Infrainguinal arterial reconstructions with vein grafts in patients with prior aortic procedures: The influence of aneurysm and occlusive disease

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Purpose: This study assessed whether infrainguinal reconstructions with autogenous vein (IR) performed in patients with prior abdominal aortic aneurysm (AAA) repairs have altered graft patency, compared with those in patients who have undergone prior aorto-bifemoral bypass grafting procedures (ABF) for aortoiliac occlusive disease.
Methods: From 1979 to 1998, 54 patients with prior aortic reconstructions underwent 64 autogenous single-segment saphenous IRs solely for infrainguinal occlusive disease. Included in this cohort were 30 IRs with an earlier AAA repair and 34 IRs with an earlier ABF repair. During the same period, 1274 patients underwent 1642 autogenous vein lower-extremity bypass grafting procedures (LEB). Lower-extremity native arterial (AAA, n = 6; ABF, n = 11) and vein graft diameters (AAA, n = 6; ABF, n = 6) were determined by means of angiography and duplex ultrasonography, respectively. The three reconstruction groups (AAA, ABF, LEB) were compared.
Results: The patients in the three groups were similar in sex, indication for operation, proximal and distal anastomotic site, and number of distal runoff vessels. The cumulative 5-year primary graft patency rate in the AAA group (92% ± 5%) was significantly higher ($P < .001$) than that in the LEB group (63% ± 2%) and the ABF group (44% ± 11%). Furthermore, cumulative 5-year primary patency was decreased in the ABF group compared with the LEB group ($P = .05$). A significant increase in both native arterial ($P = .001$) and vein graft diameter ($P < .05$) was demonstrated by using linear regression and a Student *t* test, respectively, in the AAA group compared with the ABF group.
Conclusion: These data demonstrate that, compared with those in patients without a previous aortic procedure, IRs in patients with prior AAA repairs have significantly improved graft patency, and IRs in patients with prior ABF reconstructions for aortoiliac occlusive disease have significantly decreased graft patency. Larger arterial diameter and altered vein graft adaptation may contribute to the superior long-term outcomes of IRs in patients with prior AAA repairs. (J Vasc Surg 2000;31:1128-34.)

By using duplex surveillance, we demonstrated that vein grafts performed for popliteal artery aneurysms, as opposed to those performed for occlusive disease, increase their diameter with time.[1] In a linear regression model, the initial vein graft diameter was predictive of diameter at final follow-up. These data suggested that altered remodeling of vein grafts performed in patients with peripheral arterial aneurysms might have a beneficial effect on patency rates.

Loftus et al[2] confirmed this observation by monitoring a group of infrainguinal vein grafts performed from 1990 to 1995, defining aneurysm as a focal increase of 1.5 cm or greater. Excluding all false aneurysms, they demonstrated a 42% incidence of vein graft aneurysm formation in patients undergoing vein grafting for popliteal artery aneurysm. In

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Competition of interest: nil.

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contrast, vein grafts performed for occlusive disease had only a 2% incidence of aneurysm formation. Loftus suggested that this provided evidence that aneurysm disease is a generalized process affecting transplanted veins and native arteries.

Fillinger et al[3] demonstrated that autogenous lower-extremity bypass grafts in patients with atherosclerotic occlusive disease, in contrast to patients with aneurysmal disease, adapt to alter various physical forces, including sheer stress, by normalizing their diameter with time. This study suggested that saphenous vein bypass grafts performed for occlusive disease remodel in an attempt to normalize certain flow characteristics. These vein grafts change their diameter, volume flow rate, and peak systolic velocity and normalize their sheer stress to approximately 20 dyne / cm^2.

We sought to determine whether infrainguinal vein reconstructions performed in patients who had undergone prior abdominal aortic aneurysm (AAA) repair might have superior graft patency, compared with those in patients who had undergone prior aortobifemoral bypass grafting (ABF) reconstructions for aortoiliac occlusive disease. We also evaluated bypass graft origin, native arterial diameter, and vein graft diameter over time to determine whether any of these parameters might contribute to altered vein graft patency.

