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ORIGINAL CONTRIBUTION

Prosthetic Vascular Graft Infection: A Multi-Center Review of Surgical Management

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A multi-center retrospective review of major prosthetic graft infection outcomes was undertaken to determine graft preservation and limb salvage rates. The management of infected prosthetic vascular grafts continues to be controversial. The purpose of this study was to review the surgical management of major extracavitary prosthetic vascular graft infections and to correlate the outcomes on the basis of bacteriology and grade. The change in patient population seen by vascular surgeons and the recent emergence of more virulent bacterial strains should influence surgical management. Bacteriology and severity of infection based on grade must play a greater role in the selection criteria for graft salvage. Despite advancement in the understanding of these interactions and the emergence of new management algorithms, we are continuing to operate without a uniform standard in managing this difficult and rapidly evolving clinical problem.

INTRODUCTION

The incidence of prosthetic graft infections has been reported to vary from 1 percent to 6 percent [1-5]. Several series have demonstrated an overall improvement in the morbidity and mortality of operative treatment of infected vascular prostheses [1,6-8]. Successful management can be attributed to the development of better staging systems, operative delineation of the extent of infection, and a better appreciation of the potential virulence of the microbes involved [3,8,9].

Samson [10], as well as Koenig and vonDongen [11], have modified the widely used classification system of extracavitary vascular graft infections established by Szilagyi [12]. These modifications allow for more precise prognostication and directed treatment (Table 1).

Debate continues over the indications for graft salvage vs. excision in extracavitary prosthetic graft infections. Traditionally, graft infections were treated by removal, over sewing of the vessel, with extra-anatomic bypass. While this modality continues to have its proponents [2,13-15], the significant morbidity of this procedure has been well documented [15,16]. Graft salvage and route salvage techniques have

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†Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*.

Table 1. Prosthetic Graft Infection Classifications

Szilagyi [12] classification	Definition	Samson [10] classification	Definition
Group 1	Infection involves only the dermis	Group 1	Infections extend no deeper than the dermis
Group 2	Infection extends into the subcutaneous tissue but does not invade the arterial implant	Group 2	Infections involve subcutaneous tissues but do not come into grossly observable direct contact with the graft
Group 3	The arterial implant proper is involved in the infection	Group 3	Infections involve the body of the graft but not at an anastomosis
		Group 4	Infections surround an exposed anastomosis, but bacteremia or anastomotic bleeding has not occurred
		Group 5	Infections involve a graft-to-artery anastomosis and are associated with septicemia and/or bleeding at the time of presentation

been developed that use the same vascular bed anatomy. Long-term success has been attainable in many case series with aggressive operative debridement and rotational muscle flaps [1,2,4-6,16-24].

This study was prompted by a combination of the recent changes in the profile of patients treated by vascular surgeons, alterations in microbiologic isolates, and an attempt to assess the variability of practice patterns in light of current clinical guidelines.

A multi-center retrospective study was conducted to determine the primary mode of therapy and rate of limb salvage for major prosthetic graft infections. Only Samson groups 3 through 5 extracavitary and distal limb aortofemoral grafts were reviewed. Groups 1 and 2 were excluded, as these infections do not involve the graft itself. This study attempted to correlate grade, bacteriology, and outcomes and compare these based on choice of surgical intervention. This is the first study in the literature to do so.

PATIENTS AND METHODS

A retrospective review of records was completed at three hospitals: the University of California-Irvine Medical Center, Yale New Haven Medical Center, and an affiliate, the Hospital of Saint Raphael. We obtained permission to perform this study from the institutional review boards of all three hospitals. The data were obtained through an extensive review of all medical records and outpatient clinic charts of vascular bypasses performed from 1997 to 2002. Only extracavitary graft infections and distal segments of aortofemoral prosthetic grafts were included in the study population. Isolated intracavitary and arteriovenous prosthetic grafts were excluded. The Samson modification of the Szilagyi system was used to select only patients with group 3 through 5 infections (as noted by clinical and operative notes). Data were collected on the initial operation and its indication, the type of prosthesis, the timing of infection, bacteriology, treatment, and outcome. Follow-up was concluded at the death of the subject or at the end of data collection in May 2004.

