20 | 70 | 43 | - |

It has advantages of avoiding the infected region and not needing autologous material. Potential hazards procedure include damage to the obturator vessels and nerve, because visualisation of the obturator foramen is difficult to obtain and passing of the graft through the foramen has to be done mostly by means of digital palpation without visual control. This is more common when crossover bypass grafting is performed.

Althuogh the obturator bypass uses an extra-anatomic route, long-term patency and peripheral hemodynamics are not affected by hip flextion. The ankle brachial index did not change with the hip flexion (70).

The obturator bypass appears to be a more direct route than the lateral subcutaneous iliopopliteal bypass and is shorter than an axillo-popliteal bypass.

The exposure of the iliac vessels by an extraperitoneal approach facilitates patient recovery and minimizes postoperative ileus.

The complications associated with this surgical procedure include injuries to the genitourinary tract and to the obturator vessels and nerve. The urologic complications described are perforation of the bladder and transection of the ureter (71). Injuries to the obturator nerve and artery occur during tunnelling.

The subsequent obturator neurophaty is severe and presents as pain radiating from the groin to the medial aspect of the knee (72,73).

Paresthesia and hypersthesia may also occur. Motor dysfunction produces a wide – based gait which is the result of adductor muscle weakness (73).

Injury of the obturator vessels may result in a retroperitoneal hematoma or blood loss.

## Crossover iliofemoral bypass

Occasionally, the atherosclerotic process involving the iliac axis is unilateral with minimal to no symptoms in the controlateral leg. In these cases, in wich stenoses are not sensitive to percutaneous angioplasty and/or stent, a less extensive procedure may be proposed, for example in aged or poor risk patient or in younger patient in whom postoperative erectile impotence is feared.

In some particular cases occlusion of the primitive iliac artery from its origin or heavy calcification may preclude an ipsilateral ileofemoral bypass grafting procedure. In the same way, when the aorta is heavy calcified, proximal clamping and anastomosis on the aorta to achieve an aortofemoral bypass grafting may be dangerous. In addition aortofemoral bypass grafting requires more extensive retroperitoneal dissection.

In these situations, femoro-femoral bypass grafting is often performed (74,75).

One of the disadvantages of femoro-femoral bypass grafting is the need of two groin incisions, with increased risk of infection (76,77).

Alternative procedure may be a crossover iliofemoral bypass grafting, using the controlateral iliac artery as inflow site after its exposition by a retroperitoneal lateral approach or midline extraperitoneal approach. The graft is tunnellized to the controlateral femoral artery through the Retzius' space behind the Poupart's ligament (Figure 6).

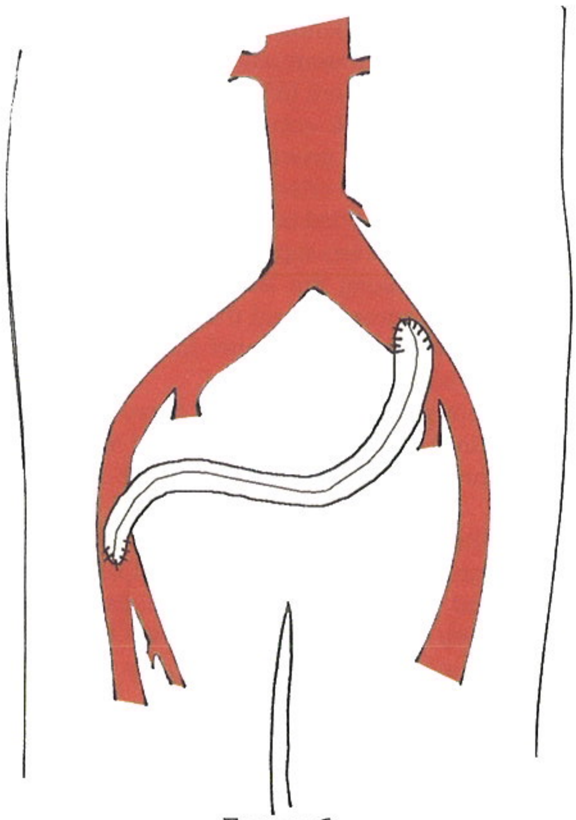

**FIGURE 6**
*Crossover ilio-femoral bypass*

## Video-assisted crossover iliofemoral obturator bypass grafting

This tecnique has been described by Geier in 1999 (78). He used this minimally invasive video-assisted approach to implant a crossover iliofemoral obturator bypass graft in a 60-year-old man with infection of the limb of an aortofemoral bifurcated graft. This appears to be the first case of extra-anatomic bypass grafting performed with a laparoscopical approach.

