In Defense of Grafts Across the Inguinal Ligament:

An Evaluation of Early and Late Results of Aorto-femoral Bypass Grafts

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THE USE of aorto-femoral bypass grafts has been criticized on the basis of high incidence of femoral false aneurysm, infections of the prosthesis in the groin and thrombosis secondary to kinking of the grafts on flexion of the hip.[8-11, 14] Since 1960 our standard reconstructive procedure for advanced aorto-iliac occlusive disease has been bypass graft from the aorta to the femoral artery bifurcation. In this report results in 58 patients who had aorto-femoral bypass grafts are evaluated regarding symptomatic relief, early and late patency and incidence of early and late complications.

Materials and Methods

Records of all patients undergoing aorto-femoral bypass graft operations from September 1960 to January 1966 were reviewed. The followup period was from 1 to 6 years. All patients have been seen regularly at 3 to 6 month intervals. Information concerning functional results has been obtained from clinic records. All living patients were reexamined prior to compiling this report. From patients who had moved from the area, followup information was obtained by telephone or written questionnaire. Followup data were obtained on every patient.

During the period covered by the study 58 men patients underwent aorto-femoral bypass grafting with 90 femoral anastomoses performed. The mean age of the patients was 61.7 years and ranged from 38 years to 79 years. All operations were performed by the resident staff under the supervision of attending or full time staff.

Operative Indications. The most frequent indication for operation was claudication (30 patients, 51.7%). It is our policy to operate upon patients with claudication only when it is sufficiently disabling to interfere with gainful employment or to curtail daily activities. Thirteen patients (22.4%) had pain at rest as the primary indication for operation and 13 patients (22.4%) were operated upon for ulceration or gangrene due to advanced ischemia. Two patients operated upon for aneurysmal disease were included in the series because of concomitant iliofemoral occlusive disease necessitating bypass to the profunda femoris artery (Table 1).

Arteriography. All patients had translumbar aortography, usually in combination with bilateral femoral arteriograms, to completely outline the vascular tree from

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TABLE 1. *Indication for Surgery*

Symptoms	No. of Patients	%
Claudication	30	51.7
Rest pain	13	22.4
Ulcer or gangrene	13	22.4
Other (aneurysm +)	2	3.5

TABLE 2. *Distribution of Lesions*

Arteriographic Findings in 58 Patients (112 Limbs)	No. of Limbs	%
Aorto-iliac occlusion	41	36.5
Aorto-iliac stenosis	58	52.0
Associated superficial femoral artery occlusion	56	50.0
Associated profunda stenosis	17	14.6

the level of the renal arteries down to and including the popliteal artery trifurcation. The arteriographic findings are presented in Table 2. Concomitant superficial femoral occlusion was present in 50% of patients and 14.6% of the profunda femoris arteries were involved with significant arteriosclerotic disease. Only two patients had disease limited to aorto-iliac region. In patients with concomitant superficial femoral occlusion, aorto-femoral bypass grafting was the initial procedure in a possible two-stage reconstruction. The second stage would have consisted of femoral-popliteal reconstruction.

Associated Disease. Six patients (10.6%) had diabetes. Thirty-five patients (60.3%) had arteriosclerotic heart disease. Eighteen (31%) had arteriosclerotic cerebrovascular disease documented by previous cerebrovascular accidents, presence of carotid bruit, or demonstration of arteriosclerotic lesions on cerebral angiography. Seven patients had operations on the carotid artery before aorto-femoral bypass. Sixteen patients (27.6%) had hypertension (Table 3).

