In situ revascularization with silver-coated polyester grafts to treat aortic infection: Early and midterm results

Michel Batt, MD,[a] **Jean-Luc Magne, MD,**[b] **Pierre Alric, MD,**[c] **Antonio Muzj, MD,**[d]
Carlo Ruotolo, MD,[d] **Karl-Gosta Ljungstrom, MD,**[e] **Roberto Garcia-Casas, MD,**[f] and
Malcolm Simms, MD,[g] *Nice, Grenoble, and Montpellier, France; Naples, Italy; Danderyd, Sweden; Pontevedra, Spain; and Birmingham, England*

Purpose: In this prospective study we analyzed the immediate and midterm outcome in patients with abdominal aorta infection (mycotic aneurysm, prosthetic graft infection) managed by excision of the aneurysm or the infected vascular prosthesis and in situ replacement with a silver-coated polyester prosthesis.
Methods: From January 2000 to December 2001, 27 consecutive patients (25 men, 2 women; mean age, 69 years) with an abdominal aortic infection were entered in the study at seven participating centers. Infection was managed with either total (n = 18) or partial (n = 6) excision of the infected aorta and in situ reconstruction with an InterGard Silver (IGS) collagen and silver acetate–coated polyester graft. Assessment of outcome was based on survival, limb salvage, persistent or recurrent infection, and prosthetic graft patency.
Results: Twenty-four patients had prosthetic graft infections, graft–duodenal fistula in 12 and graft-colonic fistula in 1; and the remaining 3 patients had primary aortic infections. Most organisms cultured were of low virulence. The IGS prosthesis was placed emergently in 11 patients (41%). Mean follow-up was 16.5 months (range, 3-30 months). Perioperative mortality was 15%; all four patients who died had a prosthetic graft infection. Actuarial survival at 24 months was 85%. No major amputations were noted in this series. Recurrent infection developed in only one patient (3.7%). Postoperative antibiotic therapy did not exceed 3 months, except in one patient. No incidence of prosthetic graft thrombosis was noted during follow-up.
Conclusion: Preliminary results in this small series demonstrate favorable outcome with IGS grafts used to treat infection in abdominal aortic grafts and aneurysms caused by organisms with low virulence. Larger series and longer follow-up will be required to compare the role of IGS grafts with other treatment options in infected fields. (J Vasc Surg 2003;38: 983-9.)

Infection of an aortic prosthetic graft is one of the complications most dreaded by vascular surgeons. Although estimated at between 0.5% and 1%,[1,2] the true incidence is certainly higher[3] because of patients lost to follow-up, insufficient follow-up, or lack of information about late infections. Conventional management of aortic prosthetic graft infections consists of excision of the infected graft, ligation of the infrarenal aorta, and extra-anatomic bypass grafting.[4] Currently available alternative treatment options to this traditional approach include in situ replacement of the infected prosthesis with an arterial allograft[5] or autogenous vein graft,[6] and reconstruction

with an antibiotic-impregnated prosthetic graft.[7] The long-recognized efficacy of silver on microbial agents and the efficacy of silver used as an antimicrobial agent on medical devices[8-11] led us to use the InterGard Silver prosthesis (IGS; InterVascular, La Ciotat, France) for management of infected aortic prostheses. Manufactured of knit or woven polyester, the IGS prosthetic graft is coated with type I bovine collagen and silver acetate. Silver acetate inhibits colonization of the prosthesis and contiguous tissues by microorganisms during the postoperative period. The results of in vitro and in vivo animal studies have demonstrated the absence of local or systemic toxicity of the IGS prosthesis and its antimicrobial efficacy; 25% of the silver salts remained on the prosthesis 20 days after implantation.[12,13] The IGS prosthesis is not approved for use in the United States. We analyzed immediate and midterm results achieved with the IGS prosthesis for in situ replacement to treat aortic infections (infected aortic prosthetic graft, mycotic aneurysm).

MATERIAL AND METHODS

From January 2000 to December 2001, a nonrandomized prospective study was conducted in seven centers that used the IGS prosthesis for in situ replacement of infected

Table I. Aortic infections in 27 study patients

	Type of aortic infection						
	Mycotic aneurysm (n = 3)		*Graft infection with fistulas (n = 13)*		*Graft infection without fistulas (n = 11)*		*Total (N = 27)*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Presentation								
Emergent	3	100	7	54	1	9	11	41
Planned	0		6	46	10	91	16	59
Graft removal								
Total	3	100	12	92	6	56	21	78
Partial	0		1	8	5	44	6	22
Repeat operation								
Early	0		3*	23	1	9	4	15
Late	1‡	33	0		3§	27	4	15
Death								
Operative	0		3	23	1	9	4	14.8
Late	0		0		0			
Graft patency		100		100		100		100
Recurrent infection	0		0		1	9	1	3.7

