From the Society for Clinical Vascular Surgery

Outcomes after redo aortobifemoral bypass for aortoiliac occlusive disease

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Objective: **Patients presenting with occluded aortobifemoral (ABF) bypass grafts are managed with a variety of techniques. Redo ABF (rABF) bypass procedures are infrequently performed because of concerns about procedural complexity and morbidity. The purpose of this analysis was to compare midterm results of rABF bypass with those of primary ABF (pABF) bypass for aortoiliac occlusive disease to determine if there are significant differences in outcomes.**

Methods: **A retrospective review was performed of all patients undergoing ABF bypass for occlusive disease between January 2002 and March 2012. A total of 19 patients underwent rABF bypass and 194 received pABF bypass during that period. Data for an indication- and comorbidity-matched case-control cohort of 19 elective pABF bypass patients were collected for comparison to the rABF bypass group. Primary end points included rate of major complications as well as 30-day and all-cause mortality. Secondary end points were amputation-free survival and freedom from major adverse limb events.**

Results: **The rABF bypass patients more frequently underwent prior extra-anatomic or lower extremity bypass operations compared with pABF bypass patients ($P = .02$); however, no difference was found in the incidence of prior failed endovascular iliac intervention ($P = .4$). By design, indications for the rABF and pABF bypass groups were the same (claudication, n = 6/6 [31.6%]; $P = 1$; critical limb ischemia, n = 13/13 [78.4%]; $P = 1$). Aortic access was more frequently by retroperitoneal exposure in the rABF bypass group (n = 13 vs n = 1; $P < .0001$), and a significantly higher proportion of the rABF bypass patients required concomitant infrainguinal bypass or intraprocedural adjuncts such as profundaplasty (n = 14 vs n = 5; $P = .01$). The rABF bypass patients experienced greater blood loss (1097 ± 983 mL vs 580 ± 457 mL; $P = .02$), received more intraoperative fluids (3400 ± 1422 mL vs 2279 ± 993 mL; $P = .01$), and had longer overall procedure times (408 ± 102 minutes vs 270 ± 48 minutes; $P < .0001$). Length of stay (days ± standard deviation) was similar (pABF bypass, 11.2 ± 10.4; rABF bypass, 9.1 ± 4.5; $P = .7$), and no 30-day or in-hospital deaths occurred in either group. Similar rates of major complications occurred in the two groups (pABF bypass, n = 6 [31.6%]; rABF bypass, n = 4 [21.1%]; observed difference, 9.5%; 95% confidence interval, −17.6% to 36.7%; $P = .7$). Two-year freedom from major adverse limb events (±standard error mean) was 82% ± 9% vs 78% ± 10% for pABF and rABF bypass patients (log-rank, $P = .6$). Two-year amputation-free survival was 90 ± 9% vs 89 ± 8% between pABF and rABF bypass patients ($P = .5$). Two-year survival was 91% ± 9% and 90% ± 9% for pABF and rABF bypass patients ($P = .8$).**

Conclusions: **Patients undergoing rABF bypass have higher procedural complexity compared with pABF bypass as evidenced by greater operative time, blood loss, and need for adjunctive procedures. However, similar perioperative morbidity, mortality, and midterm survival occurred in comparison to pABF bypass patients. These results support a role for rABF bypass in selected patients. (J Vasc Surg 2014;60:346-55.)**

The "gold standard" for management of complex aortoiliac occlusive disease (AIOD) is aortobifemoral (ABF) bypass grafting, with 10-year primary patency exceeding 75% to 80%.[1-3] However, 10% to 20% of patients experience some form of graft failure, including limb stenosis, thrombosis, infection, and degenerative pseudoaneurysm.[4,5] A subset of these patients (1%-3%)[6] present with bilateral limb occlusion, and the optimal treatment is unclear. Multiple remedial choices exist to manage an occluded ABF bypass graft, such as limb thrombectomy, axillobifemoral bypass, thoracobifemoral bypass, or "redo" ABF (rABF) bypass. Several factors influence surgical decision-making, including the patient's symptoms (eg, critical limb ischemia vs claudication), comorbidities, distribution of occlusive disease, anticipated complexity of an aortic reconstruction, durability of the remedial choice, and the patient's preference.

Major perioperative morbidity (10%-30%) and mortality (1%-4%) rates of elective ABF bypass are well documented[7-9]; however, there are limited data on the outcome of rABF bypass for AIOD, and early reports suggest that there is prohibitive risk in performing these procedures.[10,11] Because of these concerns, attempts to preserve the aortic graft (eg, graft thrombectomy) and extra-anatomic reconstruction are most frequently performed for ABF bypass graft occlusion.[12] These strategies have significant merit in

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high-risk patients, but they may be inferior to in-line aortic reconstruction with respect to patency and hemodynamic impact.

The purpose of this report was to describe our experience with rABF bypass for management of AIOD and to compare it with primary ABF (pABF) bypass to determine if there are significant differences in early and midterm outcomes.

METHODS

Database and subjects. After approval from the Institutional Review Board (IRB #201300032), a retrospective review was performed at the University of Florida to identify all patients undergoing open abdominal aortic surgery (n = 839) from January 2002 to January 2013. Patients receiving operations for aneurysm or infection-related indications were excluded. In addition, patients undergoing remedial operations for degenerative anastomotic pseudoaneurysm or axillofemoral bypass were not analyzed. Aortofemoral or thoracofemoral bypass cases performed for AIOD were further reviewed to determine which subjects underwent a reoperative aortic procedure. The study cohort is composed of 18 rABF bypass patients and an additional patient receiving thoracobifemoral bypass after a failed ABF bypass (n = 19).