## Femoro - femoral crossover bypass

Freeman first reported (79) femorofemoral bypass in 1952 with superficial femoral artery used as a conduit. In 1960, McCaughan (80) described two patients in whom they used a crossover bypass for unilateral occlusive disease of the iliac artery. In its current form, the

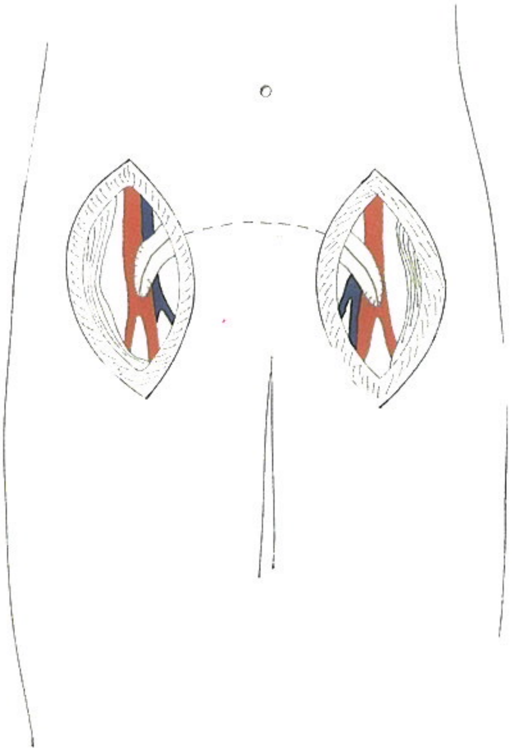

**FIGURE 7**
*Femoro-femoral bypass*

operation was popularized by Vetto 2, who reported in 1962 ten cases in high risk patients (Figure 7).

In 1966, Vetto (81) extended the indications to include good-risk patients who otherwise would have been candidates for aortofemoral bypass.

The selection of surgical treatment for iliac artery disease should weigh operative risk and life expectancy of the patient against the durability of the different procedures under consideration.

The identification of factors that favourably or adversely affect femoro-femoral bypass graft would improve the treatment selection process for the patients with iliac disease.

Ehrenfeld (82), using a sperimental canine model, was the first to demonstrate that, after a femoro-femoral bypass, the donor iliac artery increases its flow tenfold without decreasing flow to the distal arteries on the donor side.

If the resting or papaverine pressure gradient in the donor iliac artery is greater than 15 mmHg isn't indicated to perfom a femoro-femoral bypass. In this case is necessary improve the flow through the iliac donor artery by preoperative transluminal angioplasty, if feasible, or to perfom other type of bypass (iliofemoral) (83).

When the indication to perfom a femoro-femoral bypass is claudication, the patency rate is higher than when the femoro-femoral bypass is performed for limb salvage (74,84) (Table XIV).

Patients requiring limb salvage have multilevel disease with a greater popliteal and tibial artery involvement, therefore poor ouflow.

There is no significant difference in patency between the anastomosis to the common femoral artery compared with the anatomosis to the profunda femoris artery in the Kalman's experience.

When the superficial femoral artery is occluded, is clear the importance to ensuring adequate profunda femoris outflow by profundoplasty or extended profundoplaty, if necessary.

The hemodynamic considerations that are basis for the controversy between the "S" configuration and "inverted C" configuration are explained in the axillofemoral chapter.

Several authors (6,85,86) have suggested that the presence of superficial femoral artery occlusion in the recipient limb produces a significant decrease in the primary graft patency rate.

This is in constrat with other authors (87,88,89,90), which did not show a significant difference in graft patency rates between patients with or without superficial femoral artery occlusion.

However, in Criado's study more than 50% of the patients with superficial femoral artery occlusion underwent a concomitant outflow procedure, whereas only 17 % of those with patent superficial femoral artery had one (87).