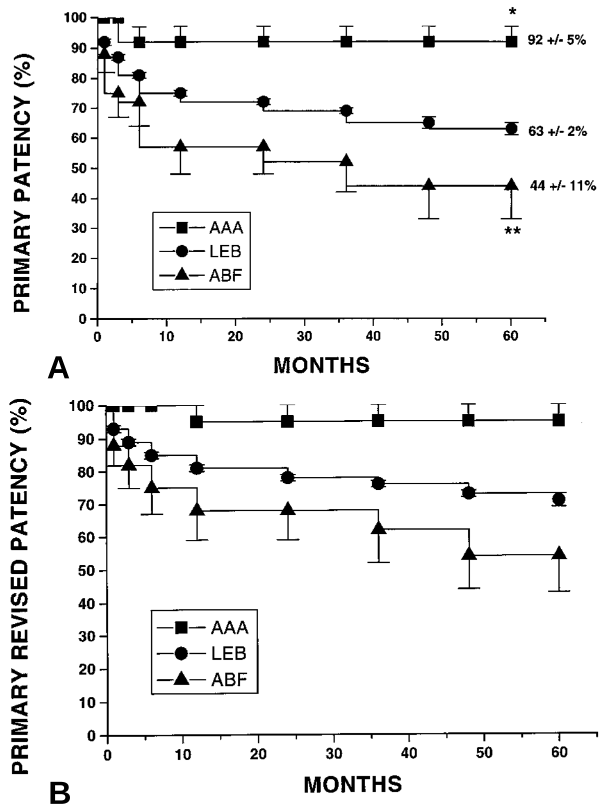

Fig 1. Life-table analysis of primary (A) and primary revised (B) patency in abdominal aortic aneurysm (*AAA*), lower-extremity bypass grafting (*LEB*), and aortobifemoral bypass grafting (*ABF*) groups. **P* < .001, compared with the LEB and ABF groups over 60 months. ***P* < .05, compared to LEB group.

METHODS

From January 1, 1979, through December 31, 1998, 54 patients underwent infrainguinal single-segment saphenous vein reconstructions (IRs) after infrarenal aortic procedures. Of the 64 vein reconstructions performed, 30 (46.9%) followed AAA repair (AAA group) and 34 (53.1%) followed ABF reconstructions (ABF group) for occlusive disease only. None of the IRs performed in the AAA or ABF groups were for femoral or popliteal artery aneurysms. During this 20-year period, 963 patients underwent infrarenal AAA repairs and 310 patients underwent ABF reconstructions. During a similar period (January 1979–December 1997), 1642 total lower-extremity vein bypass grafting procedures (LEB) were performed for atherosclerotic occlusive disease in 1274 patients at the Brigham and Women's Hospital; these patients served as a control group. Patients undergoing IR for femoral or popliteal aneurysm were not included in the LEB group. In addition, no one in the control group (LEB) had a previous AAA or ABF repair.

In a subset of the AAA group (n = 6) and ABF group (n = 11), in which measurement was technically feasible with a calibrated ruler and a measured table height, preoperative angiograms performed before IR were retrospectively reviewed in an attempt to compare inflow and outflow arterial diameters. Diameter was determined at serial locations from the common femoral artery (CFA) to the tibial vessels in a standard fashion. The CFA was measured at the superior margin of the femoral head. Profunda (PFA) and superficial femoral artery (SFA) diameters were measured 1 cm distal to their respective origins. The diameter of the popliteal artery (POP) was measured at the level of the knee joint. Distal runoff, including that from the anterior tibial (AT), posterior tibial (PT), and peroneal (PER) arteries, was measured 1 cm distal to their origin. Measurements were determined in millimeters and calibrated on the bypass graft side with a radiopaque ruler placed between the patient's legs at the time of imaging. A calibrated ruler and knowledge of the height of the table during the angiogram

Table I. Demographics of AAA, ABF, and LEB groups

Risk factor	*AAA group N (%)*	*ABF group N (%)*	*LEB group N (%)*
Mean age (y)	70.4*	60.4	67.1*
Sex (male:female)	23:7 (77)	21:13 (62)	979:662 (60)
Diabetes mellitus	6 (20)†	13 (38)	683 (42)
Smoking	19 (63)	23 (67)	818 (50)
Hypertension	22 (73)	25 (74)	973 (59)
Coronary artery disease	17 (57)	20 (59)	778 (47)
Cerebrovascular disease	3 (10)	1 (3)	148 (9)
COPD	13 (43)†‡	2 (6)	222 (14)
Chronic renal failure	4 (13)‡	0 (0)	176 (11)‡
CHF	3 (10)‡	0 (0)	NR

*$P < .001$, compared with ABF group.
†$P < .05$, compared with LEB group.
‡$P < .05$, compared with ABF group.
COPD, Chronic obstructive pulmonary disease; *CHF,* congestive heart failure; *AF,* atrial fibrillation; *NR,* not reported.