Statistical analyses were performed with SPSS for Windows (SPSS 12.0; SPSS Inc., Chicago, IL). Both descriptive and inferential statistical methods were used. All testing was based on determining statistical significance at a two-sided *P* level of .05. We used

Table 2. Type of Vascular Bypass

Vascular Bypass	N
Aortofemoral	7
Femoropopliteal	12
Femorodistal	8
Femorofemoral	10
Axillofemoral	4
Femoro-interpositional	4
Total	45

Fisher's exact tests to compare categorical variables with other categorical variables.

RESULTS

Forty-five subjects (23 men and 22 women) met the criteria for inclusion in this study. Subjects ranged in age from 40 to 85 years (mean, 67 years). Follow-up time ranged from 2 to 72 months, with an average of 27 months.

The revascularization procedures performed before the onset of infection are listed in Table 2. The most common indications for operation were tissue loss (n = 20; 44 percent) and claudication (n = 15; 33 percent). The indication for the remaining 23 percent could not be assigned from the medical record but were either tissue loss or claudication. The infected grafts were polytetrafluoroethylene in 34 cases, Dacron (DuPont, Wilmington, Delaware) in eight cases, and composite grafts in three cases. The time from implantation to the development of infection was documented as either early (less than 4 months; n = 30; 64 percent) or late (greater than 4 months; n = 15; 36 percent). Data for Samson groups 3 through 5 are shown in Table 3.

Aerobic, anaerobic, and fungal cultures were obtained with swabs from all grafts during the operation. The groin was the most common site of infection (n = 37; 82 percent). The most common organisms cultured are listed in Table 3.

Bacteriology was available in 38 of 45 cases. Gram-negative organisms were cultured in abundance in this series: 16 (45 percent) cases harbored Gram-negative organisms, and of those, only three were *Pseudomonas aeruginosa*. Two of three (group 3) patients with *P. aeruginosa* infections experienced limb salvage failure with either muscle flap or ex situ bypass. Six (55 percent) of 11 amputations occurred in patients with Gram-negative infections, and two (67 percent) of three perioperative deaths were related to Gram-negative sepsis. *Staphylococcus epidermidis* was the most common Gram-positive organism cultured (32 percent), followed by methicillin-resistant *Staphylococcus aureus* (MRSA) (26 percent). Muscle flaps or in situ bypass replacements were used to treat 71 percent of group 3 *S. epidermidis*-infected grafts. Group 4 and 5 *S. epidermidis* cases were treated primarily by excision.

The treatment regimens for MRSA-infected grafts were as mixed as the results (Table 4): 50 percent of MRSA-infected grafts were excised, 30 percent were salvaged, and 20 percent were treated by in situ graft replacement and muscle flap transposition. There was a 42.9 percent amputation rate and a 57.1 percent limb salvage rate for MRSA-infected group 3 cases.

The primary mode of therapy was muscle flap transposition, alone (n = 15) or with in situ graft replacement (n = 3). A total of 18 (40 percent) muscle flaps were performed. Ten (67 percent) of 15 grafts were preserved with muscle flap transposition. Although there was no statistical significance ($P = .081$), muscle flaps were used more often for group 3 compared with groups 4 and 5, whereas irrigation and debridement were used more frequently for group 4. Ex situ and in situ graft replacements were used more often for group 5 cases (Table 5).

Samson group 3 (n = 30) cases were treated mostly by graft excision (n = 16; 53 percent), and fewer than half were preserved (n = 14; 46 percent). The Samson group 4 (n