These observations are similar to those after aorto-bifemoral bypass and axillo-femoral bypass (42,91).

Harrington (84) showed a lower patency rate in femoro-femoral bypass graft performed with ipsilateral endarterectomy or distal bypass. This is in contrast with the series of Criado (87), Brener (92) and Dalman (93),

**TABLE XIV**
**Primary patency rates for femoro-femoral bypass for unilateral occlusive disease and CLI**

| Author | Patients (n°) | CLI % | Mortality (%) | Primary patency (%) | | |
|---|---|---|---|---|---|---|
| | | | | 1yr | 3yr | 5yr |
| Criado (87) | 110 | 44 | 4.5 | 83 | 71 | 60 |
| Lorenzi (94) | 165 | 67 | 4.2 | 91 | 81 | 75 |
| Ng (95) | 156 | 34 | 1.3 | - | - | 92 |
| Perler (96) | 26/44* | 46/50* | 1.4/1.4* | 87/81* | 79/73* | 79/59* |
| Ricco (97) | 74 | 17 | 1 | 92 | 79 | - |

* *Donor Artery Dilatation*

where the provision of adequate outflow by means of the profunda femoris artery or a bypass graft maked in the presence of superficial femoral artery occlusion is irrelevant in terms of limiting patency rates.

Some surgeons recommended large diameter graft for femoro-femoral bypass, fearing 6 mm may be small causing significant graft resistance. The increasing graft diameter, cross-sectional area and lower theoretical graft resistance are not associated with improved hemodynamic perfomance of femoro-femoral bypass (88).

Previous study has showed that turbulent flow and detectable graft resistance are unlikely to occur at flow rates estimated by Doppler examination in these femoro-femoral bypass, and that 6 mm. aortofemoral graft limbs are not associated with decline in expected postoperative ankle brachial index (91).

Criado (87) reported a lower early patency rate with PTFE grafts compared with Dacron grafts. However, he explained this result as the product of the presence of more severe disease in patients undergoing PTFE femoro-femoral bypass graft.

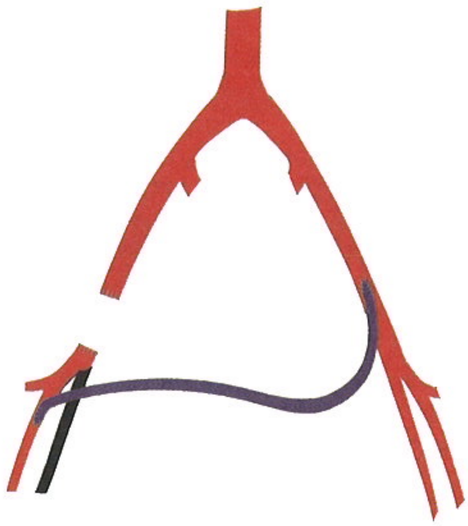

**FIGURE 9**
*Ilio-Femoral transperineal bypass*

### Femoro - femoral trans-perineal bypass

First proposed for surgical treatment of vascular disease with great deterioration of soft tissue, actually the femoro-femoral transperineal bypass (Figure 8,9) are indicated in patients with infection after primary vascular procedure, avoiding the Scarpa triangle.