Table II. Indications for bypass grafting surgery

Indication	*AAA group N (%)*	*ABF group N (%)*	*LEB group N (%)*
Claudication	8 (27)	12 (35)	423 (26)
Limb salvage	22 (73)	22 (65)	1219 (74)
Rest pain	14 (47)	16 (47)	549 (33)
Ulceration	3 (10)	5 (15)	435 (27)
Gangrene	5 (17)	1 (3)	235 (14)

allowed for accurate, reproducible measurements of vessel diameter. Occluded vessels were omitted from this analysis. In IRs originating off an ABF graft, the CFA measurement was omitted. Data was compared using linear regression (X T-REG, Stata Corporation, College Station, Tex).

In a separate subset of patients (n = 6 grafts in AAA group; n = 6 grafts in ABF group), serial duplex ultrasound scans were used as a means of examining autogenous vein graft diameters over time in infrainguinal bypass grafts. All graft scans were performed in an accredited vascular laboratory by registered vascular technicians. All graft scans were reviewed and read by a single attending physician (M. D. G-H.). Serial ultrasound scans (two per graft) were performed, with the initial surveillance ultrasound occurring within 3 months after graft insertion. The period from the initial to the final follow-up ultrasound scanning examinations ranged from 8 months to 3 years. Diameter was determined in the same location on each graft, just distal to the adductor canal. Individual graft diameters were determined by using calipers (D1), with 1 cm on the ultrasound calibration scale measured with calipers (D2). The diameter of the vein graft bypass measured in millimeters was subsequently determined to be $D1/D2 \times 10$. Data were compared by means of a paired Student *t* test.

Demographics, indications for surgery, proximal and distal anastomotic sites, distal runoff, and orientation of vein grafts were recorded in a prospective fashion in the vascular registry and reviewed in a retrospective manner. The number of distal below-the-knee runoff vessels (0-3) was determined after a review of each patient's lower-extremity angiogram. Vessels (anterior tibial, posterior tibial, peroneal) were counted as runoff when they were patent at the ankle. Results are reported as the mean plus or minus the standard error of the mean. Noncategorical variables were compared with a Fisher exact *t* test. Graft patency and limb survival were determined by means of an actuarial life table analysis. Statistical comparison between life table curves for primary patency, primary revised patency, and limb salvage were made with the Mantel-Cox rank test of significance.

RESULTS

The mean follow-up period was 32.1, 27.1, and 32.2 months in the AAA, ABF, and LEB groups, respectively. Of the 64 IRs in the AAA and ABF groups, 51 (80%) were primary procedures and 13 (20%) were secondary procedures. In the AAA

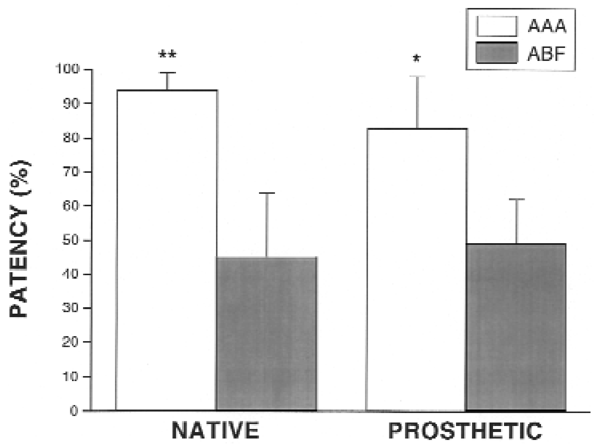

Fig 2. Cumulative 5-year limb primary patency in the abdominal aortic aneurysm (*AAA*) and the aortobifemoral bypass grafting (*ABF*) groups by origin (native or prosthetic) of infrainguinal reconstruction. *$P < .05$, compared with ABF group. **$P < .007$, compared with ABF group.