Case-control study design. To determine if rABF bypass grafting leads to elevated perioperative risk of morbidity and mortality, pABF bypass patients were used as a reference group. The 19 rABF bypass patients were analyzed to delineate parameters of mean age, gender, body mass index, and surgical indication. A previously described Society for Vascular Surgery (SVS) comorbidity score[13] was calculated for each patient to further improve matching accuracy ($\geq$8 = high risk). A control group of 19 patients matched for demographics, comorbidity, and indication undergoing elective pABF bypass grafting (all with TransAtlantic Inter-Society Consensus II type D[14] AIOD) during the same period was subsequently identified and compared with the rABF bypass patients. Specifically, once the rABF bypass covariates were defined, pABF bypass patients were selected on the basis of age (within $\pm$10 years of the mean age of the rABF bypass cohort), indication, and SVS comorbidity score (within $\pm$1 of the mean SVS comorbidity score of the rABF bypass cohort). The most recent pABF bypass patients were reviewed, and ultimately 25 patients were analyzed from 2010 to 2012, of whom 19 were found who met selection criteria. The six patients not included from the pABF bypass group were excluded because of lack of matched indication (two) or low SVS comorbidity score (four).

Data collection and definitions. Demographics, comorbidities, previous vascular operations, noninvasive vascular laboratory data, indications, postoperative outcomes, and need for reintervention or amputation were obtained through chart review. Operative records were analyzed to record aortic access method, need for adjunct procedures (defined as any concomitant visceral or renal bypass, reimplantation or endarterectomy, profundaplasty, or infrainguinal bypass), conduit type and configuration, cross-clamp location and duration, operative time (incision to dressing application), and blood loss.

Patient comorbidities were defined as any prior history of hypertension (any antihypertensive drug), coronary artery disease (angina, coronary artery bypass, percutaneous angioplasty), chronic obstructive pulmonary disease (smoking history >20 pack-years, abnormal pulmonary function test results, medication), diabetes mellitus (oral hypoglycemics, insulin), congestive heart failure (New York Heart Association class II or greater), chronic renal insufficiency (creatinine concentration $\geq$1.8 mg/dL or dialysis dependence), dyslipidemia (chart history or medication), and cerebrovascular occlusive disease (transient ischemic attack, stroke, carotid endarterectomy, angioplasty). Peripheral arterial occlusive disease severity was graded on the basis of reporting guidelines.[15] Graft patency was determined by documentation of a femoral pulse on examination and preservation of the ankle-brachial index (ABI) during the follow-up interval.

Clinical practice. A majority of rABF bypass cases (90%) were referred from other institutions after presenting with a failed pABF bypass graft. With the exception of emergent cases (eg, acute limb ischemia), most subjects underwent extensive preoperative evaluation. This included cardiopulmonary testing, such as chest radiography, electrocardiography, and echocardiography, as well as basic laboratory studies and ABI. Selected patients received vein mapping or lower extremity arteriography if infrainguinal bypass was anticipated to be needed to achieve adequate revascularization. Pulmonary function testing was obtained if a significant history of chronic obstructive pulmonary disease (more than two drugs, inhaled or oral steroid use, or oxygen dependence) was present. The surgeon's discretion determined the need for further risk stratification, including cardiology referral if functional capacity was <4 metabolic equivalents or an abnormal ejection fraction was identified on echocardiography. Preoperative imaging in all cases included an arterial phase, thin-cut ($\leq$2 mm) contrasted computed tomography angiogram. Choice of remedial strategy for a failed ABF bypass graft is further highlighted in the algorithm (Fig 1).

After operation, patients recovered in the surgical intensive care unit (ICU) and subsequently were transferred to a dedicated cardiovascular nursing ward. The individual surgeon's discretion determined timing of care transition and discharge. Postoperative surveillance included follow-up at 1, 6, and 12 months and annually thereafter, with physical examination and ABIs unless the patient had concomitant infrainguinal bypass, in which case duplex surveillance was obtained at 1, 3, 6, 9, and 12 months and every 6 months thereafter. Additional imaging (eg, computed tomography angiography) was obtained if the patient had $\geq$0.15 ABI decrease or change in clinical status. The surgeon's judgment determined timing, need, and type of reintervention.

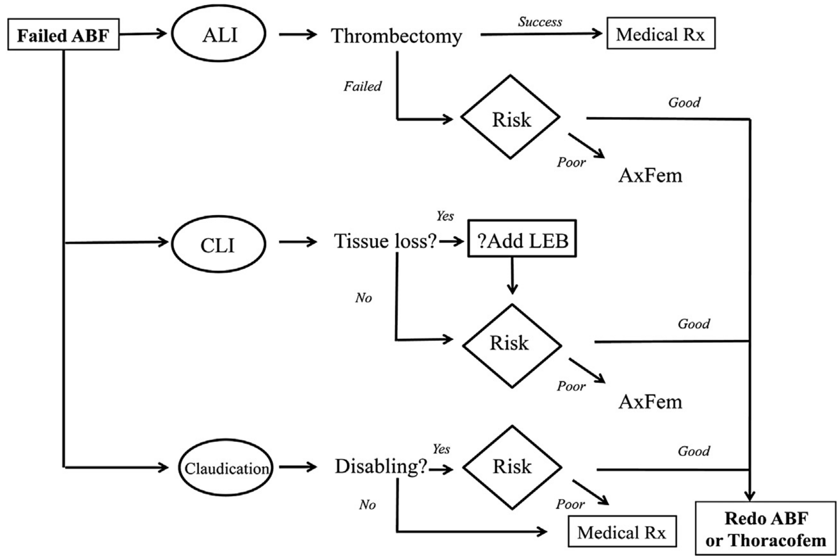

Fig 1. This decision algorithm depicts the philosophy that is applied in our practice to determine what remedial strategy will be employed for patients presenting with an occluded aortobifemoral (*ABF*) bypass graft. *ALI,* Acute limb ischemia; *AxFem,* axillofemoral; *CLI,* critical limb ischemia; *LEB,* lower extremity bypass; *Thoracofem,* thoracofemoral.

