Expanded application of in situ replacement for prosthetic graft infection

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Purpose: **The purpose of this study was to analyze the outcome of an individualized treatment algorithm for prosthetic graft infection, including the application of in situ graft replacement, based on clinical presentation, extent of graft infection, and microbiology.**

Methods: **There was a retrospective review (1991-2000) of 119 patients with 68 aortoiliofemoral or 51 extracavitary (infrainguinal, 19; axillofemoral, 16; femorofemoral, 16) prosthetic graft infections presenting more than 3 months (range, 3-136 months) after implantation/revision. The treatment algorithm consisted of graft excision with or without ex situ bypass grafts for patients presenting with sepsis or graft-enteric erosion, whereas in situ replacement (autogenous vein, rifampin-bonded polyester, polytetrafluoroethylene [PTFE]) was used in patients with less virulent gram-positive graft infection, in particular infections caused by *Staphylococcus epidermidis*. Outcomes (death, limb loss, recurrent infection) were correlated with treatment type and infecting organism.**

Results: **In situ replacement was used in 52% of aortoiliofemoral (autogenous vein, 10; rifampin-bonded polyester, 6; PTFE, 9) and 80% of extracavitary (autogenous vein, 26; PTFE, 9; rifampin, 6) graft infections. Total graft excision with ex situ bypass was performed in 34 patients, including 21 patients with graft-enteric erosion/fistula, with a 21% operative mortality and 9% amputation rate. In situ graft replacement was used to treat 76 graft infections with a 30-day operative mortality rate of 4% and an amputation rate of 2%. Graft excision alone was performed in nine patients with one 30-day death. Gram-positive cocci were the prevalent infecting organisms of both intracavitary (59% of isolates) and extracavitary (76% of isolates) graft infections. *S epidermidis* was the infecting organism in 40% of patients, accounting for the expanded application of in situ prosthetic replacement using a rifampin-bonded polyester or PTFE prosthesis. During the mean follow-up interval of 26 months, recurrent graft infection developed in 3% (1 of 34) of patients after conventional treatment, 3% (1 of 36) patients after in situ vein replacement, and 10% (4 of 40) patients after in situ prosthetic graft replacement ($P > .05$). Failure of in situ replacement procedures was the result of virulent and antibiotic-resistant bacterial strains.**

Conclusions: **In situ replacement was a safe and durable option in most (64%) patients presenting with prosthetic graft infection. In situ replacement with a rifampin-bonded graft was effective for *S epidermidis* graft infection, but when the entire prosthesis is involved with either a biofilm or invasive perigraft infection, in situ autogenous vein replacement is preferred. Virulent graft infections presenting with sepsis, anastomotic dehiscence, or graft enteric fistula should continue to be treated with total graft excision, and if feasible, staged ex situ bypass graft. (J Vasc Surg 2001;34:411-20.)**

Conventional management of an infected vascular prosthesis has emphasized an aggressive approach that includes culture-specific antibiotic administration, total graft excision combined with adjacent native artery debridement, and if collateral circulation is inadequate, ex situ bypass grafting. For infrarenal aortic graft infections, this approach has been associated with significant perioperative mortality (12%-27%) and morbidity (amputation, 10%-15%; artery disruption, 5%-10%; ex situ graft thrombosis/infection, 10%-24%) rates, and prompted a number of surgical groups to consider in situ replacement as an alternative treatment option.[1-11] Excision of the infected graft with immediate in situ graft replacement is appealing because it avoids the need for an extra-anatomic bypass graft, and the additional physiologic stress and potential morbidity associated with staged or multiple procedures. In the treatment of extracavitary graft infections, anatomic routes to bypass the infected prosthesis may not be available, requiring either in situ replacement or amputation. Several developments have fostered the expanded application in situ replacement, including (1) the realization that many late-appearing graft infections are the result of a *Staphylococcus epidermidis,* a bacterium that produces a low-grade biofilm infection amenable to either autogenous vein or prosthetic replacement, (2) the successful use of lower-limb deep veins (superficial femoral-popliteal vein [SFPV]) or cryopreserved arterial homografts as bypass conduits in the beds of excised infected prosthetic grafts, and (3) the development of antibiotic-bonded prosthetic grafts.[7-17] Although staging of extra-anatomic bypass grafting before removal of an infected aortic graft

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Table I. Indication, location, and graft material of 119 prosthetic graft infections

	Aortoiliofemoral (%)		*Extracavitary (%)*
No.	68 (58)		51 (42)
Indication			
Aneurysmal disease	41 (59)		2 (4)
Occlusive disease	25 (37)		49 (96)
Trauma	2 (4)		—
Graft location			
Aortoiliac	12 (16)	Axillofemoral	16 (31)
Aortofemoral	53 (79)	Femorofemoral	16 (31)
Iliofemoral	3 (5)	Infrainguinal	19 (38)
Graft material			
Polyester	64 (94)		6 (12)
PTFE	4 (6)		45 (88)

has reduced overall morbidity associated with the treatment of an aortic graft infection, proponents of in situ replacement therapy have reported a lower mortality and amputation rate in similar patient populations.[2,6,8,10,11]