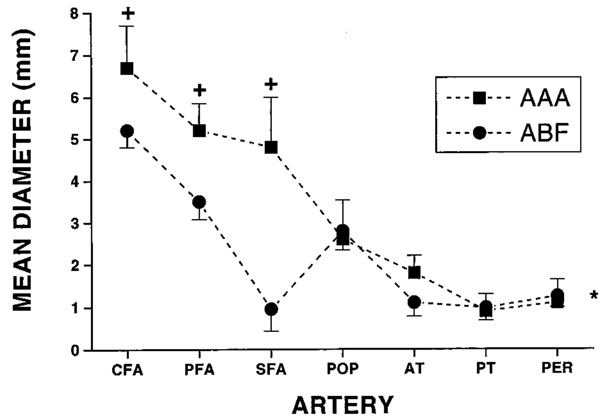

Fig 3. Mean arterial diameter by angiography in the abdominal aortic aneurysm (*AAA*) and the aortobifemoral bypass (*ABF*) groups. A significant difference in arterial diameter by disease (AAA vs ABF, *$P = .001$) and by vessel (proximal—CFA, SFA, and PFA vs distal—Pop, AT, PT, Per, $^{+}P = 0.001$) exists.

Table III. Site of proximal and distal anastomoses for bypass grafts

Site	*AAA group N (%)*	*ABF group N (%)*	*LEB group N* (%)
Proximal			
Common femoral (artery and prosthetic)	19 (63)	27 (80)	1144 (70)
Superficial femoral	8 (27)	5 (15)	307 (19)
Profunda femoral	0 (0)	1 (3)	0 (0)
Popliteal	3 (10)	1 (3)	149 (9)
Other	0 (0)	0 (0)	42 (3)
Distal			
Popliteal	15 (50)	27 (79)	783 (48)*
Above-knee	4 (13)	12 (35)	299 (18)
Below-knee	11 (37)	15 (44)	484 (30)
Tibial (including dorsalis pedis)	15 (50)	7 (21)	859 (52)*

*$P < .001$, compared with ABF group.

group (n = 30), 26 IRs (87%) were primary procedures. Of the 34 IRs in the ABF group, 25 (74%) were primary procedures, whereas 79% of the IRs in the LEB group were primary procedures. No statistical differences existed in the number of primary or secondary procedures performed in any of the three groups. In the AAA group, there were 14 aortic tube grafts, 6 aortobiiliac bypass grafts, and 10 aortobifemoral bypass grafts.

The results demonstrate that although the members of the AAA and LEB groups were older and had more comorbidities, the members of the three groups were similar in sex, indication for operation, site of proximal and distal anastomosis, and number of distal runoff vessels. The AAA group, with a mean age of 70.4 years, and the LEB group, with a mean age of 67.1 years, were significantly ($P < .001$) older than the members of the ABF group (mean age, 60.4 years). The AAA group includes fewer patients with diabetes mellitus than either the ABF or LEB groups (Table I).

Limb salvage was the primary indication for IR in all groups studied (Table II). The AAA and the ABF groups contained only continuous segment saphenous veins, with the vein placed in the nonreversed orientation in 70% and 65% of cases, respectively (P = not significant). The site of both proximal and distal anastomosis for the bypass grafts did not vary significantly (Table III). A larger number of patients in the ABF group (79%) had femoral-to-

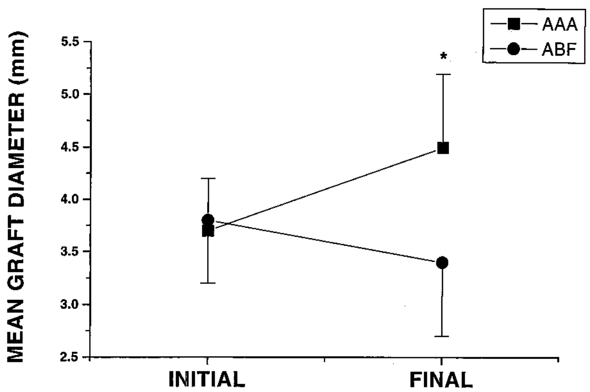

Fig 4. Mean initial and final vein graft diameter (in millimeters) by means of duplex ultrasonography scanning in a subset of grafts in patients with previous abdominal aortic aneurysms (*AAA*) and aortobifemoral bypass grafting (*ABF*) for aortoiliac occlusive disease. **P* < .05.

popliteal bypass grafting procedures, compared with the AAA group (50%), although this did not reach statistical significance. Fifty percent of the patients in the AAA group had bypass grafts to the tibial vessels (Table III). There were no differences in the number of distal runoff vessels shown by means of angiogram between the AAA and the ABF group (Table IV).