*Duodenal leakage, 2; femoropopliteal bypass, 1.
†Postoperative intestinal occlusion.
‡Access for hemodialysis.
§Femoropopliteal bypass, 2; sigmoidectomy, 1.

aortic grafts.* In these seven centers all patients with aortic infection received the IGS prosthesis, to test its efficacy in treatment of aortic infection. Diagnosis was based on findings at clinical examination and computed tomography (CT). When possible, specimens for microbiologic culture were obtained before surgery, and appropriate antibiotic therapy was prescribed. In the remaining patients, broad-spectrum antibiotic therapy, especially vancomycin against *Staphylococcus*, was administered before and during the operation. Preoperative arteriography was performed when possible.

There was no uniform treatment protocol; rather, this was left to the discretion of each surgeon.

Surgery was performed with a vertical midline transperitoneal incision in all patients but one, in whom a retroperitoneal incision was used to approach a mycotic aneurysm.

Total graft excision was performed when the infection involved the entire prosthesis; partial excision was performed when infection was limited to the body or a single limb of the prosthesis and when the remainder of the prosthesis was well-encapsulated. The prosthetic graft was covered with a pedicled anterior omentoplasty when possible. During surgery, specimens were taken for bacteriologic analysis, and the excised prosthetic graft was placed in culture medium. Povidone-iodine standard solution was

*The number of aortic infections (mycotic aneurysm, infected prothetic graft) managed with an IGS prosthesis by each author and at each participating center was as follows: M. Batt, Nice, France (n = 11); J. L. Magne, Grenoble, France (n = 5); P. Alric, Montpellier, France (n = 4); A. Muzj and C. Ruotolo, Naples, Italy (n = 4); K. J. Ljungstrom, Karlinska-Danderyd, Sweden (n = 1); R. Garcia-Casas, Pontevedra, Spain (n = 1); M. M. Simms, Birmingham, England (n = 1).

used for irrigation of the infected fields after debridement of surrounding tissues. Serial CT scans of the IGS prosthesis were obtained before discharge from the hospital, 3 and 6 months after surgery, then every 6 months. For analysis, patient data were updated to June 2002.

The primary end points of the study were patency of the IGS prosthetic graft, limb salvage, and patient survival (determined with the Kaplan-Meier method).

RESULTS

From January 2000 to December 2001, the seven participating centers entered 27 patients (25 men, 2 women) with mean age 69 years (range, 44-87 years) in this study (Table I). Eighty-seven percent of patients were present or past cigarette smokers, with a mean of 53 ± 27 pack-years. Other pertinent risk factors included coronary artery disease (36%), hypertension (41%), type II diabetes mellitus (14%), hyperlipidemia (18%), chronic obstructive pulmonary disease (22%), and renal failure (creatinine concentration, >3.0 mg/dL; 9%).

Three patients had mycotic aneurysms (two aortic aneurysms, one common iliac artery aneurysm). Clinical findings at presentation are shown in Table II. CT scans revealed chronic rupture of the aneurysm in all three patients. Infection was secondary to hematogenous spread of a dental infection, complication of subacute bacterial endocarditis, and infection of a kidney transplant, respectively. All three mycotic aneurysms were treated emergently with complete excision, debridement of surrounding tissues, and in situ reconstruction with an IGS prosthesis covered with a pedicled omentoplasty. Bacteriologic cultures were positive in two patients (Table III). No in-hospital death

Table II. Clinical symptoms in 24 patients with infected aortic prosthetic graft

Symptoms	n	%
Mycotic aneurysm (n = 3)		
Sepsis (fever, hyperleukocytosis, septicemia)	3	100
Abdominal pain	3	100
Infected prosthetic grafts (n = 24)		
Sepsis (fever, hyperleukocytosis, septicemia)	9	37.5
Severe gastrointestinal bleeding; collapse	6	25
Abdominal pain	4	17
Inguinal abscess	8	33
Acute lower limb ischemia	1	4
Aortic false aneurysm	2	8
Anorexia and weight loss	2	8

Table III. Bacteria isolated in positive bacteriologic cultures of infected prostheses and mycotic aneurysms

Organism	n	%
Mycotic aneurysms (n = 2)		
Streptococcus	2	66
Enterobacteriaceae	1	33
Haemophilus parainfluenzae	1	33
Candida albicans	1	33
Infected prosthetic grafts (n = 22)		
Staphylococcus epidermis	5	24
Staphylococcus aureus	5*	24
Streptococcus	5	24
Escherichia coli	4	19
Enterococcus faecalis	7	33
Bacteroides fragilis	2	10
Clostridium perfringens	2	10
Proteus mirabilis	1	5
Klebsiella	1	5
C albicans	4	19
Corynebacterium	1	5

*Methicillan-resistant *S aureus*, 2.