Most vascular groups use a singular approach toward the treatment of prosthetic graft infections, especially aortoiliac-femoral infections (ie, conventional management or in situ replacement). On the basis of our experimental and clinical research on *S epidermidis* graft infections, our vascular division evolved to a patient-specific treatment algorithm for both intracavitary and extracavitary graft infections.[7,13-16] We have used both conventional and in situ replacement management to treat an infected vascular prosthesis based on clinical presenting signs, extent of graft involvement, and the microbiology of the infectious process. For low-grade graft infections caused by staphylococci, in situ prosthetic (segmental *S epidermidis* infections), or vein (entire graft infected by *S epidermidis* or *Staphylococcus aureus*), replacement is the preferred approach, whereas for patients with aortic graft infections complicated by sepsis or graft-enteric erosion/fistula, preliminary axillofemoral bypass graft followed by total graft excision has remained our standard treatment. More recently, we have used an antibiotic (rifampin)–bonded graft as the preferred replacement conduit in treating *S epidermidis* biofilm graft infections.[17] The purpose of this report was to analyze outcomes after application of this individualized treatment to patients presenting with late-appearing (> 3 months after implantation) prosthetic graft infections. This patient cohort was selected because several treatment options are possible, in contrast to the treatment of early postoperative graft infection, which in our experience is a less common occurrence and primarily involves the management of a postoperative wound infection or exposed graft. A 10-year experience treating 119 consecutive patients was reviewed to assess patient-specific management with an expanded application of both in situ prosthetic and vein replacement treatment for treatment of intracavitary (aortoiliofemoral) and extracavitary prosthetic graft infections.

CLINICAL MATERIAL AND METHODS OF STUDY

Patients. Between 1991 and 2000, 119 patients (82 men, 37 women) having a mean age of 69 ± 8 years (range, 46-84 years) were referred to the Division of Vascular Surgery with a proven or suspected diagnosis of an aortoiliofemoral (n = 68) or extracavitary (n = 51; including infrainguinal, 19; axillofemoral, 16; femorofemoral, 16) prosthetic graft infections. Although all patients were beyond 3 months from graft implantation or revision, 24 patients had undergone recent incision and drainage procedures to treat perigraft infection presenting in the groin, in the thigh, or along an axillofemoral graft. Patient and outcome data were obtained by review of our vascular registry and archived referring physician, hospital, and outpatient clinic records. Study end points were death, limb loss, recurrent graft infection, and secondary procedures related to the treatment of graft infection during the follow-up period that extended to December 2000.

Initial aortoiliofemoral bypass grafting was prompted by aneurysmal and occlusive disease in similar frequency, whereas 96% of the extracavitary grafts were implanted to treat symptomatic atherosclerotic occlusive disease (Table I). All but four infected aortic grafts were constructed of polyester, and 53 (78%) of 68 were in an aortofemoral bypass configuration. Extracavitary graft infections primarily involved a polytetrafluoroethylene (PTFE) conduit (88%).

The postoperative time interval and mode of presentation of aortoiliofemoral (intracavitary) and extracavitary graft infections differed (Table II). Intracavitary graft infections presented an average of 35 months later than extracavitary peripheral graft infections and were more commonly associated with gastrointestinal bleeding and false aneurysm. The most common presentation of an aortofemoral graft infection was a patient without a fever and with a sinus tract or inflammatory mass contiguous with the prosthetic graft in the femoral or groin region. Obvious signs of graft infection (fever, purulent wounds) were common presenting signs of extracavitary graft infections. Sepsis or blood cultures positive for bacteria were

Table II. Time from graft implantation and presenting signs (expressed as % of patients) of 68 aortoiliac-femoral and 51 extracavitary (axillofemoral, femorofemoral, infrainguinal) prosthetic graft infections

	Aortoiliofemoral	*Extracavitary*	P *value*
Time interval (mo) from graft implantation/revision (range)	42 ± 28 (3-142)	7 ± 4 (3-18)	< .001
Presenting signs			
Sepsis	10%	8%	
Gastrointestinal bleeding	33%	—	
Fever	36%	57%	
Groin sinus	18%	10%	
Groin mass	20%	8%	
Purulent wound	8%	65%	< .001
False aneurysm	28%	5%	< .01
Hydronephrosis	15%	—	
Septic emboli	0%	2%	
Graft thrombosis	2%	8%	

Table III. Criteria used for patient-specific treatment of a prosthetic graft infection based on presenting signs, extent of graft involvement, and microbiology of the infectious process

Treatment option	*Presenting signs*	*Microbiology*
Graft excision	Graft thrombosis, viable limb after graft excision (adequate collaterals)	Any organism
Total excision		
With preliminary ex situ bypass graft	Graft-enteric erosion in stable patient or aortofemoral or intracavitary graft infection associated with sepsis or bilateral hydronephrosis*	Any organism
With simultaneous ex situ bypass graft	Graft-enteric fistula in unstable patient	Any organism
In situ replacement		
Autologous vein	Invasive perigraft infection without sepsis or anastomotic hemorrhage	Any organism
Antibiotic-bonded prosthetic	Total† or segmental graft involvement	*S epidermidis/S aureus* biofilm infection‡

*Signs of extensive retroperitoneal infection/inflammation.
†Total graft replacement for a biofilm infection limited to axillofemoral bypasses or aortofemoral graft infections in patients not candidates for deep vein replacement because of vein availability or multiple comorbidities.
‡No organisms identified on Gram stain of perigraft exudate/fluid.

uncommon, occurring in only five patients with isolates of *S aureus* (n = 3), *Klebsiella pneumoniae* (n = 1), or *Pseudomonas aeruginosa* (n = 1).