Patency, limb salvage, and mortality. Life table analysis comparing primary and primary revised patency after IR in the AAA, ABF, and LEB groups was revealed (Fig 1). Primary graft patency in the AAA group at 3, 24, and 60 months was superior to that in the LEB and ABF groups. At 3 months, the primary patency rate in the AAA group was 100%, whereas the primary patency rate in the ABF group was 75% ± 7% (*P* < .001). Similarly, at 24 months, the cumulative primary patency rate in the AAA group was 92% ± 5%, compared with 57% ± 9% in the ABF group (*P* < .008) and 72% ± 1% in the LEB group (*P* < .008). These differences persisted to 60 months, with a primary patency rate of 92% ± 5% in the AAA group, compared with 44% ± 11% in the ABF group (*P* < .001) and 63% ± 2% in the LEB group (*P* < .001; Fig 1, *A*). The 5-year cumulative primary revised patency rate in the AAA group was 95% ± 5%. The 5-year cumulative primary revised patency rate was 54% ± 11% in the ABF group (*P* < .001, compared with the AAA group) and 71% ± 2% in the LEB group (*P* < .001, compared with the AAA group; Fig 1, *B*). The cumulative 5-year limb salvage rate was significantly improved in the AAA group (95% ± 5%), compared with the ABF group (62% ± 14%; *P* < .01) and the LEB group (85% ± 1%; *P* < .001).

The low primary and primary revised IR patency rates in the ABF group could not be explained by inferior ABF bypass graft patency, because the cumulative 5-year primary patency rate was 88% ± 4% for the ABF bypass grafts. When the origination of the IR was examined, 65% of the lower-extremity bypass grafts originated off prosthetic material in the ABF group, compared with 27% of those in the AAA group (*P* < .002). In the AAA group, 10 patients (33%) had aortic reconstructions that involved at least one aortofemoral bypass graft. At 3 months, there was a statistically significant difference in IR primary patency in the ABF group among IRs originating from different sites: 100% from native artery versus 72% from prosthetic graft (*P* < .002). This difference did not persist to 24 or 60 months. When 5-year cumulative IR primary patency was compared by origin, the AAA group had a significantly higher primary patency rate (*P* < .001), whether the IR originated off of native artery or prosthetic, than the ABF group (Fig 2).

Native arterial diameter measurements. Native inflow (CFA, PFA, SFA) and outflow (POP, AT, PT, and PER) arterial diameters were evaluated by means of arteriography in 17 patients. A significant difference in overall arterial diameter between the AAA and ABF groups (*P* = .001) was revealed by means of linear regression analysis (Fig 3). This overall difference in arterial diameter existed primarily because of a significant increase (*P* = .001) in the inflow size (CFA, SFA, and PFA) in the AAA group, compared with that in the ABF group. These two smaller cohorts were well matched for sex, demographics, indication for operation, graft orientation, anastomotic site, and number of runoff vessels. Similar to the comparison made between the two larger groups, patients with a prior AAA repair in this cohort had a significantly improved IR primary patency rate (82% ± 16%) at 4 years, compared with patients with a prior ABF bypass graft (27% ± 13%, *P* < .005).

Table IV. Number of distal runoff vessels in the AAA and ABF groups

Number of runoff vessels	*AAA group N (%)*	*ABF group N (%)*
3	5 (17)	8 (24)
2	8 (27)	12 (35)
1	12 (40)	10 (29)
0	1 (3)	3 (9)
Not available	4 (13)	1 (3)

Table V. Vein graft diameters in AAA and ABF groups

Aortic surgery	*Initial diameter (mm)*	*Final diameter (mm)*	*Increase/decrease*
AAA group			
Patient 1	4.0	4.7	Increase
Patient 2	3.6	4.7	Increase
Patient 3	3.6	4.9	Increase
Patient 4	3.6	4.9	Increase
Patient 5	3.4	4.6	Increase
Patient 6	3.8	3.9	Increase
ABF group			
Patient 1	3.8	3.4	Decrease
Patient 2	3.7	3.6	Decrease
Patient 3	4.0	3.6	Decrease
Patient 4	3.6	3.4	Decrease
Patient 5	3.6	3.2	Decrease
Patient 6	3.9	3.1	Decrease

Duplex measurement of vein graft diameters. Variations over time in vein graft diameter were measured by using serial duplex ultrasonography of the 12 native vein bypass grafts. Serial ultrasound scans (two per graft) were performed, with the initial surveillance ultrasound scanning occurring within 3 months after graft insertion. The period from the initial to the final follow-up ultrasound scanning examinations ranged from 8 months to 3 years (P = not significant, AAA vs ABF groups). When mean vein graft diameter was determined, a progressive increase in vein graft diameter occurred with time in the AAA group, from 3.7 ± 0.5 mm to 4.5 ± 0.7 mm ($P < .05$). No significant difference occurred in vein graft diameter in the ABF group (initial, 3.8 ± 0.6 mm vs final, 3.4 ± 0.7 mm; Fig 4). Table V demonstrates that each of the vein graft diameters increased over time in the AAA group, compared with a decrease over time in the ABF group.