Technical conduct of redo ABF bypass through retroperitoneal access. Aortic access in a majority (68.4%) of rABF bypass patients was achieved by a retroperitoneal approach through a curvilinear left posterolateral incision extending from the midline halfway between the umbilicus and the pubic bone to the eighth or ninth intercostal space. Patients are placed in a right lateral decubitus position on a bean bag with the kidney break centered between the anterior superior iliac crest and caudal margin of the ribs. The hips are left as flat as possible to facilitate access to the femoral vessels, and the chest/upper torso is rotated approximately 30 degrees with the left shoulder elevated and immobilized on an armrest (Fig 2, *A*).

After oblique muscle division, the plane posterior to the left kidney is entered and the viscera are reflected to the right. A fixed retractor system is used to facilitate exposure (eg, Bookwalter retractor; Codman & Shurtleff, Raynham, Mass). The lumbar vein is routinely divided to gain exposure to the infrarenal aorta and serves as a marker for the left renal artery. Depending on the patient's body habitus and need for adjunctive visceral or renal procedures, the left crus of the diaphragm is divided to expose the suprarenal aorta. Because of extensive scarring, it may be difficult or dangerous to attempt retroperitoneal tunnels in the vicinity of the right iliac vessels, so we prefer to place the right limb into a more anterior, preperitoneal position coursing cephalad to the bladder. This tunnel is created by bluntly dissecting in the preperitoneal plane with one hand and deep to the inguinal ligament on the right with the other hand (Fig 2, *B*).

Clamp application level is chosen on the basis of the impression of the preoperative computed tomography angiogram, palpation of the aorta intraoperatively, and adequacy of aorta below the renal arteries but above the prior repair. Most frequently, a suprarenal clamp position was employed immediately above the renal arteries and an end-to-end anastomosis with a collagen-impregnated double velour prosthetic graft (Hemashield; Atrium, Hudson, NH) constructed after infrarenal aortic transection immediately above the previous repair (Fig 2, *C*). In addition, if the patient had previously undergone pABF bypass with an end-to-end configuration that was immediately below the renal arteries, we have transected the existing graft and used a small ring of residual graft in the new anastomosis. Irrespective of anastomotic reconstruction technique, the main body of the conduit is left as long as possible, thereby providing maximal graft length to facilitate access to the right femoral vessels.

The limbs of the graft are tunneled through the retroperitoneal space created by rotating the viscera to the patient's right. Alternatively, a femorofemoral bypass can be constructed if the preperitoneal space is scarred or difficulty is encountered in creating the tunnels. The femoral anastomosis is extended onto the profunda vessels, with concomitant profundaplasty or infrainguinal bypass frequently needing to be performed.

Statistical analysis. Primary end points included 30-day and in-hospital mortality and postoperative morbidity. Secondary end points were all-cause mortality, need for reintervention, major adverse limb events [MALEs],[16] and amputation-free survival. Log-rank tests and Kaplan-Meier product-limit estimates were performed to determine differences between the rABF and pABF bypass cohorts. Fisher exact and Mann-Whitney tests were used to compare nominal and continuous categorical variables when appropriate. All deaths were verified from the Social Security Death Index Masterfile. The R-statistical software package (V.2.15.0;