Operative Technic. The abdominal aorta was exposed through a long midline incision extending from the xiphoid to the pubis. The femoral arteries were exposed through vertical incisions placed directly over each artery (Fig. 1). The proximal anastomosis was usually placed between the inferior mesenteric and renal arteries. This segment of the aorta was suitably prepared by anterior and lateral mobilization. A Crafoord clamp was placed vertically for proximal control and a second Crafoord clamp tangentially along the posterior portion of the aorta for distal control and to prevent back bleeding from adjacent lumbar vessels (Fig. 2). An aortotomy 3 to 4 cm. long was made and a crimped, knitted, Dacron graft beveled at a 45° angle sutured into place with double arm 3-0 braided Dacron sutures. Particular attention was paid to a generous purchase in both the graft and the aorta (Fig. 3). No ellipse of aorta was removed. When the anastomosis was completed, the aorta was flushed proximally and distally. The graft interstices were clotted under pressure. The proximal portion of the graft was then clamped, allowing flow to be restored through the aorta during the subsequent portion of the procedure. At this point all residual blood was aspirated from the graft. The limbs of the graft were tunneled retroperitoneally and brought out to each groin under the inguinal ligament. The femoral artery anastomoses were carried out as follows (Fig. 4): proximal control of the femoral artery was obtained with an angled artery clamp; distal control of patent superficial femoral and profunda femoris arteries with intraluminal catheters held in place with circumferential umbilical tapes. These catheters prevented back bleeding and permitted installation of dilute heparinized saline solution (10 mg./100 cc.) into the distal arterial tree.[2]

If the superficial femoral artery was patent, arteriotomy was started on the common femoral artery and extended past the orifice of the superficial femoral artery. The distal limb of the bypass graft was tailored

with a 45° angle bevel, leaving a square cut tip of approximately 4 mm. The advantage of this technic is that it permits the distal portion of the anastomosis to flare out and avoids any possibility of stenosis of the run-off vessel. The anastomoses were performed with double arm 4-0 braided Dacron sutures. The anastomosis was started at the heel of the graft and continued around laterally from both directions to end in the midportion of one side of the femoral anastomosis. Just before the anastomosis was completed the heparinized saline tubes were flushed for the final time. Both tubes were then removed and anastomosis rapidly completed. At this point scrupulous attention was paid to avoiding back bleeding into the graft by placing a clamp at the distal portion of the graft in addition to the one at the proximal part of the graft. Since the graft had already been completely evacuated of blood, it was not necessary to flush it out before completion of anastomosis. The anastomosis completed, tapes around the superficial femoral and profunda femoris vessels were loosened, the graft opened and flow established.

If the superficial femoral artery was occluded, arterotomy began on the common femoral artery and was carried across the orifice of the profunda femoris artery, so that the end to side anastomosis patched open the orifice of the profunda femoris artery, which is often stenotic. If the superficial femoral artery was open and the midportion of the profunda femoris stenotic, the bypass graft was sutured in place across the orifice of the superficial femoral artery and a profundoplasty performed using a vein patch. Particular care was taken to avoid an endarterectomy of the common femoral artery because this leaves the artery too weak to accept a graft anastomosis. An anastomosis to an endarterectmoized vessel is a potential cause of false aneurysm formation. After both femoral anastomoses were completed an operative angiogram ascertains the adequacy of the anastomosis and that no intravascular thrombosis or embolization has occurred. If a technical error were discovered, or if a vessel were thrombosed, the anastomosis was opened and the defect corrected. This technic is now used, although variations were made during its evolution. In earlier operations many anastomoses were performed with silk sutures. The types of suture materials used for proximal and distal anastomoses are individually tabulated (Table 4).