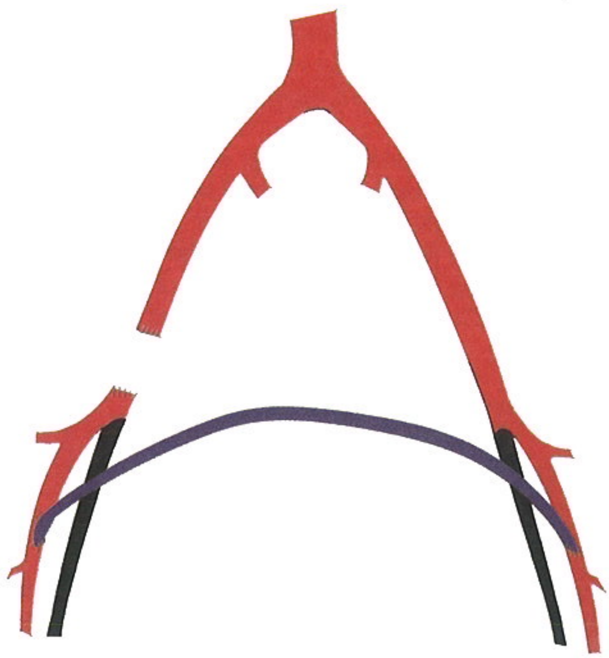

**FIGURE 8**
*Femoro-Femoral transperineal bypass*

### Combined femoro - femoral bypass and percutaneous iliac angioplasty

The first two cases of donor iliac artery percutaneous angioplasty and femoro-femoral bypass for limb salvage were reported by Porter in 1973 (98).

Percutaneous angioplasty is well accepted as a safe and effective treatment for focal iliac artery stenoses. In a study of 3000 cases of iliac artery angioplasty, the immediate success rate was 92% and the 5-year patency rate was 72% (99).

The iliac artery stenting may result in superior patency rates, either as adjunct to angioplasty, or as primary treatment (100).

Graft occlusion infrequently results from progressive inflow disease in the absence of donor iliac artery percutaneous angioplasty (Table XV).

The enhancing outflow might retard disease progression in the donor artery and recurrent disease at the angioplasty site (81).

As already told, Ehrenfeld (82) described that flow through the canine iliac artery increased after performing femoro-femoral bypass as a result of decreased peripheral resistance associated with bypass. Schenk (101) suggested that this decrease in peripheral resistance leads to dilatation of the proximal vessel. This hemodynamic effect is observed in arteriovenous fistula (101).

Gama (102) studied with angiography, after a mean of 18 months, 18 patients submitted to femoro-femoral bypass. He described a modest increase in the diameters of the donor iliac and femoral artery in all 18 cases.

**TABLE XV**
**Femoro-femoral bypass failed as a results of progressive donor iliac artery occlusive disease**

| Author | N° FF bypass | N° failed bypass | % | Year |
|---|---|---|---|---|
| Lamerton (103) | 54 | 1 | 2 | 1985 |
| Plecha (104) | 113 | 1 | 1 | 1984 |
| VA Cooperative Study (105) | 317 | 2 | 6 | 1991 |
| Perler (75) | 26 | 3 | 11 | 1996 |

**TABLE XVI**
**Primary patency after donor iliac balloon angioplasty and femoro-femoral bypass**

| Author | Patients (n°) | Patency (%) | | | Comment |
|---|---|---|---|---|---|
| | | 1yr | 3yr | 5yr | |
| Peterkin (106) | 20 | - | - | 83 | Iliac angioplasty + FF |
| Criado (87) | 24 | 78 | - | - | Iliac angioplasty + FF |
| Perler (75) | 26 | - | - | 79 | Iliac angioplasty + FF |
| Abu Rahma (107) | 41 | 96 | 85 | 85 | Iliac angioplasty + FF |
| Schneider (5) | 8 | - | 42 | - | Iliac angioplasty + FF |

Inferior patency rates has been clearly demonstrated with angioplasty of complete occlusions when compared with stenotic lesions (99,100).

Finally, performing the iliac angioplasty in the same setting of femoro-femoral bypass there is a protective effect exerted on the angioplasty site, by improving outflow with the bypass graft (96) (Table XVI).

## Femoro-femoral bypass for aortofemoral bypass graft occlusion

Aortofemoral bypass graft is the standard surgical procedure for the treatment of aortiliac occlusive disease and aneurismal disease of aortoiliac arteries. Aortofemoral bypass is one of the most durable arterial reconstructive procedures with patency rates of 85 % to 90 % at 5 years and 75% at 10 years (108).

Despite these favourable results, aortofemoral graft occlusions are reported in 5 to 15 % of cases at 5 years and up to 40% at 20 years (108).

Occlusion of a single limb of the graft occurs most often, leaving the controlateral limb patent.

When aortofemoral graft occlusion occurs, few patients remain symptoms free.

Failure in these cases may be due to a variety of causes, including mechanical problems, pseudoaneurysm formation, or, more frequently, progression of disease distal to the femoral anastomosis. This failure may due to kinking of the graft limb through its retroperitoneal course, presence of thrombotic plug in the proximal graft limb, layered buildup of fibrinous pseudointima along the laminal surface of the graft limb (109).