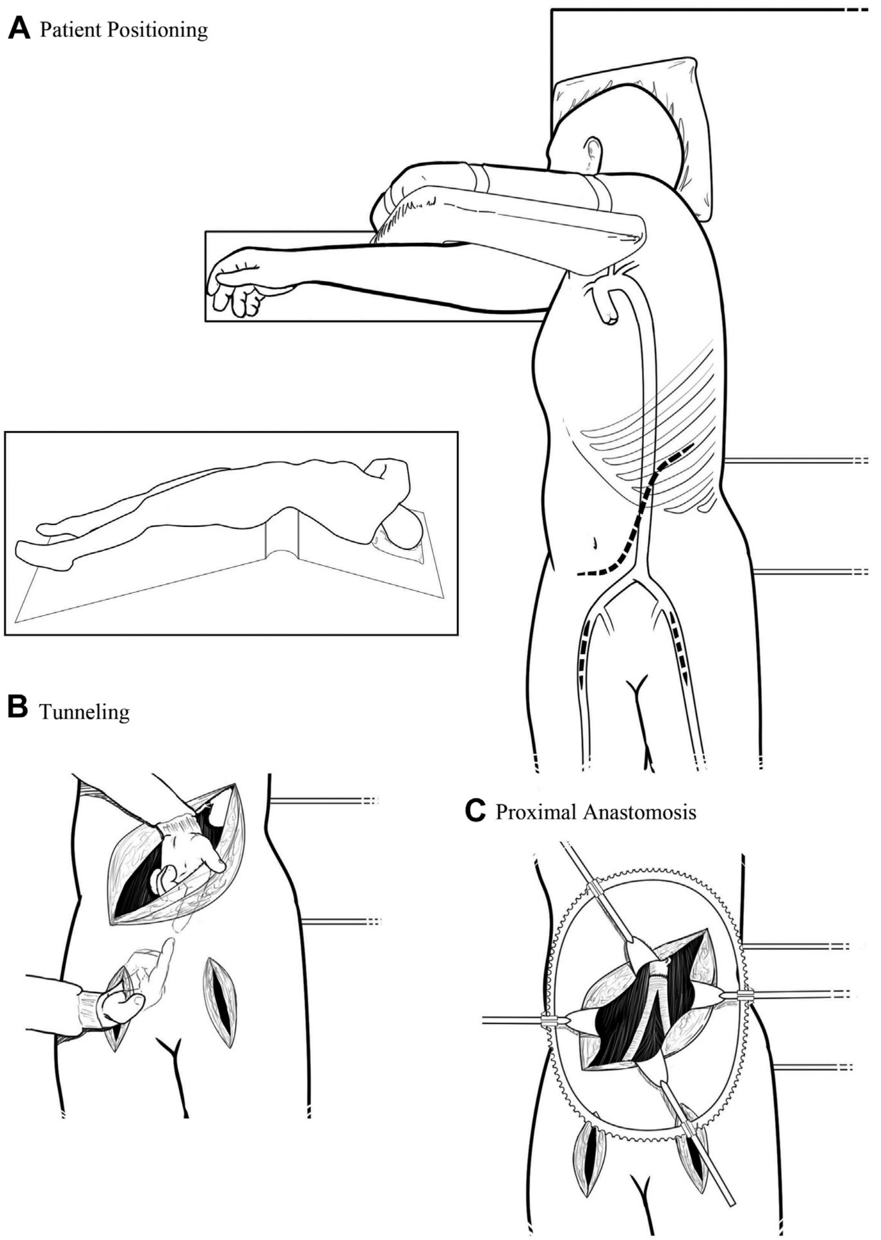

Fig 2. A, Depiction of the patient positioning for redo aortobifemoral (ABF) bypass surgery through a left retroperitoneal aortic exposure. Note (*inset*) that the hips are left as flat as possible to allow access to the right femoral incision, and the patient is placed over the kidney break to facilitate maximal separation of the iliac crest and costal margin. **B,** The retroperitoneal tunnels are created by reflecting the viscera to the right and performing blunt dissection between the right and left femoral incisions. The right retroperitoneal tunnel occurs cephalad to the bladder and allows the limb of the graft to course in a long, gentle arc. **C,** Demonstration of the end-to-end proximal anastomosis of a redo ABF bypass that frequently can be constructed in a juxtarenal location immediately above the prior repair but below the renal arteries.

Vienna, Austria) was used for all analyses. A *P* value $< .05$ was considered significant.

RESULTS

Patient population. During the study interval, 238 aortofemoral and 6 thoracobifemoral bypass procedures for AIOD were performed. Primary aortic operations for AIOD included the following: pABF bypass, 196 cases; aorto-unifemoral bypass, 24 cases; and thoracobifemoral bypass, 5 cases. Eighteen patients underwent rABF bypass, with one patient receiving thoracobifemoral bypass after a failed ABF bypass. Median time from index ABF bypass

Table I. Patient characteristics and comorbidities

Feature	*ABF (n = 19)*	*Redo ABF (n = 19)*	P *value*
Age, years	57.4 ± 7.7	57.6 ± 7.9	.8
Female	12 (63)	8 (42)	.3
BMI	26.1 ± 6.9	29.1 ± 6.8	.2
Comorbidities			
Hypertension	15 (79)	12 (63)	.5
Smoking	19 (100)	18 (95)	1
Dyslipidemia	14 (74)	18 (95)	.2
CAD	7 (37)	11 (58)	.3
Diabetes	5 (26)	8 (42)	.5
CVOD	5 (26)	6 (32)	1
COPD	4 (21)	7 (37)	.5
CHF	3 (16)	2 (11)	1
Renal insufficiency	3 (16)	0	.2
Composite total	3.8 ± 1.6	4.5 ± 1.4	.1
SVS comorbidity score	3.7 ± 1.3	3.9 ± 1.5	.7

ABF, Aortobifemoral bypass; *BMI,* body mass index; *CAD,* coronary artery disease; *CHF,* congestive heart failure; *COPD,* chronic obstructive pulmonary disease; *CVOD,* cerebrovascular occlusive disease; *SVS,* Society for Vascular Surgery (≥8 = high risk).
Categorical variables are presented as number (%) and continuous data as mean ± standard deviation. Mann-Whitney test for continuous and ordered categorical variables; Fisher exact test for nominal categorical variables.

to reoperation was 6.8 years (range, 1.4-9 years). Details regarding demographics and comorbidities of the matched cohorts of pABF and rABF bypass patients are highlighted in Table I. By design, no significant differences in age, gender, body mass index, or major comorbidities were present.

Prior operative history and indications. Previous surgical history, indications, and mode of presentation are depicted in Table II. The rABF bypass patients more frequently underwent prior extra-anatomic or lower extremity bypass compared with pABF bypass patients ($P = .02$), but no difference in prior failed endovascular iliac intervention before the index ABF bypass ($P = .4$) was found. No aortoiliac endovascular interventions were attempted after the initial failed ABF bypass before attempted rABF bypass. Indications for rABF bypass and pABF bypass were the same (claudication, n = 6/6 [31.6%]; $P = 1$; critical limb ischemia, n = 13/13 [78.4%]; $P = 1$). Three rABF bypass patients (15.8%) presented with acute limb ischemia, and after initial attempts at graft thrombectomy failed, they underwent aortic reconstruction.

Operative procedure. Conduit choice in all patients for both groups was a bifurcated Dacron graft. Aortic access was more frequently by retroperitoneal exposure in the rABF bypass group (n = 13 vs n = 1; $P < .0001$), and a significantly higher proportion of the rABF bypass patients required concomitant infrainguinal bypass or intraprocedural adjuncts such as profundaplasty (n = 14 vs n = 5; $P = .01$). The rABF bypass patients experienced greater blood loss (1097 ± 983 mL vs 580 ± 457 mL; $P = .02$), received more intraoperative fluids (3400 ± 1422 mL vs 2279 ± 993 mL; $P = .01$), and had longer overall

Table II. Previous vascular surgery history, indications, and preoperative characteristics