Diagnostic evaluation. Patient evaluation was individualized according to graft type, presenting signs, and symptoms. Patients with aortic graft infections underwent computed tomography (CT) scanning of the abdomen, pelvis, and, if appropriate, the femoral regions so that the extent of graft infection could be identified and other possible infection-related (false aneurysm, perigraft air, or hydronephrosis) complications could be identified. All patients treated for graft-enteric erosion had abnormalities revealed on CT scanning. Upper endoscopy performed in 18 of 21 patients with suspected graft erosion into the gastrointestinal tract visualized graft material in the duodenum in only two patients. In 24 patients with inflammatory groin masses or perigraft abscesses, wound exploration in the operating room was performed as an initial procedure to drain a septic focus or obtain microbiologic samples to isolate the infecting organism(s). CT-guided aspiration of perigraft fluid was used in only four patients with subsequently proven *S epidermidis* aortofemoral graft biofilm infections. All stable patients underwent arteriography to aid in planning the subsequent graft excision and reconstructive procedure.

Treatment algorithm. Patients were managed with several methods (Table III), including graft excision alone, conventional treatment (ex situ bypass and total graft excision), or in situ replacement of the infected prosthesis with either autogenous vein (greater saphenous, upper extremity, lower-limb superficial femoral vein [SFV]) or prosthetic conduit (PTFE, rifampin-soaked gelatin-sealed polyester). If the infected graft could be excised because of adequate collateral circulation or acute thrombosis, this option was selected. Total graft excision coupled with axillofemoral bypass graft (with externally supported ringed PTFE) was selected for patients with aortoiliac graft infections presenting with graft enteric erosion/fis-

Table IV. Intraoperative culture results from 119 patients with 68 aortoiliofemoral and 51 extracavitary graft infections

	Type of graft		
Microorganism isolated	*Aortoiliofemoral grafts*	*Extracavitary*	*Total (%)*
No growth	2	3	5 (4)
Streptococcus	0	1	1 (<1)
Staphylococcus			
S aureus	13	27	40 (31)
S epidermidis	33	11	44 (34)
Gram-negative rods			
E coli	18	2	20 (15)
Pseudomonas species	6	5	11 (8)
K pneumoniae	2	1	3 (2)
Enterococcus	5	2	7 (5)
Candida species	2	0	2 (2)
	79 isolates	49 isolates	128 isolates

tula, sepsis, or bilateral hydronephrosis (indicating extensive retroperitoneal inflammation and diffuse graft infection). In situ replacement with autologous vein was performed when patients with invasive perigraft infections (intracavitary or extracavitary) were identified by preoperative culture positive for *S aureus*, *S epidermidis* (total graft involvement), or gram-negative bacteria, and when intraoperative Gram stain of perigraft fluid demonstrated bacteria. Preoperative venous mapping was performed in all patients in whom in situ autogenous venous reconstruction was considered an option. Deep, lower-limb vein (superficial femoral popliteal [SFP]) reconstruction of the aortic iliac segment for aortofemoral graft infection or femoral-femoral graft infections was performed with the technique described by Clagett et al.[8] In situ prosthetic (PTFE, rifampin-soaked, gelatin-impregnated polyester) replacement was performed in patients with documented biofilm graft infections (ie, afebrile, negative intraoperative Gram stain, sterile preoperative perigraft culture). Diagnostic criteria for biofilm graft infections and the technique of in situ prosthetic graft replacement have not changed from prior reports.[7,15] Rifampin bonding of a gelatin-sealed polyester graft (Gelsoft; Vascutek Ltd, Glasgow, UK) was performed by soaking the graft at room temperature in a rifampin solution of 60 mg/mL (Rifadin; Merrill Dow Pharmaceutical, Kansas City, Mo) for 15 minutes.[16,17]

Microbiologic recovery techniques. At the time of graft excision, Gram stain of perigraft fluid was performed and swab cultures placed in transport media and cultured for aerobic and anaerobic bacteria. Explanted graft specimens were cultured in tryptic soy broth to enhance the recovery of microorganisms, including coagulase-negative staphylococci.

Antibiotic administration. All patients received parenteral broad-spectrum antibiotics before graft excision. In patients with known or suspected biofilm graft infections, vancomycin was administered for at least 3 days before in situ replacement treatment. All patients received parenteral culture–specific antibiotic for 4 to 6 weeks after treatment. After in situ prosthetic replacement, oral antibiotics were continued for an additional 6 weeks to 2 months.

Follow-up. Patients were evaluated in the Vascular Surgery Clinic at 3- to 6-month intervals by means of clinical examination and duplex ultrasonography for signs of graft infection, false aneurysm, or development of graft stenosis. Patients treated for an aortic graft infection were evaluated with serial CT scans initially at 3- to 6-month intervals; if the scan results were normal, then patients were evaluated at yearly intervals. Six patients were lost to follow-up after 1 year, 4 patients after 2 years, and 5 patients after 4 years. No patient treated with prosthetic replacement was lost to follow-up.

Data analysis. Statistical comparisons were made with the χ^2 test with a P value less than .05 considered significant. Cumulative survival for the study groups was calculated by means of the Kaplan-Meier method.

RESULTS

Microbiology. Bacteria isolates recovered from explanted infected graft segments are listed in Table IV. *S epidermidis* was the most common–infecting organism isolated from 44 (37%) of 118 explanted grafts (aortoiliofemoral, 49%; extracavitary, 22%). No microorganisms were isolated from two infected aortic grafts and three extracavitary grafts despite clinical signs of an *S epidermidis* biofilm graft infection. *S aureus* was isolated from 40 patients and included 11 (27%) methicillin-resistant *S aureus* (MRSA) strains. Gram-negative bacteria or *Enterococcus* strains were isolated from 31 (46%) of 68 aortoiliofemoral, and 10 (20%) of 51 extracavitary grafts. *Escherichia coli* and *P aeruginosa* were the two most common gram-negative bacteria strains isolated. *Candida* species was recovered from two infected aortic grafts with clinical signs of a biofilm graft infection.