Table IV. Type of arterial reconstruction in 27 patients with InterGard Silver* prosthetic graft

	n		%
Aortoaortic tube graft	4	(1 mycotic aneurysm)	15
Aortobiiliac bypass graft	4	(1 mycotic aneurysm)	15
Aortobifemoral bypass graft	11		41
Aortounifemoral bypass graft	2		7
Iliofemoral graft	6	(1 mycotic iliac aneurysm)	22

*InterVascular, La Ciotat, France.

occurred, and the three patients were followed up for a mean of 16 months (range, 3-26 months). None of the patients died during follow-up, with Kaplan-Meier survival of 100% at 2 years. No follow-up CT scans demonstrated any recurrent infection or perigraft fluid collection. Patients received antibiotic therapy for no more than 3 months, except for the one patient operated on to treat a mycotic aneurysm after subacute bacterial endocarditis, who received antibiotic therapy for 6 months. Primary and secondary patency of the bypass grafts at 24 months was 100%.

In 24 of the 27 patients, the aortic prosthetic graft was infected. Twelve of these 24 patients had a secondary graft-duodenal fistula (8 graft duodenal erosions, 4 direct aortoduodenal fistulas due to communication at the level of a proximal false aneurysm), and 1 patient had a graft-sigmoid fistula. The remaining 11 patients had prosthetic graft infection without intestinal or duodenal involvement (Table I).

Initial graft placement was prompted by occlusive disease in 17 patients (70%) and by an aneurysm in 7 patients (30%). Mean interval between placement of the prosthetic graft and diagnosis of graft infection was 78 months (range, 1-264 months). The bypass configuration of the infected grafts was aortoaortic in 2 patients, aortobiiliac in 7 patients, aortobifemoral in 13 patients, and aortounifemoral in 2 patients. All of the 24 infected prosthetic grafts were made of polyester. Clinical findings at presentation are shown in Table II. CT scans revealed perigraft fluid collection in 14 patients, with an air-fluid interface in 7 patients, retroperitoneal abscess in 10 patients, ureterohydronephrosis in 4 patients, and proximal anastomotic false aneurysm in 4 patients.

Aortic reconstruction with the IGS prosthesis was performed as an emergency procedure in 8 patients (33%), because of gastrointestinal bleeding with shock (n = 6), acute lower limb ischemia (n = 1), and peritonitis from a sigmoid fistula (n = 1); the remaining 16 patients (66%) underwent elective repair.

In 6 of 24 patients with an infected aortic prosthesis, the infection was limited to a segment of the graft (body of the prosthesis in 1 patient, limb in 5 patients); the remainder of the prosthesis was well-encapsulated. In all patients but one, the infected graft limb or body was replaced in situ with a segment of IGS prosthesis and covered with a pedicled omentoplasty.

Eighteen of 24 patients had complete prosthetic graft infection. Ten had a retroperitoneal abscess. All 18 of these patients underwent complete excision of the prosthesis, debridement of surrounding tissues, and in situ replacement with an IGS prosthesis (aortoiliac in 2 patients, aortobiiliac in 3 patients, aortobifemoral in 11 patients, and aortounifemoral in 2 patients, with conservation of the encapsulated, infection-free crossover bypass in 1 of these last 2 patients; Table IV). In 16 of these 18 patients, the IGS prosthesis was covered with a pedicled omentoplasty.

For the 12 patients with a prosthetic graft–duodenal fistula, duodenorrhaphy was performed, with two layers of suture material (n = 10) or segmental duodenal resection and end-to-end suture in two layers, because of severe loss of duodenal substance (n = 2). A gastroduodenal catheter was placed in the proximal duodenum. Six of these patients required an associated jejunostomy. Two patients with a prosthetic graft–duodenal fistula underwent early repeat operation (days 7 and 15, respectively), because of duodenal leakage after duodenorrhaphy closed solely with suturing. The two recurrent duodenal fistulas were not due to

recurrent graft infection but to breakdown of the duodenal wall, which was of poor quality. One of these patients died after the repeated surgery (day 50); he was 80 years old and in poor physiologic condition. The other patient underwent duodenal resection with Y-shaped jejunal anastomosis, with no recurrent infection of the IGS prosthesis and an uneventful recovery.