Table 3. Organism and Treatment Data

Patient No.	Group*	Organism	Treatment	Outcome
1	3	*Citrobacter koseri*	Flap	Limb salvage
2	3	Diphtheroids, *Escherichia coli*	Flap	Amputation
3	3	*Enterobacter* sp.	Excision	Limb salvage
4	3	*Enterobacter* sp., enterococci	Flap	Amputation
5	3	GNR	Excision	Amputation
6	3	MRSA	Ex situ	Amputation
7	3	MRSA	Excision	Limb salvage
8	3	MRSA	Excision	Limb salvage
9	3	MRSA	I & D	Limb salvage
10	3	MRSA	I & D	Limb salvage
11	3	MRSA	In situ & flap	Amputation
12	3	MRSA, *Pseudomonas* sp.	Excision	Amputation
13	3	No growth	Excision	Death
14	3	No growth	Excision	Limb salvage
15	3	No growth	Flap	Limb salvage
16	3	No growth	I & D	Limb salvage
17	3	No growth	I & D	Limb salvage
18	3	*Proteus* sp., *E. coli, Enterobacter* sp.	Flap	Limb salvage
19	3	*Pseudomonas* sp.	Flap	Amputation
20	3	*Pseudomonas* sp., enterococci	Ex situ	Amputation
21	3	*Staphylococcus aureus*	Flap	Amputation
22	3	*S. aureus*, diphtheroids	In situ	Amputation
23	3	*S. epidermidis*	Excision	Limb salvage
24	3	*S. epidermidis*	Flap	Limb salvage
25	3	*S. epidermidis*	Flap	Limb salvage
26	3	*S. epidermidis*	Flap	Limb salvage
27	3	*S. epidermidis*	In situ	Limb salvage
28	3	*S. epidermidis, Bacteroides* sp.	Flap	Limb salvage
29	3	*S. epidermidis, Torulopsis glabrata*	Excision	Limb salvage
30	3	Streptococci, diphtheroids, *Proteus* sp	Flap	Limb salvage
31	4	*Citrobacter* sp.	I & D	Limb salvage
32	4	*Enterobacter* and *Candida* sp.	Ex situ	Limb salvage
33	4	MRSA; *Enterobacter* and *Candida* sp.	Flap	Limb salvage
34	4	MRSA, *S. epidermidis*, diphtheroids	Ex situ	Limb salvage
35	4	No growth	I & D	Limb salvage
36	4	*Proteus* sp., *E. coli, Morganella* sp.	I & D	Death
37	4	*Proteus* sp., *Haemophilus influenzae*	Flap	Limb salvage
38	4	*S. epidermidis*	Excision	Limb salvage
39	4	*S. epidermidis*, enterococci	Excision	Limb salvage
40	5	MRSA	In situ & flap	Limb salvage
41	5	No growth	Flap	Amputation
42	5	S. aureus	Excision	Limb salvage
43	5	*S. aureus, diphtheroids, Enterobacter* sp., yeast	Ex situ	Death
44	5	*S. epidermidis, Bacteroides* sp.	In situ & flap	Limb salvage
45	5	*S. epidermidis, Candida* sp.	Ex situ	Limb salvage

*Samson classification.

GNR, gram-negative rod; MRSA, methicillin-resistant *Staphylococcus aureus*; I & D, irrigation and debridement.

Table 4. Distribution of Treatment Modalities by Organisms

Organism	Surgical Treatment						Total
	Ex Situ	Excision	Flap	I&D	In Situ	In Situ and Flap	
MRSA	2 (20.0%)	3 (30.0%)	1 (10.0%)	2 (20.0%)	0	2 (20.0%)	10 (100.0%)
S. epidermidis	1 (9.1%)	4 (36.4%)	4 (36.4%)	0	1 (9.1%)	1 (9.1%)	11 (100.0%)
Gram-negative organisms	3 (21.4%)	2 (14.3%)	7 (50.0%)	2 (14.3%)	0	0	14 (100.0%)
No growth	0	2 (28.6%)	2 (28.6%)	3 (42.9%)	0	0	7 (100.0%)
Total	6 (14.3%)	11 (26.2%)	14 (33.3%)	7 (16.7%)	1 (2.4%)	3 (7.1%)	42 (100.0%)

Data are count (% within organism).
I & D, irrigation and debridement; MRSA, methicillin-resistant *Staphylococcus aureus*.

= 9) and group 5 (n = 6) cases were managed with a variety of surgical treatments: ex situ bypass (n = 4; 27 percent), graft excision alone (n = 3; 20 percent), muscle flaps (n = 3; 20 percent), and in situ bypass with muscle flap (n = 2; 13 percent) (Table 3). Additionally, irrigation and debridement according to Kwaan and Connolly's method [21] was performed on three patients (20 percent).