Surgical outcomes. In situ replacement was used in 52% of aortoiliofemoral and 80% of extracavitary pros-

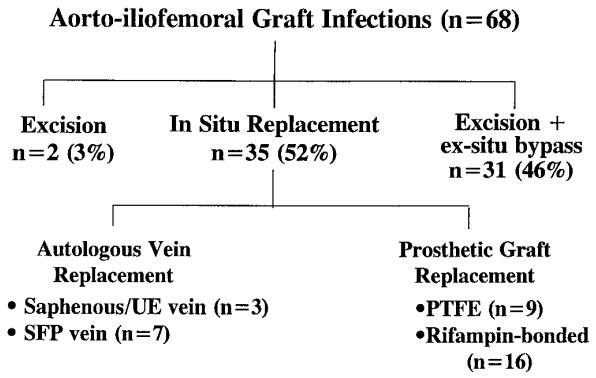

Fig 1. Surgical treatment used for 66 aortic and two iliofemoral prosthetic graft infections. *PTFE,* Polytetrafluoroethylene; *SFP,* superficial femoral popliteal; *UE,* upper extremity.

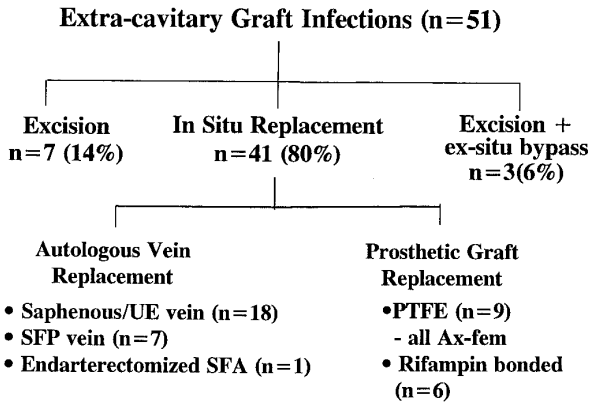

Fig 2. Surgical treatment used for 51 extracavitary (infrainguinal [19], axillofemoral [16], femorofemoral [16]) prosthetic graft infections. *PTFE,* Polytetrafluoroethylene; *SFA,* superficial femoral artery; *SFP,* superficial femoral popliteal; *UE,* upper extremity.

thetic graft infections (Figs 1 and 2). In situ replacement with a "new" prosthetic (rifampin-bonded [16], PTFE [9]) graft (25 [37%] of 68) was used more frequently than autogenous vein (saphenous/upper limb [3]; SFPV [7]) reconstruction (10 [15%] of 68) for intracavitary, aortoiliofemoral graft infections. The entire aortic prosthesis was explanted in only two of 25 aortofemoral graft infections treated with in situ prosthetic replacement. A biofilm graft infection, documented in approximately 40% of patients by a negative intraoperative Gram stain but positive culture for either *S epidermidis* or *Candida* species, accounted for the expanded application of in situ prosthetic replacement and was associated with a 5% (2 of 40 patients) 30-day mortality rate and zero amputation rate (Table V). In several patients, autogenous venous reconstruction was used to treat a biofilm infection because of diffuse graft involvement.

The most common procedure used to treat an aortic graft infection was a staged ex situ bypass graft followed by total graft excision, which was performed in 31 (45%) patients, including 21 patients with a graft-enteric erosion (n = 17) or fistula (n = 4). Conventional management of intracavitary aortic graft infection was associated with a 21% (7 of 34 patients) 30-day mortality rate and an overall 9% amputation rate, but there was a 5% (1 of 24 patients) incidence of limb loss in survivors (Table V). Graft excision alone was performed in nine patients with one (11%) death, a 75-year-old man who presented with sepsis and hemorrhage caused by a *Pseudomonas* infection of a femoropopliteal PTFE bypass graft. Overall, the operative mortality rate was increased ($P < .02$) in patients treated for an intracavitary (15% [10 of 68]) compared with an extracavitary (2% [1 of 51]) prosthetic graft infection. More than half (6 of 11) of the 30-day operative deaths in this series occurred in patients with secondary aortoenteric fistula/erosion.

Autogenous vein reconstruction was used to treat 10 (15%) of 68 aortic graft infections and 26 (51%) of 51 extracavitary graft infections. Overall, the mortality rate of in situ autogenous venous reconstruction was 6% (2 of 36 patients), and one (3%) below-knee amputation occurred in this treatment group. In seven patients with diffuse aortofemoral graft infection, SFPV reconstruction was used to replace the aortoiliac segment after total graft excision. Seven patients with femorofemoral graft infection underwent total graft excision and SFPV replacement. Two patients died after deep vein SFP in situ reconstruction of persistent MRSA infection; anastomotic rupture occurred in one patient. In the treatment of extracavitary prosthetic graft infections, autogenous vein replacement was the most common procedure (26 [51%] of 51) performed and the only option used in the 19 patients with infrainguinal PTFE graft infection. In general, perigraft abscesses were incised and drained, and graft replacement was performed after several days of culture-specific antibiotic administration. In situ prosthetic replacement for extracavitary graft infection used in 15 (29%) of 51 patients was limited to the treatment of low-grade axillofemoral (n = 11) or femoral-femoral (n = 8) extracavitary graft infections.