Bacteriologic cultures were negative in 2 patients (8%). In the 22 patients with positive cultures (92%), several organisms were cultured from the excised graft in 16; only one organism was cultured in the other 6 patients (Table III). In nearly all cases, these were organisms with low virulence.

Perioperative mortality rate was 16.6% (4 of 24 patients). Three patients who died had undergone complete prosthetic graft replacement, and 1 patient died after segmental replacement of the body of the prosthesis. Perioperative mortality rate was 23% (3 of 13 patients) for patients with an enteric fistula, versus 9% (1 of 11 patients) for patients with an infected aortic prosthetic graft without an enteric fistula.

In 2 of the 24 patients entered in the study after infection of the initial prosthetic graft, infection developed in the early postoperative period. The first early infection was revealed 2 weeks postoperatively by acute ischemia of a lower limb after occlusion of a prosthetic graft limb. Exploratory surgery revealed a retroperitoneal abscess. Bacteriologic cultures yielded methicillin-resistant *Staphylococcus aureus* (MRSA). The second early graft infection was revealed 10 weeks postoperatively by the finding of septicemia. Bacteriologic analysis revealed the presence of *Bacteroides fragilis*. Both patients had an uneventful course after in situ replacement with an IGS prosthesis.

Among the 22 patients with late infection after placement of the initial prosthetic graft, none died who underwent planned replacement of the infected prosthetic graft. In contrast, four of eight patients who underwent emergency repair died in-hospital (mortality, 50%), respectively, 4, 6, 45, and 50 days postoperatively. None of these deaths was related to sepsis. One of two early deaths was due to multiple organ failure in a 87-year-old man with a ruptured proximal aortic false aneurysm; the other early death was secondary to cardiac and respiratory failure in a 57-year-old patient with coronary disease and cardiac insufficiency (ASA III) who had a prosthetic graft–duodenal fistula. The third postoperative death, which occurred on day 45, was due to colonic ischemia in an 87-year-old patient with cachexia; autopsy demonstrated no recurrent infection of the IGS prosthesis. The fourth postoperative death occurred after 50 days; a recurrent fistula at the level of the duodenal suture had been found at repeat surgery (day 15). No prosthetic graft thrombosis or amputation was observed in any of the 24 patients.

None of the 20 patients who survived the hospital course was lost to follow-up (mean follow-up, 17 months; range, 1-31 months). The probability of survival at 24 months was 85% ± 7%. All patients received antibiotic therapy postoperatively for a mean duration of 2 months

(range, 3 weeks–3 months). There was no incidence of IGS thrombosis. Primary and secondary patency of the bypass grafts at 24 months was 100%.

In one patient (3.7%) who had undergone segmental replacement of a graft limb without omentoplasty, recurrent infection developed, with cutaneous fistulization, in the sixth postoperative month. The associated perigraft fluid collection was drained, but bacteriologic cultures were negative, and there was no recurrence. The other 19 survivors underwent CT verification of IGS prosthesis status. No CT scans demonstrated recurrent infection or perigraft fluid collection.

DISCUSSION

Immediate and midterm results in our study patients reveal the safety and efficacy of the IGS prosthesis for management of mycotic aneurysm and aortic prosthetic graft infection, two of the most serious complications seen by vascular surgeons. The early mortality rate was 15%, and none of the deaths was related to recurrent infection. Outcome after recurrent infection (3.7%) was favorable. Because the IGS prosthetic graft was used in situations in which risk for infection is usually high (10 retroperitoneal abscesses, 12 graft-duodenal fistulas, 1 colonic fistula), and often in an emergency setting because of a life-threatening situation (41%), the results of our series compare favorably with those in the literature (Table V).

Traditional management of infected aortic prosthetic grafts, consisting of extra-anatomic bypass grafting, has several disadvantages compared with in situ replacement. First, the procedure is longer and patency at midterm is not so good. No instance of graft thrombosis and no amputations occurred in our series, even though 70% of the patients had severe atherosclerotic lesions; these results are comparable to those reported for various methods of in situ aortic replacement (Table V). Second, aortic stump suture is not always possible when the stump is short; the risk for thrombosis ascending toward the renal arteries is compounded by the risk for aortic stump blowout.[4,14] No anastomotic rupture occurred in our series with the IGS prosthesis. Third, blood supply to the pelvis and the left colon is usually compromised with conventional treatment, because it is impossible to revascularize the internal iliac arteries or the inferior mesenteric artery. Bacourt et al[14] reported five patients with colonic ischemia and two patients with paraplegia in their series.