Feature	*ABF (n = 19)*	*Redo ABF (n = 19)*	P *value*
Previous iliac intervention	6 (32)	3 (16)	.4
Prior infrainguinal bypass	0	6 (32)	.02
Prior extra-anatomic bypass	0	6 (32)	.02
Indication			
Claudication	6 (32)	6 (32)	
Rest pain	9 (47)	8 (42)	
Tissue loss	4 (21)	5 (26)	1
Preprocedural variables			
Urgency			
Elective	12 (63)	8 (42)	
Urgent	7 (37)	8 (42)	
Emergent	0	3 (16)	.2
Mode of admission			
Elective	13 (68)	6 (32)	
Hospital transfer	4 (21)	11 (58)	
Emergency department	2 (11)	2 (11)	.04
Right leg ABI	.44 ± .2	.36 ± .27	.5
Left leg ABI	.39 ± .26	.31 ± .23	.5

ABF, Aortobifemoral bypass; *ABI,* ankle-brachial index.
Urgent procedure is defined as receiving operation within 48 hours of admission; *Emergent* procedure is defined as receiving operation same day as admission. Categorical variables are presented as number (%) and continuous data as mean ± standard deviation. χ^2 or Fisher exact test when appropriate.

procedure times (408 ± 102 minutes vs 270 ± 48 minutes; $P < .0001$). Additional intraprocedural details are summarized in Table III.

POSTOPERATIVE OUTCOMES

Total ICU (days ± standard deviation: pABF bypass, 4.6 ± 3.8; rABF bypass, 3.7 ± 1.4; $P = .9$) and hospital (days ± standard deviation: pABF bypass, 11.2 ± 10.4; rABF bypass, 9.1 ± 4.5; $P = .7$) lengths of stay were similar. No 30-day or in-hospital deaths occurred in either group. Similar rates of major complications were detected in the two groups (pABF bypass, n = 6 [31.6%]; rABF bypass, n = 4 [21.1%]; observed difference in rates, pABF − rABF = 9.5%; 95% confidence interval for difference in rates, −17.6% to 36.7%; $P = .7$). No major bleeding (return to operating room or ≥4 units postoperative transfusion) or early graft or lower extremity ischemia events occurred in either cohort. No perioperative renal complications occurred in the rABF bypass subgroup, whereas two pABF bypass patients experienced a temporary, ≥5% decrease in preoperative estimated glomerular filtration rate ($P = .5$); however, both patients were at their preoperative baseline at time of discharge or their last clinic appointment. The 30-day clinical outcomes are displayed in Table IV.

Six pABF bypass patients experienced a major complication postoperatively. Two had significant dysrhythmias requiring ICU readmission, with one ultimately receiving a pacemaker. Two additional patients developed pulmonary complications: pneumonia (one) and pleural effusion

Table III. Categorization of procedural variables after aortobifemoral (*ABF*) bypass

Variable	*ABF (n = 19)*	*Redo ABF (n = 19)*	*P value*
Aortic access			
Retroperitoneal	1 (5)	13 (68)	
Transperitoneal	18 (95)	5 (26)	
Thorax	0	1 (5)	<.0001
Aortic anastomosis			
End to end	8 (42)	14 (74)	
End to side	11 (58)	5 (26)	.01
Aortic cross-clamp position			
Thorax	0	1 (5)	
Supraceliac	0	2 (11)	
Suprarenal	6 (32)	6 (32)	
Infrarenal	13 (68)	10 (53)	.4
Cross-clamp time, minutes	24.7 ± 7.9	22.8 ± 5.0	.8
Renal ischemia, minutes	21.0 ± 3.3	24.7 ± 5.7	.2
Adjunct	5 (26)	14 (74)	.01
Lower extremity bypass	2 (11)	8 (42)	.06
Intraoperative details			
Estimated blood loss, mL	580 ± 457	1097 ± 983	.02
Intravenous fluid, mL	2279 ± 993	3400 ± 1422	.01
Packed red blood cells, units	1.0 ± 1.2	2.2 ± 2.0	.06
Plasma, units	0.3 ± 0.7	0.7 ± 1.2	.3
Autotransfusion, mL	105 ± 254	179 ± 334	.4
Colloid, mL	289 ± 356	500 ± 441	.1
Procedure time, minutes	270 ± 48	408 ± 102	<.0001

Procedure time is defined as time from incision to dressing application. Categorical variables are presented as number (%) and continuous data as mean ± standard deviation. Mann-Whitney test for continuous variables and ordered categorical variables; Fisher exact test for nominal categorical variables when appropriate.

requiring pleurocentesis (one). The final two patients in the pABF bypass cohort who developed major complications were one patient with profound electrolyte disturbances secondary to chronic steroid use and adrenal insufficiency and one patient with prolonged ileus necessitating nasogastric drainage and parenteral nutrition until resolution.

Four rABF bypass patients experienced a major complication, including non-ST elevation myocardial infarction (1), bradyarrhythmia needing temporary pacer placement (1), and tachyarrhythmia requiring ICU readmission with pharmacologic intervention (1). The final patient was treated for presumptive pneumonia after respiratory failure and reintubation. This patient required an additional 3 days in the ICU and eventually was discharged to a skilled nursing facility.

MALEs. The 1- and 2-year rates for freedom from MALEs were 93% ± 7% and 82% ± 9% vs 78% ± 8% and 78% ± 10% for pABF vs rABF bypass patients, respectively (log-rank, $P = .6$; Fig 3). The corresponding primary patency of pABF bypass and rABF bypass is 76% and 78% at 24 months (log-rank, $P = .61$; Supplementary Fig, online only). At median follow-up of 11.9 months (range, 0.2-42 months), four patients (21.1%) in the rABF bypass group experienced MALEs vs three patients (15.8%) in the pABF bypass cohort ($P = 1$). All cases occurred in elective patients who were managed for critical limb ischemia (Rutherford class 4-6[15]). Details of MALEs are summarized in Table V.

Survival. Two-year amputation-free survival was 90% ± 9% vs 89% ± 8% between pABF and rABF bypass patients (log-rank, $P = .5$; Fig 4). Two-year survival (±standard error mean) was 91% ± 9% and 90% ± 9% for pABF and rABF bypass patients (log-rank, $P = .8$) (Fig 5).