In 22 patients a rifampin-bonded graft was used to treat low-grade prosthetic graft infection involving single (n = 16) or bilateral (n = 2) aortofemoral graft limbs, femoral-femoral graft (n = 3), or an axillofemoral graft (n = 1). Sartorius muscle flap coverage of the in situ replacement graft in the groin was performed in 15 (68%) patients. One patient died after anastomotic rupture of an SFV reconstruction performed to treat MRSA infection of the replaced rifampin-bonded graft. No amputations occurred early or late in the rifampin-bonded graft treatment group (mean follow-up of 18 ± 9 months).

During a mean follow-up interval of 26 months (range, 3 to 96 months), 18 patients (graft excision alone, 1 of 8 survivors; graft excision plus ex situ bypass graft, 4

Table V. Thirty-day or in-hospital operative morbidity and mortality

Treatment group	*No of patients*	*Mortality (%)*	*Morbidity*
Total graft excision alone			
Aortoiliofemoral	2	1	None
Extracavitary	7	0	Above-knee amputations (2)
In situ graft replacement			
Autogenous conduit			
Aortofemoral	10	1 (10)	Bowel obstruction (1) Below-knee amputation (1)
Extracavitary	26	1 (6)	Graft thrombectomy (2)
PTFE			
Aortoiliofemoral	9	0	Wound infection (1)
Extracavitary*	9	0	Wound infection (2)
Rifampin-bonded			
Aortofemoral	16	0	None
Extracavitary	6	1†	MRSA infection
Graft excision and ex situ bypass graft			
Graft-enteric erosion/fistula	21	6 (29)	Chylous ascites (1) Below-knee amputation (1)
Invasive graft infection			
Aortoiliofemoral	10	1 (10)	Chylous ascites (2) Above-knee amputation (2)
Extracavitary	3	0	None
Total	119	11 (9)	Amputation (6 [6%])

*All axillofemoral polyester graft infection.
†Patient expired after deep vein replacement of the rifampin-bonded femoral-femoral graft.

of 27; rifampin-bonded replacement, 5 of 21; PTFE replacement, 2 of 18; autogenous vein reconstruction, 6 of 34) died at intervals ranging from 5 to 80 months after treatment. Two late deaths were related to treatment for recurrent graft infection. Patient survival, including perioperative deaths, was 89% at 6 months, 82% at 2 years, and 70% at 4 years. Survival of patients with intracavitary infection was 85% at 30 days, 81% at 1 year, and 70% at 2 years. No surviving patient treated for aortic graft infection with either conventional management (n = 24) or SFV reconstruction (n = 7) had aortic stump infection or aorta/graft aneurysm formation. Recurrent graft infection developed in 4 (10%) of 40 patients after in situ prosthetic replacement of an aortofemoral graft limb (3 of 25) or extracavitary graft (1 of 15), and infection developed in 1 (3%) of 36 patients after autogenous vein replacement ($P > .05$, χ^2). Secondary procedures, all autogenous vein replacement procedures, isolated *P aeruginosa* in 1 patient with urinary conduit, rifampin-resistant *S epidermidis* strains in 2 patients, and MRSA in 2 patients.

Seventeen (16%) of the surviving 108 patients required secondary procedures for infection (n = 5), graft stenosis (n = 6), graft thrombosis (n = 4), bypass for limb ischemia (n = 1, femoral-femoral SFV bypass graft), or iliac stent placement for inflow occlusive disease (n = 1). In the conventional treatment group, four patients had late ex situ bypass graft thrombosis (n = 3) or infection (n = 1), resulting in one below-knee amputation after an obturator bypass graft thrombosis and one below-knee amputation after recurrent axillofemoral graft thrombosis (Table VI). Six patients with autogenous vein graft replacement, including two patients with SFP reconstruction, required graft revision for stenosis. One patient presented with graft failure and underwent below-knee amputation after femoral-peroneal saphenous vein replacement of an infected femoral-popliteal PTFE bypass graft. Forty-five (66%) of 68 patients treated for intracavitary and 32 (63%) of 51 patients treated for extracavitary prosthetic graft infection experienced no significant in-hospital morbidity or late complication (recurrent graft infection, secondary procedure for graft thrombosis/stenosis, limb loss).

DISCUSSION

The clinical spectrum of prosthetic graft infection permits surgeons to individualize treatment and, as documented in this series, perform in situ replacement in most patients (52% for intracavitary and 80% for extracavitary infections). In situ replacement after removal of the entire infected graft or a graft segment involved by a biofilm infection was safe (4% [3 of 76 patients] in-hospital mortality rate), durable, and associated with a low (3%) incidence of limb loss (one 3-day and one late amputation). As in earlier reports, we have found in situ prosthetic replacement to be appropriate treatment for selected patients with a localized graft biofilm infection. On the basis of experimental research that indicated efficacy of a rifampin-bonded graft in treating low-grade graft infections, we now use a gelatin–sealed polyester conduit that has been soaked in a high concentration (60 mg/mL) solution of rifampin in preference to PTFE to replace infected graft segments with a "biofilm" infection. In a recent report, replacement of vascular prosthesis infected by gram-positive bacteria (*S aureus, S epidermidis*) with rifampin-bonded polyester graft was effective in eradicat-

Table VI. Late outcome of 108 survivors after conventional, graft excision, or in situ replacement treatment of a prosthetic graft infection