One theoretical advantage of extraanatomic bypass grafting is lower risk for graft infection, because revascularization is usually performed at a distance from the site of infection. However, secondary infections have been noted in as many as 27% of recent series (Table V). Recurrent infection developed in only one patient (3.7%) in our series, with mean follow-up of 16.5 months. While 13 of our patients had relatively low-grade infection (negative cultures, n = 3; *Staphylococcus epidermidis*, n = 5; Candida, n = 4; *Corynebacterium*, n = 1), 44% had signs of sepsis, with *S aureus* (MRSA, n = 2), *Enterococcus faecalis*, and *Streptococcus* organisms most frequently isolated. The same

Table V. Results of management of aortic prosthetic graft infection with extraanatomic bypass grafting (conventional) and in situ graft replacement

Author	Year	No. of patients	Mean follow-up (mo)	Operative mortality (%)	Amputation (%)	Secondary infection (%)
Conventional treatment						
O'Hara et al[19]	1986	54	13	28	27	27
Bacourt et al[14]	1992	98	34.6	24	16	7
Sharp et al[20]	1994	20	—	3.7	5	5
Yeager et al[4]	1999	60	41	13	10	10
Bandyk et al[18]	2001	31	26	21	9	3
In situ graft replacement						
Allograft						
Kieffer et al[5]	1993	43	13.8	12	0	7
Verhelst et al[23]	2000	90	36	17	1	1
Leseche et al[21]	2001	28	35.4	17.8	0	0
Vogt et al[22]	2002	49	27	6	0	2
Noel et al[16]	2002	56	5.3	13	5	4
Autogenous vein						
Nevelsteen et al[25]	1995	15	17	7	7	0
Clagett et al[24]	1997	41	32	7.3	5	0
Bandyk et al[18]	2001	10	26	10	10	3
Antibiotic bonded prosthesis						
Hayes et al[26]	1999	11	—	18	0	9
Young et al[27]	1999	9	36	8	0	11
Bandyk et al[18]	2001	16	18	0	0	10
IGS* prosthesis						
Zegelman & Gunther[15]	2002	44	11	6.5	—	6.5
Current series	2003	27	17	16.6	0	3.7

*Intergard silver; InterVascular, La Ciotat, France.

distribution was reported by Zegelman and Gunther,[15] who found *S epidermis* in 6 patients, *Pseudomonas* in 11 patients, and *S aureus* in 47 patients in their series. In our series, the infected prosthesis was surrounded by purulent material in 10 patients, and 13 patients had an enteric fistula; even in these conditions, the IGS prosthesis resisted infection, and no anastomotic rupture occurred. Thorough debridement of all infected surrounding tissues is essential and must be completed with irrigation with povidone-iodine solution; the prosthetic graft should also be covered with a pedicled omentoplasty when possible.[16]

Traditional management of partially infected prosthetic grafts consists of complete excision. However, Miller[17] demonstrated that when the remainder of the prosthesis is well-encapsulated, it can be safely left in place. For patients with poor general condition, this reduces operative morbidity and mortality; the new prosthesis is placed in situ in an adjacent position. The apparently better outcome with partial graft removal may not result from the technique but because the infection was limited. Six patients with segmental graft infection underwent in situ replacement of a segment of IGS prosthesis. This approach was used for patients in poor general condition in whom the remainder of the prosthesis was macroscopically free of infection. In one of these six patients, recurrent infection developed, with a favorable outcome; another patient died after recurrence of a duodenal fistula. In contrast, 3 deaths occurred among 18 patients who required complete replacement of an infected prosthetic graft.

Table VI. Results of management of digestive fistulas with extraanatomic bypass grafting (conventional) and in situ graft replacement

Author	Operative mortality (%)
Conventional treatment	
O'Hara et al[19]	51
Bacourt et al[14]	30
Yeager et al[4]	19
Bandyk et al[18]	29
In situ graft replacement	
Allograft	
Ruotolo et al[41]	38
Verhelst et al[23]	29
Leseche et al[21]	30
Vogt et al[22]	14
Noel et al[16]	50
Autogenous vein	
Nevelsteen et al[25]	50
Antibiotic-bonded prosthesis	
Hayes et al[26]	25
IGS*	
Current series	23

*Intergard silver; InterVascular, La Ciotat, France.

Thirteen aortic graft infections in our series were due to graft-duodenal fistula (n = 12) or graft-sigmoid fistula (n = 1). Three of these 13 patients (23%) died. One death was due to recurrence of the sutured duodenal fistula. If the

opening of the duodenal fistula is fairly small and the duodenal wall is of good quality, suturing alone and placement of a gastroduodenal catheter in proximal duodenum may suffice. When the duodenal wall is of poor quality or the opening is large, prevention of fistula recurrence requires resection of the fourth duodenum and the proximal jejunum, and lateral anastomosis or Y-shaped anastomosis to the second duodenum. The early mortality rate in this series is within the range reported in recent series with alternative therapies (Table VI). None of the three deaths was due to recurrent graft infection.