Three perioperative deaths were related to graft infection; the other eight deaths were from various unrelated causes. Overall, there was a 6 percent perioperative mortality rate in this series. There were 11 total amputations (24 percent).

Table 6 shows the distribution of outcomes by group and organism. The distribution of outcomes was statistically significant between organism type for group 3 ($P = .03$) but not for groups 4 ($P = .9$) or 5 ($P = .3$). Group 3 patients with Gram-negative or MRSA-infected grafts were less likely to achieve limb salvage than those infected with S. epidermidis or negative cultures. Beyond this, there was insufficient evidence to suggest outcomes varied by group, organism, or treatment method.

DISCUSSION

This study is the first of its kind to evaluate management practices of extracavitary prosthetic vascular graft infections based on the extent of infection by Samson grading

Table 5. Distribution of Treatment Modalities by Group

Group	Surgical Treatment						Total
	Ex Situ	Excision	Flap	I&D	In Situ	In Situ and Flap	
3	2 (7.1%)	9 (32.1%)	11 (39.3%)	4 (14.3%)	1 (3.6%)	1 (3.6%)	28 (100.0%)
4	2 (22.2%)	2 (22.2%)	2 (22.2%)	3 (33.3%)	0	0	9 (100.0%)
5	2 (40.0%)	0	1 (20.0%)	0	0	2 (40.0%)	5 (100.0%)
Total	6 (14.3%)	11 (26.2%)	14 (33.3%)	7 (16.7%)	1 (2.4%)	3 (7.1%)	42 (100.0%)

Data are count (% within group).
I & D, irrigation and debridement.

Table 6. Distribution of Outcomes by Group and Organism

	Outcome			Total
Organism	Amputation	Death	Limb salvage	
Group 3				
MRSA	3 (42.9%)	0	4 (57.1%)	7 (100.0%)
Staphylococcus epidermidis	0	0	7 (100.0%)	7 (100.0%)
Gram-negative	5 (55.6%)	0	4 (44.4%)	9 (100.0%)
No growth	0	1 (20.0%)	4 (80.0%)	5 (100.0%)
Total	8 (28.6%)	1 (3.6%)	19 (67.9%)	28 (100.0%)
Group 4				
MRSA		0	2 (100.0%)	2 (100.0%)
S. epidermidis		0	2 (100.0%)	2 (100.0%)
Gram-negative		1 (25.0%)	3 (75.0%)	4 (100.0%)
No growth		0	1 (100.0%)	1 (100.0%)
Total		1 (11.1%)	8 (88.9%)	9 (100.0%)
Group 5				
MRSA	0	0	1 (100.0%)	1 (100.0%)
S. epidermidis	0	0	2 (100.0%)	2 (100.0%)
Gram-negative	0	1 (100.0%)	0	1 (100.0%)
No growth	1 (100.0%)	0	0	1 (100.0%)
Total	1 (20.0%)	1 (20.0%)	3 (60.0%)	5 (100.0%)

Data are count (% within organism).
MRSA, methicillin-resistant *Staphylococcus aureus*.

and bacteriology. It is clear from this analysis that surgeons have not yet broadly adopted these management principles and continue to select widely divergent interventions for a given infection.

Success of graft or route salvage is often determined by the infective organism, with pseudomonas- and MRSA-infected grafts being particularly difficult to salvage [7,25]. Generally, the microbiologic profile of prosthetic vascular graft infections mirrors that of nosocomial infections, and there is great concern that patterns of sensitivity are rapidly and continuously changing [26,27]. Graft and route salvage have been met with success in other series, particularly when infected with *S. epidermidis*, as well as some Gram-positive and Gram-negative organisms [2,7,8,5]. Despite this evidence in the literature, the data found in Table 3 and Table 4 indicate bacteriology did not play a consistent role in the management algorithms of these institutions.