Late (>30 d) outcome	*Conventional treatment (27) or graft excision (8)*	*In situ replacement*	
		Vein (34)	*Prosthetic (39)*
Death related to graft infection*	0	1 (3%)	1 (3%)
Treatment for recurrent infection	1 (3%)	1 (3%)	4 (10%)
Graft thrombosis	2 (6%)	1 (3%)	1 (3%)†
Graft revision for stenosis	0	6 (17%)‡	0
Amputation	2 (6%)§	1 (3%)	0

*One patient died of pneumonia 2 months after deep vein replacement of an aortofemoral graft infection caused by MRSA, and one patient died 3 months after conventional treatment of an infected retained aortic graft initially treated by graft limb replacement 2 years prior.
†Axillofemoral graft thrombosis successfully treated with thrombectomy and distal anastomotic revision.
‡Saphenous (4) or cephalic (1) vein bypass grafts; one lower-limb deep vein bypass graft required revision for stenosis.
§Below-knee amputation after obturator bypass graft thrombosis and above-knee amputation after recurrent thrombosis of axillofemoral bypass graft.

ing all clinical signs of infection in 90% of patients.[17] Modes of failure after in situ prosthetic replacement included the development of recurrent infections caused by a rifampin-resistant *S epidermidis* strain or persistent infection in retained aortic graft segments. The morbidity and late infection rate with the rifampin-bonded graft as a replacement conduit was similar to prior reports with PTFE replacement for *S epidermidis* graft infections, but in the rifampin-treated group six patients had graft infection caused by *S aureus,* including three with MRSA.[7,15,17] Patient outcomes after in situ prosthetic replacement in this series were similar to the in situ autogenous vein reconstruction group despite differences in microbiology and the extent of graft infection.

The treatment algorithm used in this patient series was developed to incorporate newer advances in the treatment of prosthetic graft infections, including staged extra-anatomic bypass graft in patients with aortic graft infections, the use of antibiotic-bonded grafts, and autogenous venous reconstruction with lower-limb deep veins as described by Clagett and Nevelsteen.[2,8,10,15-19] Because the patient selection criteria used limited in situ replacement treatment to less serious graft infections, the finding of a higher operative mortality and morbidity in the conventional management and graft excision alone groups was expected. Although the overall 30-day operative mortality rate was 9% (11 of 119 patients), treatment of a secondary graft-enteric/fistula was associated with a 28% (6 of 21 patients) mortality rate, and graft infection caused by MRSA was associated with a 30% (3 of 11) mortality rate, accounting for 75% of the operative deaths. The higher perioperative mortality rate in the conventional treatment group (21% [7 of 34 patients]) occurred despite the use of staged preliminary axillofemoral bypass graft, when possible, and culture-specific antibiotic administration. The observation of increased procedural mortality rates with repair of graft enteric erosion/fistula has been reported with all treatment options: conventional staged ex situ bypass graft and total graft excision (19%-25%), in situ prosthetic replacement (13%-30%), deep vein replacement (12%-20%), and allograft replacement (20%-40%).[1-4,10-12,18,20] Improved outcome in this group of patients depends, in part, on earlier recognition of the graft-enteric erosion, thus avoiding emergency procedures in a septic or hemodynamically unstable patient.

Patients with prosthetic graft infection transferred or presenting to our referral vascular surgery service had the clinical presentation of a late-appearing and, in most instances, a low-grade infectious process. Presenting signs of sepsis, fever, and bacteremia were limited to patients with aortoenteric erosion/fistula or extracavitary femorofemoral or infrainguinal PTFE infections. In this series, 40% of patients were treated for a biofilm graft infection caused by *S epidermidis* strains. In most of these patients, the biofilm infection involved only a segment(s) of the vascular prosthesis, typically the prosthetic graft limb segment in the groin or pelvis. In our experience, contrast-enhanced CT scanning coupled with direct surgical exploration of unincorporated graft segments for microbiologic sampling has allowed accurate distinction between a biofilm and an invasive graft infection because no microorganisms have been found on Gram stain, and if culture findings were positive, coagulase-negative bacteria were isolated, thereby, permitting the "preoperative selection" of a patient for in situ prosthetic replacement therapy.

If preoperative vascular imaging studies indicated diffuse aortic graft infection or operative exploration indicated the entire prosthesis may be colonized, we preferred the technique described by Clagett et al[8] of using the SFP venous segment from the lower limbs for reconstruction of the arterial segment after aortic or femorofemoral graft excision. Patients must be evaluated to determine if they are candidates for this procedure. When adequate SFPV caliber is documented by venous imaging and patients are sufficiently healthy enough to undergo this procedure, we think that total prosthetic graft excision and in situ autogenous reconstruction is the "best" treatment option for the patient. In our series of 13 patients, failure of the SFP

reconstruction occurred in only one patient with an MRSA infection, and other morbidity (compartment syndrome, acute deep venous thrombosis, limb swelling) associated with lower limb deep vein excision was minimal and did not result in any long-term patient disability. We did encounter several patients who were judged not to be candidates for neoaortoiliac SFP venous reconstruction because of prior deep venous thrombosis, small caliber vein, or medical conditions that precluded a procedure of this magnitude. In these instances, if a biofilm graft infection was present, treatment was either in situ prosthetic replacement or conventional management. Of note, we have not used SFP venous reconstruction to treat secondary aortoenteric fistula. In patients with aortic false aneurysm, bilateral hydronephrosis, or extensive retroperitoneal perigraft inflammation, conventional treatment was used.