Recent publications[5-16,18-29] have reported the safety of in situ replacement of infected aortic prosthetic grafts or mycotic aneurysms of the infrarenal aorta using various graft materials (Table V).

In situ replacement with cryopreserved arterial allograft is another option for treatment of these infected grafts. In experimental studies, allografts were more resistant to infection than conventional prostheses were,[30-32] although a report from the Mayo Clinic[16] found that 23% of complications were attributable to the allograft, including hemorrhage, persistent infection, occlusion, and pseudoaneurysm. Autogenous reconstruction with the superficial femoral veins is the most effective means to prevent secondary infection, but the additional operative time required is not always compatible with life-threatening situations or fragile patients.[18] Previous deep venous thrombosis is a contraindication to this operative approach. Similarly, a history of femoropopliteal reconstruction complicates excision of a segment of the superficial femoral vein.[25] Postoperative compartment syndrome has also been described in 12% of patients.[24]

The efficacy of rifampicin-impregnated polyester prostheses for in situ replacement of infected aortic prosthetic grafts has been demonstrated both experimentally[33,34] and in clinical trials.[18,26,27] However, their efficacy depends on the bacterium responsible for the infection. Experimental studies have shown that gelatin-coated polyester prostheses impregnated with rifampicin exhibit satisfactory resistance to *S epidermis* but are insufficient against MRSA and *Escherichia coli*.[35,36] These experimental findings confirm the work of Hayes et al,[26] who emphasized the limitations of rifampicin-bonded polyester grafts for management of major aortic graft infection with MSRA. This problem warrants particular attention because of the appearance of rifampicin-resistant strains of *S epidermis*.[37]

The evolution of nosocomial infections in the United States and in Europe highlights the changing epidemiology of infections, because bacteria such as *S aureus* and *S epidermis* are increasingly resistant to antibiotic therapy.[38] Because of risk for bacterial resistance to rifampicin, alternatives to the antibiotic agents bonded to these prostheses must be envisaged for in situ replacement of infected aortic prosthetic grafts. Experimentally, bacterial resistance develops more rapidly and more easily with antibiotic agents than with antiseptic agents.[39] The antiseptic properties of silver salts have long been recognized. Because of their biocompatibility, and experimental and clinical efficacy

when used as antimicrobial agents on implantable medical devices,[8-11] we selected the IGS prosthesis for management of infected aortic prosthetic grafts. Our study findings show that in situ IGS prostheses are a safe and effective option for management of mycotic aneurysms and infected aortic prosthetic grafts.

This study does, however, have limitations. In particular, there were no instances of *Pseudomonas* graft infection in this series, 13 patients had low-grade infection, and the number of infected grafts treated at each participating center varied considerably. However, prosthetic graft infections are infrequent, and few cases are treated. Mean follow-up was only 16.5 months, which is insufficient for detection of late infection, and prolonged follow-up of the patients in this series will be necessary. Finally, a recent experimental study[40] reported that rifampicin-impregnated prostheses are more resistant to infection than IGS prostheses are. Clinical trials do not confirm these experimental findings, however, and secondary infections are more frequent with rifampicin-impregnated prostheses than with IGS prostheses (Table V). This discrepancy between experimental findings and clinical trials is probably attributable to the fact that *S aureus* and *S epidermis* develop resistance to rifampicin more rapidly than to silver salts.[26,36,38]

In conclusion, preliminary results of this series show favorable results with use of IGS graft for in situ replacement of infected aortic prosthetic grafts and mycotic aneurysms. The IGS graft may be an appropriate option for treatment of infected aortic grafts, particularly when autogenous deep vein reconstruction is not possible. However, this series has limitations in that most of the patients had late graft infection caused by organisms with low virulence. Furthermore, long-term follow-up will be necessary to exclude recurrent graft infection. In addition, larger series will be required to compare the role of IGS grafts in infected fields with other available treatment options.