DISCUSSION

The results of our study further establish the role of rABF bypass grafting in patients with AIOD and highlight that in appropriately selected patients, outcomes comparable to those of pABF bypass can be achieved. Notably, although rABF bypass had higher procedural complexity compared with pABF bypass as evidenced by greater operative time, blood loss, and need for adjunctive procedures, no significant differences in perioperative morbidity or mortality were identified. Equivalent hemodynamic improvement was detected as measured by ABIs, and similar rates of MALEs occurred in both groups. Furthermore, midterm durability of rABF bypass was consistent with pABF bypass, and similar survival was observed. The significance of these findings is further underscored by the fact that our study represents one of the largest published experiences of rABF bypass for AIOD.

The principle reasons that ABF bypass for management of AIOD remains the gold standard against which all other therapies should be compared are its well-documented durability, superior functional outcomes (hemodynamic improvement, symptom relief, and limb salvage), and applicability to virtually all patterns of AIOD.[17] Primary patency of ABF bypass grafts for AIOD has been reported to be 76.6% to 95% at 5 years and 75% at 10 years.[2,5,17] Postoperative

Table IV. Categorization of complications and outcomes after aortobifemoral (*ABF*) bypass

Outcomes	*ABF (n = 19)*	*Redo ABF (n = 19)*	P *value*
Length of stay, days	11.2 ± 10.4	9.1 ± 4.5	.7
Death, 30-day and in-hospital	0	0	NA
ICU days	4.6 ± 3.8	3.7 ± 1.4	.9
Disposition			
Home	14 (74)	12 (63)	
Rehabilitation	5 (26)	6 (32)	
Skilled nursing facility	0	1 (5.35)	.7
Increase right ABI (δ)	.43 ± .51	.51 ± .25	.6
Increase left ABI (δ)	.50 ± .52	.50 ± .32	.8
Category			
Major complication	6 (32)	4 (21)	.7
Pulmonary	3 (16)	1 (5)	.6
Renal	2 (11)	0	.5
Bleeding	0	0	NA
Cardiac	2 (11)	3 (16)	1
Gastrointestinal	1 (5)	1 (5)	1
Wound	2 (11)	3 (16)	.3
Urinary tract infection	1 (5)	2 (11)	1
Total number of complications	0.6 ± 1.1	0.7 ± 0.8	.3

ABI (δ), Ankle-brachial index change/delta from preoperative baseline value; *ICU,* intensive care unit; *NA,* not applicable.
Categorical variables are presented as number (%) and continuous data as mean ± standard deviation. Mann-Whitney test for continuous variables and ordered categorical variables; Fisher exact test for nominal categorical variables when appropriate.

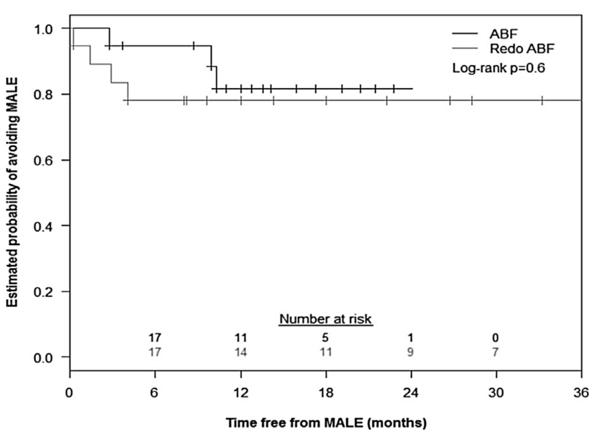

Fig 3. The freedom from major adverse limb events (*MALEs*; any graft thrombosis, revision, or amputation) after primary and redo aortobifemoral (*ABF*) bypass. All demonstrated intervals are <10% standard error mean.

complication rates range from 10% to 30%, with 1% to 4% mortality in the elective setting for appropriately selected patients.[6,9,18] Indeed, our results are consistent with the literature and further support a role for rABF bypass grafting.

The predominant etiology of ABF bypass failures is attributed to problems at the femoral anastomosis, including development of neointimal hyperplasia, pseudoaneurysms, and progression of infrainguinal occlusive disease.[2,19] Unilateral limb complications are traditionally managed with thrombectomy, femoral anastomotic revision or interposition grafting, femorofemoral bypass, or axillofemoral bypass.[20] Interestingly, similar complications involving the aortic anastomosis leading to graft failure are less frequent, ranging between 0.2% and 27% at 15 years by life-table estimates, with most series focusing on aneurysmal and pseudoaneurysmal disease.[21-23]

Series focusing on reoperative aortic surgery after failed ABF bypass grafting for AIOD have relatively few cases of rABF bypass for a thrombosed graft. The heterogeneous nature of the reports describing reoperative strategies after failed ABF bypass makes it difficult to determine the "true" perioperative outcomes of rABF bypass grafting. Among 1520 aortic procedures performed during 29 years by Kraus et al,[21] 36 aortic reoperations were performed, and only six of these patients underwent rABF bypass for graft thrombosis. Of 329 consecutive aortic procedures performed during a 5-year period, Hagino et al[24] described 11 aortic reoperations for proximal anastomotic failure and commented that proximal aortic graft complications are difficult to repair and associated with significant morbidity (27%). Tapper et al[25] described 19 patients with occluded ABF bypass grafts, and eight underwent rABF bypass. Notably, one rABF bypass patient had unrecognized ureteral injury that ultimately required a nephrectomy, and two major amputations occurred in the rABF bypass subgroup after hospital discharge. The two major amputations occurred in patients presenting with acute aortic occlusion, so the outcome was likely dictated by the clinical presentation and not the remedial choice of rABF bypass. Their conclusions were that rABF bypass was useful in selected patients who had surgically correctable lesions, such as anastomotic stricture, native aortic atherosclerotic disease below the renal arteries (but above the pABF bypass), redundant graft, or identifiable distal anastomotic disease.[25,26]

There are few indications for direct, redo aortic reconstruction for AIOD, and the absolute numbers performed at most large medical centers annually are relatively small.