Recurrent graft infection was low in all treatment groups (conventional management, 3%; in situ vein replacement, 3%; in situ prosthetic replacement, 10%); the highest number of infections occurred after in situ prosthetic replacement. Recurrent infection was the result of either progression of a graft biofilm infection in nonexcised graft segments or persistent MRSA infection. When recurrent graft infection was encountered a policy of in situ autogenous venous reconstruction was followed, if feasible. In four patients treated with unilateral aortofemoral graft limb replacement, infection of the retained aortic graft and contralateral limb developed. In these instances, the prior in situ replaced graft was not infected, thereby allowing conventional management because one groin now had no clinical signs of infection and an axillofemoral prosthetic bypass graft and autogenous femorofemoral bypass graft could be performed. The low incidence of axillofemoral graft infection and thrombosis observed in this series was in part due the patient selection process. When groin regions were infection free (ie, an infected aortoiliac bypass graft), conventional management was typically selected, and in most patients, the superficial femoral artery was patent. Aortofemoral graft infections were primarily treated with autogenous vein or prosthetic in situ replacement.

The interest in alternative methods, especially in situ replacement, to treat prosthetic graft infection is understandable. In today's vascular surgery practice, graft salvage involved by an early (< 3 month) postoperative infectious process is usually possible if aggressive surgical wound care is provided, appropriate culture–specific antibiotic administered, staged debridement procedures performed, and muscle flap coverage of the exposed graft used. Similarly for late-appearing graft infections, the microbiology and anatomic features of the infectious process permit several options to be considered in an individual patient. The goal of therapy for patients presenting with a prosthetic graft infection is to select a procedure that first, the patient can tolerate and recover from and that also eradicates the clinical manifestations and potential complications of the infectious process. Thus, vascular surgeons need to be familiar with multiple techniques for treating prosthetic graft infection, including conventional management and in situ replacement technique with SFPV, antibiotic-bonded grafts, and, if available, cryopreserved allografts. In situ treatment avoids the failure-prone, extra-anatomic reconstruction, aortic stump blowout, and increased physiologic stress associated with multiple or staged procedures. In situ prosthetic replacement is appropriate in properly chosen patients, but autogenous reconstruction may be superior in reducing the risk of reinfection.

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DISCUSSION

Dr James M. Seeger (Gainesville, Fla). Dr Bandyk and his colleagues are to be congratulated on their results in the management of a relatively large number of patients with prosthetic arterial graft infections and for a nice presentation of their results. One hundred nineteen patients with various types of infected grafts were managed using multiple techniques, including conventional treatment for those patients with aortoenteric fistulas, retroperitoneal sepsis and extensive graft sepsis, and in situ graft replacement for those who had less severe infections. I certainly agree with the authors' conclusion that no one approach is adequate in the treatment of all patients with prosthetic arterial graft infections. The algorithm presented by Dr Bandyk and his colleagues used the degree of graft infection, the patients' presenting symptoms, and their ability to withstand treatment to select patients for these various treatments, and I would agree that all of these factors are important selection criteria. Furthermore, the type of treatment selected for an individual patient with an infected arterial graft should be based on expected outcomes for that type of treatment, and the value of this study is to add to our understanding of those expected outcomes. In contrast, the comparisons between groups presented by the authors in this study are too heavily influenced by their treatment algorithm that used different approaches in patients with very different potential outcomes to be of value in choosing between treatment options.

As recent series reviewing outcomes after conventional treatment and in situ autogenous vein graft replacement of infected arterial grafts have presented results from larger numbers of patients, I will confine my comments and questions to the patients in this study who underwent in situ prosthetic graft replacement for biofilm infections, a particular interest of the authors. I would, however, note the two patients undergoing in situ autogenous graft replacement for aortic graft infections who died of graft disruption, as we have not seen this complication. Forty patients with limited biofilm graft infections, 25 with intracavitary grafts, and 15 with extracavitary grafts, were treated with in situ prosthetic graft replacement with a 25% 30-day mortality rate and a 0% amputation rate. Long-term outcome, with a mean followup of 18 ± 9 months, demonstrated that 10% of the surviving patients developed clinical signs of recurrent graft infection, one patient died of graft infection, one had a graft thrombosis, but no amputations were required. I think these results, at least in the short term, confirm the authors' suggestion that this is a probably acceptable approach to management of prosthetic graft infection in this very select group of patients. However, I have several questions for the authors.

1. What happens to patients with biofilm graft infections treated with in situ prosthetic graft replacement? Is the infection eradicated, or do patients treated in this manner merely live in symbiosis with their infection after placement of a new prosthetic graft? If the infection is indolent but still present, what then is the value of removing the old graft and what would happen if this type of infection were treated with local measures, such as irrigation, debridement, and antibiotics alone?
2. Is the use of in situ prosthetic graft replacement for treatment of arterial graft infection actually expanding? While I agree with you that Dr Clagett's work has convinced us to more commonly use in situ autogenous replacement of infected aortic grafts, at least in our practice, we are not seeing an increasing number of patients who appear to have isolated biofilm infections appropriate for treatment with in situ prosthetic graft replacement.
3. If the recurrent infection rate is 10% at 18 months, will the rate of clinically evident infections continue to increase as time goes by after in situ prosthetic graft replacement? This goes back to my first question as to whether infection is truly eliminated or merely suppressed by this technique. As 70% of patients presenting with arterial graft infection now live for 5 years, will a significant percentage of these patients be coming back to us with recurrent and more diffuse infections, and will they then have to be managed when they are older and less able to tolerate a definitive procedure?