REFERENCES

1. Lorentzen JE, Nielsen OM, Arendrup H, Kimose HH, Bille S, Andersen J, et al. Vascular graft infection: an analysis of sixty-two graft infections in 2411 consecutively implanted synthetic vascular grafts. Surgery 1985;98:81-6.
2. Bunt TJ. Synthetic vascular graft infections. I: Graft infections. Surgery 1983;93:733-46.
3. Hallet JW, Marschall DM, Petterson TM, Darryl TG, Bower TC, Cherry KJ, et al. Graft-related complications after abdominal aortic aneurysm repair: reassurance from a 36 year population-based experience. J Vasc Surg 1997;25:277-86.
4. Yeager RA, Taylor LM, Moneta GL, Edwards JM, Nicoloff AD, McConnell DB, et al. Improved results with conventional management of infrarenal aortic infection. J Vasc Surg 1999;30:76-83.
5. Kieffer E, Bahnini A, Koskas F, Ruotolo C, Le Blevec D, Plissonnier D. In situ allograft replacement of infected infrarenal aortic prosthetic grafts: results in forty-three patients. J Vasc Surg 1993;17:349-56.
6. Clagett GP, Bowers BL, Lopez-Viego MA, Rossi MB, Valentine RJ, Myers SI, et al. Creation of a neo-aorto iliac system from lower extremity deep and superficial veins. Ann Surg 1993;218:239-49.
7. Naylor AR, Clark S, London NJM, Sayers RD, MacPherson DS, Barrie WW, et al. Treatment of major aortic graft infection: preliminary

experience with a rifampicin-bonded prosthesis. Eur J Vasc Endovasc Surg 1995;9:252-6.

8. Ahearn DG, Grace DT. Effects of hydrogel/silver coatings on in vitro adhesion to catheters of bacteria associated with urinary tract infections. Curr Microbiol 2000;41:120-5.

9. Raad I, Hanna H. Intravascular catheters impregnated with antimicrobial agents: a milestone in the prevention of blood stream infections. Support Care Cancer 1999;7:386-90.

10. Tweden KS, Cameron JD. Biocompatibility of silver-modified polyester for antimicrobial protection of prosthetic valves. J Heart Valve Dis 1997;6:553-61.

11. Carrel T, Nguyen T, Kipfer B, Althaus U. Definitive cure of recurrent prosthetic endocarditis using silver-coated St Jude medical heart valves: a preliminary case report. J Heart Valve Dis 1998;7:531-3.

12. NAM SA. Inc. Data on file at InterVascular, La Ciotat, France.

13. Charles River, Pharmacology Services. Data on file at InterVascular, La Ciotat, France.

14. Bacourt F, Koskas F, Association Universitaire de Recherche Chirurgie. Pontages axillo-bifémoral et exclusion aortique pour lésions septiques: étude rétrospective multicentrique de 98 cas. Ann Vasc Surg 1992;6: 119-26.

15. Zegelman M, Gunther G. Infected grafts require excision and extra-anatomic reconstruction. In: Greenhalgh RM, ed. The evidence for vascular or endovascular reconstruction. Philadelphia, Pa: Saunders, 2002:252-8.

16. Noel AA, Glowiczki P, Cherry KJ, Safi H, Goldstone J, Morasch MD, et al. Abdominal aortic reconstruction in infected fields: early results of the United States cryopreserved aortic allograft registry. J Vasc Surg 2002; 35:847-52.

17. Miller JH. Partial replacement of an infected arterial graft by a new prosthetic polytetrafluoroethylene segment: a new therapeutic option. J Vasc Surg 1993;17:546-58.

18. Bandyk DF, Novotney ML, Back MR, Johnson BL, Schmacht DC. Expanded application of in situ replacement for prosthetic graft infection. J Vasc Surg 2001;34:411-20.

19. O'Hara PJ, Hertzer NR, Beven EG, Krajewski LP. Surgical management of infected abdominal aortic grafts: review of a 25-year experience. J Vasc Surg 1986;3:725-31.

20. Sharp WJ, Hoballah JJ, Mohan CR, Kresowik TF, Martinasevic M, Chalmers RTA, et al. The management of the infected aortic prosthesis: a current decade of experience. J Vasc Surg 1994;19:844-50.

21. Leseche G, Castier Y, Petit MD, Bertrand P, Kitzis M, Mussot S, et al. Long-term results of cryopreserved arterial allograft reconstruction in infected prosthetic grafts and mycotic aneurysms of the abdominal aorta. J Vasc Surg 2001;34:616-22.

22. Vogt PR, Brunner-La Rocca HP, Lachat M, Ruef C, Turina MI. Technical details with the use of cryopreserved arterial allografts for aortic infection: influence on early and midterm mortality. J Vasc Surg 2002;35:80-6.

23. Verhelst R, Lacroix V, Vraux M, Lavigne JP, Vandamme H, Limet R, et al. Use of cryopreserved arterial homografts for management of infected prosthetic grafts: a multicentric study. Ann Vasc Surg 2000;14:602-7.