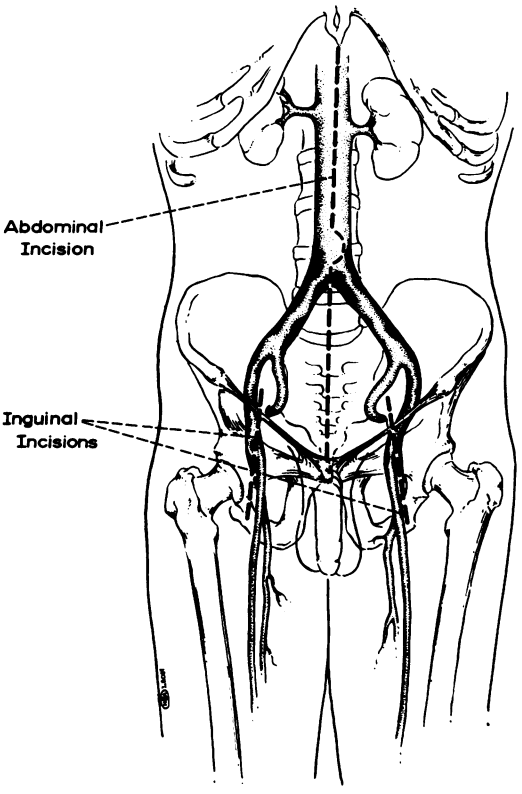

FIG 1. Typical aorto-ilio-femoral atheromatous disease with dotted lines outlining abdominal and femoral incisions.

Results

When discharged from the hospital 30 patients were asymptomatic, 15 were significantly improved, five were unchanged and three were worse. No patient operated upon for claudication lost a limb as a re-

TABLE 3. *Associated Disease*

	No. of Patients	%
1. Heart disease	35	60.4
(a) Prior myocardial infarction	19	32.8
(b) Abnormal EKG	16	27.6
2. Cerebrovascular disease	18	31.0
(a) Carotid artery operations prior to aortic operations	7	12.0
3. Diabetes	6	10.2
4. Hypertension	16	27.6

sult of operation. Of 45 patients who were asymptomatic or significantly improved, 33 (73%) remained essentially unchanged for a period of 1 to 6 years. In patients with concomitant superficial femoral occlusion, if good inflow was restored to the profunda femoral-popliteal reconstruction was unnecessary.

Status of Patients Facing Amputations. In nine patients preoperative ischemia was so severe that an above knee amputation would have been required without revascularization. One patient would have required bilateral above knee amputations. Following aorto-femoral reconstruction, five above knee amputations were avoided (56%). In one patient the level of ischemia was lowered so that it was possible to perform a below knee instead of an above knee amputation. In three patients revascularization failed to prevent above knee amputation. One patient died following operation. An additional 11 patients were scheduled to undergo below knee amputation before vascular reconstruction. Following aorto-femoral bypass grafting, eight of these amputations became unnecessary. The course of three patients was unaltered by revascularization and below knee amputations were performed. There were no deaths in patients facing below knee amputation.

Operative Mortality. Five Patients (8.6%) died within 30 days of operation. Two deaths occurred secondary to cardiac arrhythmia (one following endotracheal suctioning), two deaths resulted from mesenteric thrombosis, and one patient died from massive pulmonary embolus. All deaths occurred prior to 1963. Thirty-one consecutive cases have been performed from January 1963 to January 1966 without a death.

Postoperative Complications. (Table 5). Two grafts thrombosed in the immediate postoperative period and both were successfully reopened. One femoral artery thrombosis was discovered during postoperative arteriography and was successfully opened 10 days after the initial operation. All thromboses in the postoperative period occurred prior to adoption of routine intraoperative angiography.