Table V. Major adverse limb events (*MALEs*) after aortobifemoral (*ABF*) bypass

	Initial indication	*Event*	*Reintervention*	*Time to MALE, months*	*Eventual outcome*
Primary ABF					
Patient 1, 49 F	CLI Rutherford 5	Right limb thrombosis	Revision distal bypass	10.2	AKA at 11.5 months
		Left limb thrombosis	Revision distal bypass	15.3	AKA at 23.1 months
Patient 2, 65 F	CLI Rutherford 4	Right limb thrombosis	Thrombectomy distal bypass	9.8	Patent graft
Patient 3, 57 M	CLI Rutherford 5	Infected LEB	Excision LEB	3.1	Patent graft
Redo ABF					
Patient 1, 46 M	CLI Rutherford 5	Thrombosis LEB	None	2.9	AKA at 3.1 months
Patient 2, 68 M	CLI Rutherford 6	Progression gangrene	None	0.1	BKA at 0.1 month
Patient 3, 41 F	CLI Rutherford 4	New digital gangrene	Autogenous LEB	1.4	Patent graft
Patient 4, 5 1F	CLI, Rutherford 5	Failing LEB	PTA of SFA	4.1	Patent graft

AKA, Above-knee amputation; *BKA,* below-knee amputation; *CLI,* critical limb ischemia; *LEB,* lower extremity bypass; *PTA,* percutaneous transluminal angioplasty; *SFA,* superficial femoral artery.

This is reflected in our experience, in which rABF bypass represented only 7.8% (19 of 244) of the open aortic cases for AIOD during an 11-year period. Patient selection and preoperative planning for rABF bypass are weighted on multiple factors, including comorbidity severity and anatomic distribution of disease. Several remedial strategies can be employed to address a failed ABF bypass, and the mode of presentation initiates a treatment algorithm (Fig 1) that spans a spectrum of interventions from medical therapy to extra-anatomic revascularization to redo aortic operations. Younger, less comorbid patients with progressive occlusive disease in the infrarenal segment of the aorta above the initial proximal anastomosis and those with repeated limb failures without an identifiable lesion in the outflow vessels represent a subset of patients who are probably best managed with direct, redo aortoiliac revascularization. Indeed, in this current series, the average age (57.6 ± 7.9 years) and SVS comorbidity score (3.9 ± 1.5) are consistent with this bias. Another important consideration for operative planning is conduit choice, which can be influenced by patient age, donor or recipient vessel diameters, and underlying mechanism of failure (eg, hypercoagulable syndrome). Our series used prosthetic graft for all ABF bypass operations; however, Jackson et al[27] have demonstrated that autogenous femoral-popliteal vein may be superior in patients with premature atherosclerotic disease (eg, age <55 years).

The conduct of rABF bypass is technically more demanding compared with pABF bypass. Three elements of the procedure present the most challenge: the groin dissection, the aortic dissection, and the tunnel creation. Whereas repeated groin operations are familiar in contemporary practice, extensive dissection of the profunda femoris artery is often required, and there is frequent need for concomitant infrainguinal bypass, particularly in cases of ischemic tissue loss. Notably, 42.1% (n = 8) of the rABF bypass patients underwent lower extremity bypass compared with only 10.5% (n = 2) in the pABF bypass group ($P = .06$). In our experience, the perirenal aortic dissection planes are often undisturbed, despite the redo nature of the operation, because the original anastomosis was inappropriately constructed too caudal on the aorta. In cases in which the original anastomosis was sited at the correct juxtarenal location, our preferential use of retroperitoneal access makes the dissection in this region relatively straightforward. Perhaps the most challenging and anxiety-provoking component of rABF bypass when it is performed by the transperitoneal approach is construction of the tunnels for the limbs. The ureters are often densely adherent to the fibrous capsule around the pABF bypass limbs, making identification difficult. It is sometimes possible to dissect the capsule away from the graft and gain access to the original tunnels; however, this can be tedious and dangerous, with reports of obstructive uropathy or ureteral injury being described after transperitoneal rABF bypass.[28] Our evolution to preferential use of a retroperitoneal approach obviates concerns about tunnel creation and potential ureteral injury. The left limb simply passes through the large retroperitoneal space created by rotating the viscera, and the right limb is passed in the preperitoneal

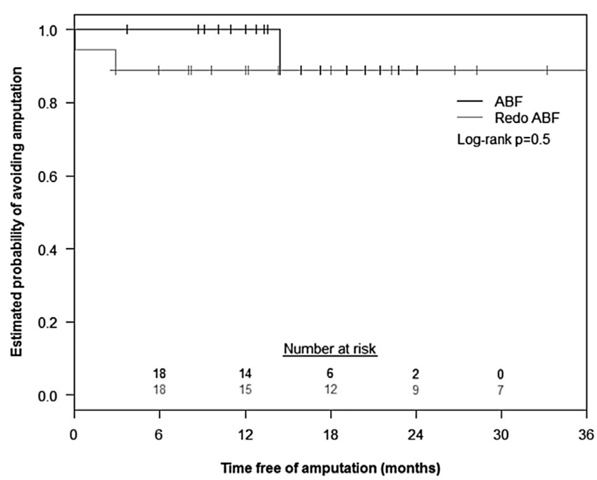

Fig 4. The amputation-free survival after primary and redo aortobifemoral (*ABF*) bypass. Standard error mean is <10% up to 24 months.