I enjoyed your presentation and agree with you that the management of prosthetic arterial graft infection continues to evolve. However, I would caution all of us to remember that patients with arterial graft infections, particularly those with aortic graft infections, have a complex and life-threatening problem. They often have only one good shot at achieving both limb salvage and infection control, which depends on selection of the appropriate treatment for the patient's particular type of infection. The introduction of multiple new techniques for managing patients with this complex problem appears to have improved the outcome for individual patients with this difficult problem but also has made the selection of the best treatment for an individual patient more critical and more difficult.

Dr Michael Novotney. The outcome of patients with biofilm infections was similar in this series to that reported by Towne and Bandyk (J Vasc Surg 1994;19:226). All symptoms and signs of graft infection were eradicated in more than 80% of patients long term. Graft imaging by ultrasound or computed tomography has demonstrated residual perigraft fluid involving a segment of the retained or replaced prosthetic graft in approximately 20% of patients, and it was in this group that reintervention was required, usually to treat a biofilm infection of the contralateral aortofemoral graft limb. Recurrent biofilm of an "in situ" replaced axillofemoral or femoral-femoral graft did not occur in this series. The use of "local measures" such as antibiotics and surgical debridement and muscle flap coverage is usually not successful when dealing with a biofilm graft infection. We recommend excision of all involved, unincorporated graft, followed by either in situ autogenous vein or rifampin-bonded gelatin-impregnated graft replacement.

As our series documents, a biofilm infection caused by *S epidermidis* is the most common type of graft infection presenting to our vascular surgery service. Many of the patients have had prolonged administration of antibiotics to resolve a "groin sinus" often judged initially to not involve the graft, and because of "negative" cultures, a medical treatment program is prescribed. When this treatment fails or the groin does not heal after an attempt at surgical debridement, the patient is referred for definitive treatment.

Recurrence of infection after in situ replacement for a biofilm infection is typically evident within the first year after prosthetic

graft replacement. No late occurrences after in situ autogenous replacement have occurred. I agree with Dr Seeger that all patients with graft infection need to be followed closely. If reinfection occurs, treatment should proceed using the same guidelines as were used for initial treatment. As indicated in the presentation, we prefer in situ autogenous replacement for biofilm graft infections when the patient has appropriate-size lower-limb deep vein and can medically withstand the procedure.

Dr Spence Taylor (Greenville, SC). It has been interesting; we have had over the last 3 years three different approaches presented at this meeting to treat graft infection of which the results are very similar. Each appears to be an effective treatment, whether it be extra-anatomic bypass and graft excision or whether it be an in situ replacement as presented by the South Florida group. I think it would be interesting to have Dr Clagett and Dr Seeger and the South Florida group comment. In Greenville we generally use extra-anatomic bypass as our treatment of choice. However, I have always been disappointed by the long-term limb salvage and graft patency. If the infection eradication with the in situ technique is similar to the extra-anatomic treatment, then superior late graft patency with in situ technique would be very attractive. Are limb salvage results and patency better with in situ in your experience? What is everybody's feeling in terms of that? I think that may sway you one way or the other. I would be interested in your comments. Thanks.

Dr Novotney. As Dr Taylor has alluded to, the results of conventional treatment have also improved during the past several decades, and excellent vascular surgery groups have continued to prefer this approach. Dr Seeger and his colleagues at the University of Florida have shown that the failure rate of axillopopliteal bypass is high and should be avoided. Similarly, the patency of an axillo-deep femoral bypass that bypasses the common femoral region is also reduced, especially when the superficial femoral artery is occluded. Best results occur in patients with aortic graft infection confined to the abdomen allowing for a preliminary axillofemoral bypass to the common femoral artery. As indicated in our series, late revision of a lower limb deep vein bypass was uncommon (1 of 12 grafts). Most revisions for vein graft stenosis occurred in patients having saphenous or upper extremity vein bypass to treat an extracavitary graft infection.

Dr Thomas Bergamini (Louisville, Ky). For the recurrent infections of the in situ prosthetics, what was the distribution between the rifampin Dacron grafts and the PTFE grafts? Does the advantage of the ability to bond rifampin to Dacron outweigh the decreased bacterial adherence of PTFE?

Secondly, you mentioned nothing about the antibiotic regimens. In the orthopedic literature, as I am sure you are aware, the combination of rifampin with a floxin drug does offer benefit to clearance of prosthetic adherence bacteria. I am wondering what your antibiotic regimen was in these patient groups.

Dr Novotney. Intervention for recurrent infection after in situ PTFE or rifampin-bonded graft replacement was similar. The application of the rifampin antibiotic-bonded graft has been expanded to include several patients with *S aureus* infections, which became apparent only after obtaining the intraoperative culture results. Experimentally, our group has documented a lower reinfection rate when an antibiotic-bonded graft was used, especially in the setting of an immune-suppressed animal.

Our antibiotic regimen includes vancomycin and a broad-spectrum antibiotic(s) begun several days before graft excision if possible. We try to administer culture-specific antibiotics based on preoperative or intraoperative graft culture results. Parenteral antibiotics are administered for at last 6 weeks, and in the case of a graft biofilm infection consists of vancomycin and oral floxin antibiotic. After this time period, an oral fluoroquinolone (ciprofloxacin) or macrolide (erythromycin, minocycline) is prescribed for an additional 3 to 4 months. In several patients not felt to be candidates for total aortic graft excision, we have continued antibiotics.