DISCUSSION

In this study, infrainguinal vein bypass graft primary patency, primary revised patency, and limb salvage rates were superior in patients with prior AAA repairs, compared with patients who had undergone prior ABF repairs for aortoiliac occlusive disease. In addition, patients with prior ABF reconstructions had significantly decreased patency and limb salvage rates, compared with patients without prior aortic reconstructions. Although more of the IRs in the ABF group originated off a limb of prosthetic material than those in the AAA group, we could not demonstrate that graft origination contributed to the poorer-than-expected patency rate results in the ABF group. In fact, the primary patency rate of IRs originating from both native artery and prosthetic material was significantly decreased in the ABF group, compared with the AAA group, regardless of the IR origin in the latter group. This suggests that other mechanisms, unrelated to graft origination, may contribute to the decreased IR patency rates in the ABF group. One can speculate that the presence of significant CFA, SFA, and outflow atherosclerotic disease may have contributed to this result.

In an attempt to provide other possible mechanisms to explain the superior patency rates in IRs in patients with prior AAA repairs, we examined native arterial size and vein graft diameter in two subsets of AAA and ABF patients undergoing IRs. Although the numbers of IRs examined were small, a larger arterial diameter on angiogram in the AAA group was documented in the proximal lower-extremity arteries (CFA, SFA, and PFA). In addition, an increase in vein graft diameter over time occurred in the AAA group, but not in the ABF group, suggesting that changes in vein graft adaptation occurs in patients with centrally located aneurysms, similar to our initial observation in patients with popliteal artery aneurysms.[1] These data support the hypothesis that aneurysm disease is a systemic process affecting the vascular wall biology of veins and arteries in patients with aortic and peripheral arterial aneurysms. A number of other studies support this hypothesis, because vein graft aneurysms have been reported after distal lower-extremity[4-6] and aortocoronary[7-8] reconstructions. Although the exact mechanism responsible for the greater-than-expected IR patency rates in the AAA group remains undefined, graft origination, larger arterial diameter, and increasing vein graft diameter may contribute.

One needs to consider the possibility that a type II statistical error may have occurred when compar-

ing demographics, graft patency rates, and limb salvage rates. Because the numbers in the present retrospective analysis are small, any attempt to make a demonstrable statement about the exact mechanism by which alterations in graft patency occurred would be overstated. Another possible type II error may have occurred when we were trying to discover whether graft origination (native vs prosthetic) contributed to differences in IR patency rates. Because most of the IR graft failures in the ABF group occurred in the first 6 months, technical differences, such as graft origination (native vs prosthetic), are likely important. In addition, because of the small numbers, the effect of having fewer patients with diabetes mellitus in the AAA group on IR graft patency could not be validly determined.

In a previous study, we documented that vein grafts performed for popliteal artery aneurysms increased in diameter with time.[1] Altered remodeling of vein grafts performed in patients with peripheral arterial aneurysms lead to improved bypass grafting patency rates. The development of aneurysmal dilation of arterialized autogenous saphenous vein grafts, primarily in patients with popliteal artery aneurysms, has recently been studied by others. Loftus et al[2] suggested that 42% of patients undergoing lower-extremity bypass grafting with autogenous vein for popliteal artery aneurysms have an increase of more than 1.5 cm in the graft diameter with time. This is compared with only 2% in patients with chronic lower-extremity ischemia with atherosclerotic disease. Szilagyi et al[4] examined the incidence of true aneurysm formation in vein grafts and observed aneurysmal changes in 10 of 260 bypass grafts.

The present study is the first to report improved patency rates in IRs in patients with previous AAA repairs. In addition to this observation, it was also noted that IRs in the ABF group had a much lower patency rate than those in patients without prior aortic surgery. Although patients with aortoiliac occlusive disease may have a larger burden of atherosclerosis and the distal arterial disease may be more progressive, in this analysis, the members of the AAA group were older and had more co-morbidities.

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