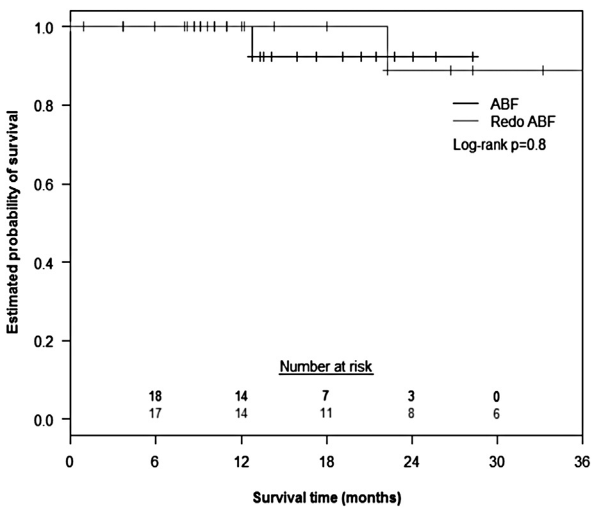

Fig 5. The midterm survival after primary and redo aortobifemoral (*ABF*) bypass. Standard error mean is <10% up to 24 months.

space, coursing in a long, gentle arc toward the right femoral vessels (Fig 2, *B*). To date, this graft configuration has worked well for us, and no rABF bypass limb occlusions have occurred.

The demanding nature of rABF bypass has led to reports of different approaches to deal with a failed ABF bypass. The most common remedial strategy is an extra-anatomic configuration, such as axillofemoral bypass.[29] Operative mortality rates for extra-anatomic bypass might be expected to be better than those for ABF bypass because of the extracavitary nature of these procedures and the fact that aortic cross-clamping is not required during the operation. However, an operative mortality rate of 0% to 4% for femorofemoral bypass and 2% to 11% for axillobifemoral bypass is a reflection of the selected patients in whom these procedures are performed.[20,29] Five-year primary patency of extra-anatomic bypasses performed for AIOD ranges from 19% to 50% for axillobifemoral bypass and 44% to 85% for femoral-femoral bypass.[20,29] These operations are inferior to direct, primary (or secondary) aortic reconstruction, so we reserve them for older patients with extensive comorbidities and short life expectancy.

An alternative aortic reoperation to rABF bypass is thoracobifemoral bypass, which has comparable magnitude and outcomes to pABF bypass.[30,31] This operation has technical demands similar to those of rABF bypass, but our enthusiasm for this approach is muted by three factors: (1) thoracic aortic cross-clamp potentially places the spinal cord at risk; (2) remedial options for an infected graft are poor; (3) prevalence of smoking or chronic obstructive pulmonary disease history and need for thoracotomy leading to postoperative pulmonary morbidity. We readily concede that these complications are rare; however, we submit that the "true" rate of complications from any of the repeated aortic operations for AIOD is poorly understood because of the limited published experience. Thoracobifemoral bypass is most often used as a tertiary option in our practice (initial operation, ABF bypass; second operation, rABF bypass; third operation, neoaortoiliac system if enough residual perirenal aorta is present to construct an anastomosis or thoracobifemoral bypass). Other scenarios in which we have used this procedure are in patients with significant visceral aortic occlusive disease in whom an infrarenal anastomosis is not possible and in cases of multiple failed axillofemoral bypass grafts performed after aortic ligation for graft infection.

The current study has several limitations inherent to its retrospective case-control design. Propensity matching was not performed. The patients had extensive selection bias based on multiple physiologic, anatomic, and comorbid factors. The small sample size and lack of comparison to alternative remedial strategies make definitive conclusions and comparisons difficult to make. The risk of type II error from this analysis cannot be overstated, and it is possible that results of rABF bypass are worse than the outcomes reported in our experience. The limited follow-up time does not allow any insight into the long-term durability or reintervention risk of the procedure. This issue is particularly important in a patient population that frequently has more advanced AIOD disease burden compared with pABF bypass patients.

CONCLUSIONS

The rABF bypass for AIOD is a technically demanding operation; however, it can be performed safely with short- and midterm outcomes comparable to those of pABF bypass in selected patients. Greater patient numbers and longer term follow-up are needed to further define the role of rABF bypass.

AUTHOR CONTRIBUTIONS

Conception and design: SS, TH
Analysis and interpretation: SS, BS, TH
Data collection: SS, BS
Writing the article: SS, BS, TH
Critical revision of the article: SS, BS, RF, AB, CC, AW, SB, TH
Final approval of the article: SS, BS, RF, AB, CC, AW, SB, TH
Statistical analysis: SS, BS
Obtained funding: Not applicable
Overall responsibility: SS
SS and BS contributed equally to this article and share co-first authorship.

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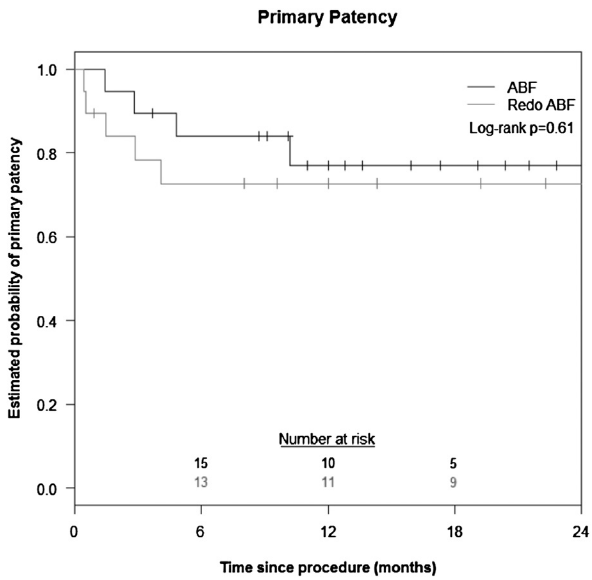

Supplementary Fig (online only). The primary patency of primary and redo aortobifemoral (*ABF*) bypass. Standard error mean is <10% up to 24 months.