False Aneurysms. Five femoral false aneurysms occurred in three patients (two

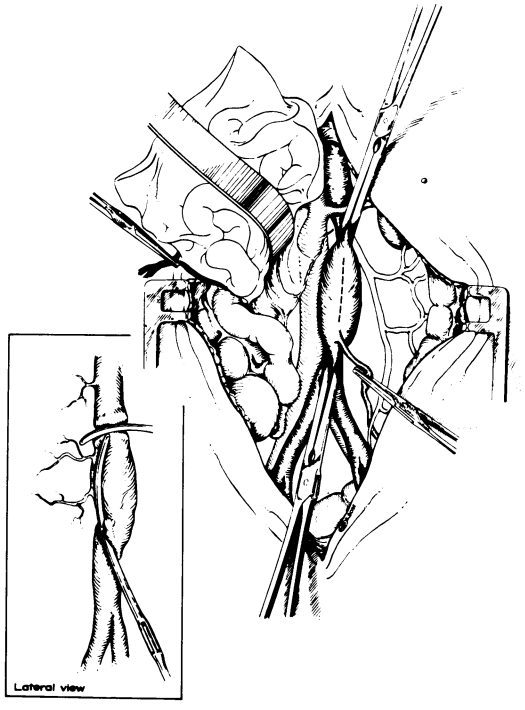

FIG. 2. Vascular clamps applied to infrarenal abdominal aorta. Note that tangential placement of distal clamp controls lumbar back bleeding as well as distal aortic bleeding.

TABLE 4. *Anastomotic Suture Material*

Suture Material	Aorta		Femoral				False Aneurysm*	
	No.	%	No.	%	Groins	%	No.	%
Silk	15	25.6	27	46.6	47	51.6	5	5.5
Mersilene	33	57.0	20	34.4	27	29.6	0	0
Polyethylene	7	12.1	8	13.8	11	12.2	0	0
Unknown	3	5.3	3	5.2	6	6.6	0	0

* Femoral.

patients had bilateral false aneurysms). The aneurysms developed 48 months, 54 months and 60 months after operation. Silk suture material was used in all three of these patients. At reoperation the silk sutures were found disrupted. No false aneurysms have occurred in anastomoses performed with braided Dacron sutures.

Graft Infections. Three patients developed infected prostheses. Two did not manifest infection until 4 years following operation. The third patient developed infection 3 months after operation. In one patient with an infected prosthesis the graft was removed and bilateral above knee amputations were later performed. In another patient the infection was limited to one femoral limb. The limb of the graft was removed and a bypass through the obturator foramen was carried out. This operation successfully revascularized the limb, but the patient died postoperatively from a myocardial infarct. The third patient was operated upon in another hospital for removal of the aortic prosthesis and died from an exsanguinating aortotomy in the postoperative period.

Discussion

The distal anastomoses of bypass grafts originating from the abdominal aorta can be made at the level of the iliac or common femoral arteries. When occlusive disease is localized to the aorto-iliac system, the graft is kept within the abdomen and the distal anastomoses made to external iliac arteries; however, arteriosclerotic disease frequently involved the common femoral artery and the common femoral bifurcation. Many patients also had associated superficial femoral artery occlusions. In these instances there is distinct advantage in exploring the common femoral artery as well as evaluating the orifices of the superficial and profunda femoral arteries. If stenotic disease is present, the graft is used to bypass the common femoral stenosis and patch open any stenosis in the orifices of the run-off vessels, principally the profunda femoris artery. Arteriosclerotic lesions can involve the first centimeter of the profunda femoris artery, but usually the distal portion of this artery is widely patent. The importance of the profunda femoris artery as a significant collateral to the distal lower extremity has been well described.[1, 5, 7, 12] Many surgeons have found that even in the presence of a superficial femoral artery occlusion, if good inflow is restored to the profunda femoris artery collateral pedal pulses frequently return. In these circumstances patients with proximal and distal disease are rendered

TABLE 5. *Postoperative Complications*

	No.	%
Graft limb thrombosis	2	2.2
Femoral artery thrombosis	1	1.1
Transfusion reaction	2	3.4
Hepatitis	1	1.7
Renal artery emboli	1	1.7
Transient oliguria	1	1.7
Superficial groin infection	2	2.2
Postoperative hemorrhage	1	1.7
Postoperative gastrointestinal bleeding	1	1.7

TABLE 6. *Cause of Late Deaths*

	No.	%
Myocardial infarction	5	33.3
Graft infection	2	13.3
Carcinoma	3	20.0
Cerebrovascular accident	1	6.7
Perforated sigmoid diverticulum	1	6.7
Unknown	3	20.0
Total	15	100.0

asymptomatic by a satisfactory proximal operation.[5, 7, 13] On the basis of our experience, we fully agree with this concept.