24. Clagett GP, Valentine RJ, Hagino RT. Autogenous aortoiliac/femoral reconstruction from superficial femoral-popliteal veins: feasibility and durability. J Vasc Surg 1997;25:255-70.

25. Nevelsteen A, Lacroix H, Suy R. Autogenous reconstruction with the lower extremity deep veins: an alternative treatment of prosthetic infection after reconstructive surgery for aorto-iliac disease. J Vasc Surg 1995;22:129-34.

26. Hayes PD, Nasim A, London NJM, Sayers RD, Barrie WW, Bell PRF, et al. In situ replacement of infected aortic grafts with rifampicin-bonded prostheses: the Leicester experience (1992 to 1998). J Vasc Surg 1999;30:92-8.

27. Young RM, Cherry KJ, Davis PM, Gglowiczki P, Bower TC, Panneton JM, et al. The results of in situ prosthetic replacement for infected aortic grafts. Am J Surg 1999;178:136-40.

28. Fichelle JM, Tabet G, Cormier ?? Ph, Farkas JC, Laurian C, Gigou F, et al. Infected infrarenal aortic aneurysms: When is in situ reconstruction safe? J Vasc Surg 1993;17:635-45.

29. Oderich GS, Panneton JM, Bower TC, Cherry KJ, Rowland CM, Noel AA, et al. Infected aortic aneurysms: aggressive presentation, complicated early outcome, but durable results. J Vasc Surg 2001;34:900-8.

30. Koskas F, Goeau-Brissonniere O, Nicolas MN, Bacourt F, Kieffer E. Arteries from human beings are less infectible by *Staphylococcus aureus* than polytetrafluoroethylene in an aortic dog model. J Vasc Surg 1996;23:472-6.

31. Knosalla C, Goeau-Brissoniere O, Leflon V. Treatment of vascular graft infection by in situ replacement with cryopreserved aortic allografts: an experimental study. J Vasc Surg 1998;27:689-98.

32. Camiade C, Goldschmidt P, Koskas F, Ricco JB, Jarraya M, Gerotal J, et al. Optimization of the resistance of arterial allografts to infection: comparative study with synthetic prostheses. Ann Vasc Surg 2001;15: 186-96.

33. Colburn MD, Moore WS, Chapvil M, Gelabert HA, Quinones-Baldrich WJ. Use of an antibiotic-bonded graft for in situ reconstruction after prosthetic graft infections. J Vasc Surg 1992;16:651-60.

34. Goeau-Brissoniere O, Mercier F, Nicolas MH, Bacourt F, Coggia M, Lebrault C, et al. Treatment of vascular graft infection by in situ replacement with a rifampin-bonded gelatin-sealed Dacron graft. J Vasc Surg 1994;19:739-44.

35. Vicaretti M, Hawthorne W, Ao PY, Fletcher JP. Does in situ replacement of a staphylococcal-infected vascular graft with a rifampicin-impregnated gelatin-sealed Dacron graft reduce the incidence of subsequent infection? Int Angiol 1999;18:225-32.

36. Koshiko S, Sasajima T, Muraki S, Azuma N, Yamazaki K, Chiba K, et al. Limitations in the use of rifampicin-gelatin grafts against virulent organisms. J Vasc Surg 2002;35:482-6.

37. Bandyk DF, Novotney ML, Johnson BL, Back MR, Roth SR. Use of rifampin-soaked gelatin-sealed polyester grafts for in situ replacement: treatment of primary aortic and vascular prosthetic infections. J Surg Res 2001;95:44-9.

38. Naylor AR, Hayes PD, Darke S, on behalf of the Joint Vascular Research Group. A prospective audit of complex wound and graft infections in Great Britain and Ireland: the emergence of MRSA. Eur J Vasc Endovasc Surg 2001;21:289-94.

39. Tambe SM, Sampath L, Modak SM. In vitro evaluation of the risk of developing bacterial resistance to antiseptics and antibiotics used in medical devices. J Antimicrob Chemother 2001;47:589-98.

40. Goeau-Brissoniere OA, Fabre D, Leflon-Guibout V, Di Centa I, Nicolas-Chanoine MH, Coggia M. Comparison of the resistance to infection of rifampin-bonded gelatin-sealed and silver/collagen-coated polyester prostheses. J Vasc Surg 2002;35:1260-3.

41. Ruotolo C, Plissonnier D, Bahnini A, Koskas F, Kieffer E. In situ arterial allografts: a new treatment for aortic prosthetic infection. Eur J Vasc Endovasc Surg 1997;14(suppl A):102-7.