The treatment in such cases required restoration of inflow and correction of the cause of compromised outflow at or beyond the graft limb.

Ballon catheter thrombectomy of the occluded graft was initially recommended to restore inflow. Simple thrombectomy of the occluded graft limb may be performed successfully if the thrombosis is treated early after the occlusion (110). In many cases, however, the fibrinous pseudointima that accumulated on the luminal surface of the graft could not be adequately removed, compromising the durability of reoperative attempts (111). Incomplete removal of this pseudointima may predispose to rethrombosis or distal embolization. The aortofemoral graft thrombectomy may cause embolization to the controlateral patent graft limb. As alternative, a femoro-femoral bypass may be recommended (112).

Difference in graft size and type (ringed/nonringed) exists in various reports, but useful conclusions can not be reached. The PTFE aortofemoral graft does have a smooth, non corrugated flow surface similar to peripheral PTFE grafts that have extended use for infrainguinal revascularization. An extensive experience with successful graft thrombectomy for infrainguinal PTFE graft, as well as PTFE grafts used for dialysis access (113), has been reported (114).

However, femoro-femoral bypass graft is a successful and durability surgical treatment of an aortofemoral graft occlusion. Extended patient survival and an increasing number of patients undergoing aortofemoral bypass in the last years makes this surgical solution actually.

## Femoro – popliteal bypass to the popliteal artery approached laterally

Medial and posterior approaches to the popliteal artery may are considered as standard approaches.

Lateral access route to the popliteal artery, both above (Figure 10) and below the knee (Figure 11), can be performed in secondary operations as extra-anatomical approaches (115,116).

To conduct grafts to or from a popliteal artery approached laterally, tunnels are constructed in a subcutaneous plane. For grafts from the femoral arteries via a standard groin incision, the course should be across the anterior aspect of the third mid tigh and then down laterally on lower thigh to the popliteal fossa.

If the inflow artery is external iliac artery, axillary artery or thoracic aorta, the tunnel follows a curve from the inflow site to the lateral aspect of the thigh and then inferiorly to the popliteal fossa (117).

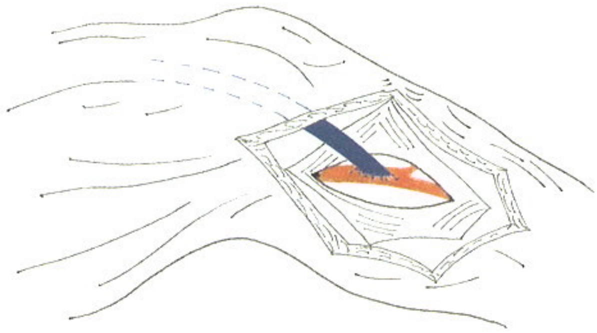

**FIGURE 11**
*Femoro-popliteal bypass lateral access to the below the knee popliteal artery*

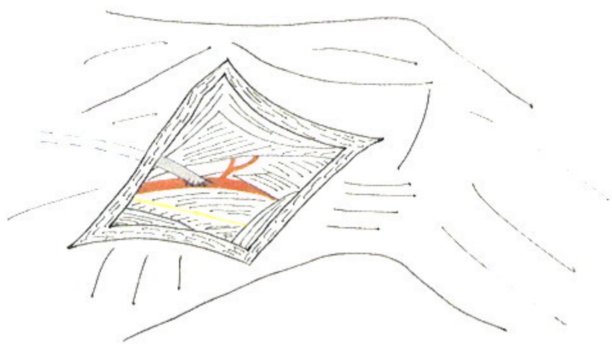

**FIGURE 10**
*Femoro-popliteal bypass lateral access to the above the knee popliteal artery*

## Current perspective

In conclusion, no single option is optimal in all istances. In every patients the decision about which is the best choice is made by consideration of several factors.

The extent and distribution of disease and the risk of the alternatives must be considered.

The success of the surgical procedures, in terms of hemodynamic improvement, symptom relief and patency, can usually be predicted with accuracy and such estimates must be judged respect to patient age, expected length survival and specific needs of each patients. Durability must be balanced against the advantages of safety and expediency.

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