Many surgeons avoid the use of a bypass graft to the groin because of the high reported incidence of femoral false aneurysms and prosthesis infections. The reasons for femoral false aneurysm formation have been stated to be motion of a stiff graft across the hip joint creating a shearing force at the anastomosis with disruption of the anastomotic attachment to the arterial wall. In addition, weakness of the arterial wall, lack of surrounding supporting structures in the groin, subclinical wound infection and breaking of silk sutures have been implicated as factors predisposing to femoral false aneurysms. No specific reason is given for a higher infection rate, other than that the groin is a relatively contaminated area.[8-11] In our experience these observations have not been verified. Only three patients developed false aneurysms in patients followed from 1 to 6 years. The most important factor in the formation of false aneurysms is the type of suture material used for the anastomosis. In three patients who developed false aneurysms, silk sutures had been used for the anastomoses. At the time of repair of the aneurysms it was seen that these sutures were broken. No false aneurysms followed use of braided Dacron type suture. Several points in the technic of femoral anastomosis are important to avoid this complication. The most important is the type of suture material. Permanent Dacron type sutures should be used. Silk sutures ultimately fracture and lead to late false aneurysms. Another factor in false aneurysm formation is suture of a graft to an endarterectomized vessel. An endarterectomy of the common femoral artery leaves the artery thinner and weaker than if the intima and associated arteriosclerotic plaques were left intact. These layers provide additional strength and may be left intact if the graft is brought to the groin. The final point in technic involves taking a large purchase of host artery with the suture, rather than a small delicate purchase. This maneuver avoids having suture pull out of the arterial wall. If a beveled end-to-side anastomosis is carried out, the graft serves as a patch for the artery and permits a significant amount of arterial wall to be included in the suture line without narrowing the lumen. The reasons for infection in the groin are not clear. The point of presentation of an infected graft will be that area which is closest to the skin surface. If the bifurcation graft crosses the inguinal ligament, the groin is the most superficial area. If the bifurcation graft is within the abdomen, then the presentation of the infection is more subtle. These infections may result in retroperitoneal abscesses, or may

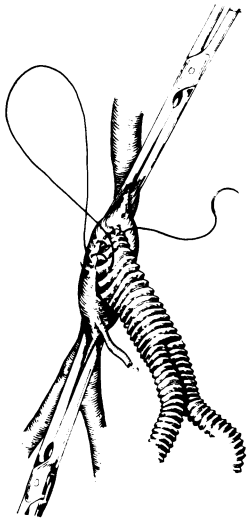

FIG. 3. Graft being sutured to the aorta. Note the generous purchase of both graft and aorta by the suture material.

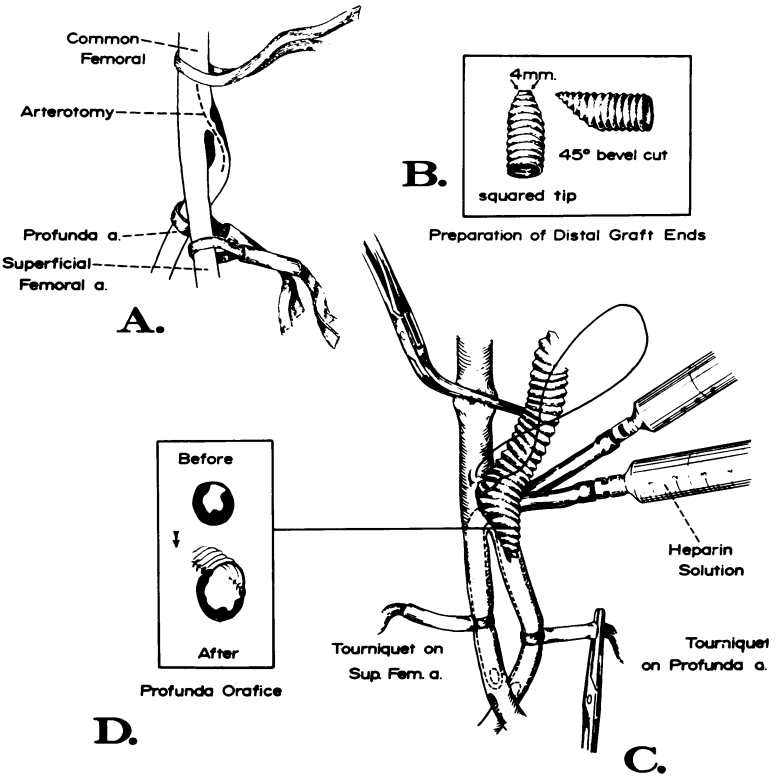

FIG. 4. A. Common femoral bifurcation with a stenosis at the origin of the profunda femoris artery. B. Appearance of the beveled distal limb of graft. C. Femoral anastomosis being performed. Note indwelling catheters for control of back bleeding as well as intra-arterial installation of heparinized saline. D. Orifice of stenotic profunda femoris artery being patched open with the distal end of a bypass graft.

rupture into overlying intestine producing an aorto-enteric fistula. There were three infections in the series, which is consistent with other experiences using prosthetic grafts, regardless of the site of distal anastomosis.[4]

In the early postoperative period two graft limbs thrombosed and were successfully reopened. Since adopting the routine use of intra-operative angiography, the incidence of early graft thrombosis has dropped to zero. The value of intra-operative angiography cannot be emphasized enough. Numerous technical defects have been disclosed by operative angiography, such as distal thrombosis, narrowing of outflow tracts and dissection of intimal flaps. All these complications can ensue in spite of good palpable pulses in the graft and outflow vessels. Operative angiography permits correction of these lesions at the time of operation. This safeguard is largely responsible for a current early graft patency rate of 100 per cent.[3] It has been implied that fibrotic grafts crossing the inguinal ligament would have a higher thrombosis rate because of kinking at the time of hip flexion.[14] However, late patency rate in our patients followed from 1 to 6 years is 97 per cent.

In this series many patients had far advanced arteriosclerotic occlusive disease, involving both the aorto-iliac and the femoral popliteal systems. Many were operated upon for rest pain, ulceration, or gangrene. Twenty-one limbs were scheduled for amputation, but revascularization made 13 of these amputations unnecessary and lowered the level of amputation in one patient from above knee to below knee. One of these patients died (operative mortality 5%). In a similar series operative mortality rate for below knee amputation alone was 16% and that for above knee amputation was 35%.[14] Arterial reconstruction carries a much lower mortality rate than does ma-

jor amputation and, where technically feasible, revascularization in a poor risk patient is preferable to amputation.

The long term results demonstrate that 65% of patients have remained asymptomatic or significantly improved—62% (39/58) were still alive at the end of the followup period. Causes of late deaths in the 1-to 6 -year followup period are analyzed in Table 6.

Summary

The immediate and long term results in 58 patients undergoing aorto-femoral bypass grafts were reviewed. In evaluating the morbidity of bringing a plastic graft across the inguinal ligament, the high incidence of femoral false aneurysms, graft infection and thrombosis reported by others was not found in our series. Only three patients developed femoral false aneurysms and these were related to the late disruption of silk sutures. No false aneurysms occurred since braided Dacron sutures have been used for vascular anastomoses. The long term patency of grafts across the inguinal ligament has been 97%. In patients facing major amputation, 62% of amputations were prevented by revascularization. Mortality when aorto-femoral bypass was used to prevent major amputation was 5%. The indications for operation, technic and symptomatic results are presented. The advantage of bringing the graft to the femoral artery is that the maximum of disease is bypassed and good inflow of blood to run-off vessels, particularly the profundis femoris artery, is assured.

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