The current literature indicates Samson group 3 patients are most often considered for graft salvage and route salvage (in situ reconstruction) [28]. Aggressive perigraft debridement with vascularized muscle transposition has been a very successful treatment method for group 3 infections (Table 7). We were surprised to find the Samson group 3 (n = 30) cases were treated mostly by graft excision (n = 16; 53 percent) instead of preservation (n = 14; 46 percent). Those Samson group 3 patients who were treated with muscle flap and graft salvage in this study resulted in seven of 11 limbs salvaged, results comparable to those in other studies (Table 7).

Table 3 illustrates that patients in Samson group 4 were managed in an ad hoc manner, and there was no sign that bacteriology influenced treatment choice. Our data indicate bacteriology played a key role in determining the outcome for group 3 cases, but not for group 4 or 5 cases, perhaps because of the small sample size. Unfortunately, therapeutic decisions were not guided by bacteriology. This may have diminished overall graft preservation and limb salvage rates.

The prevalence of methicillin-resistant *Staphylococcus aureus* in the vascular surgery patient has increased since the sample

of patients in this study was taken. Widespread misuse of antibiotics and a lack of compliance with preventative measures in the hospital setting have been credited for a rapid increase in prevalence of MRSA infection [29]. A recent study cited MRSA as being the leading cause of post-operative infection in vascular surgery patients [30].

The current literature suggests that MRSA-infected graft preservation should only be attempted with minor graft involvement [25,31]. The high proportion of amputations (24 percent) was likely due to the prevalence of MRSA and the excision of the graft in a population with already threatened limbs. Despite the success of irrigation and debridement in group 3 MRSA-infected grafts in our sample, it is probably imprudent to treat this virulent organism with local measures alone.

Poor outcomes with pseudomonas infections in this study were expected based on the literature from Calligaro, et al. [7] Our results suggest that pseudomonas infections of grade 3 or higher are best treated with excision.

The incidence of *S. epidermidis* was likely underestimated, particularly in the no-growth cultures, because of the routine swabbing of wound cultures [32]. Other microbiologic methods, such as ultrasonification, are essential to increase the detection of *S. epidermidis* [3]. The low virulence of this organism makes either muscle flap salvage or in situ graft replacement a reasonable option [2,7,8,15]. Our limb salvage rate for *S. epidermidis* infections was 100 percent; however, only 4 (36 percent) of 11 grafts were preserved with muscle flaps.

Many limbs were salvaged (six of seven; 86 percent) with irrigation and debridement alone. This method can be used with success in critically ill patients; however, the use of a muscle flap would greatly decrease the risks associated with this process. These risks include graft desiccation, thrombosis, rupture, and prolonged hospital stays [21]. The use of irrigation and debridement as the sole therapy in group 4 Gram-negative infections was inadequate in this study. Irrigation and debridement best serves as an adjunctive rather than a primary therapy [6,28].

In situ graft replacement supplemented with muscle flaps is a promising strategy for complicated perigraft infections that may not tolerate extra anatomic reconstruction. Preserving the vascularization route with in situ graft replacement and reinforcing it with muscle flaps increases limb salvage options for Samson group 4 and group 5 infections. However, we were unable to demonstrate statistical significance with in situ graft replacement and muscle flap transposition in Samson groups 4 and 5 because of our small sample size and the infrequent use of this therapy. Graft salvage likely has limited application in Samson group 5 patients — those with sepsis, graft occlusion, and anastomotic hemorrhage. The current literature suggests excision of the graft is generally indicated and should be performed if tolerated [8,28].

Incorporating the information gathered regarding graft salvage for given grade of infection with bacteriology data has allowed a logical management algorithm to be established for the treatment of extracavitary prosthetic vascular graft infections [28]. Our study critically evaluated how this knowledge is incorporated into surgical management of prosthetic vascular graft infections from three institutions in the United States.

This study supports a surgical strategy for extracavitary vascular graft infections based primarily on the degree of infection and microbiology. Vascular graft infections should be regarded as dynamic processes that change as quickly as the organisms that create them. This challenging clinical problem requires periodic review that will lead to significant changes in management algorithm in the future. Other factors, such as patient vascular anatomy and implant location, are also essential to determine the optimal method of limb salvage. If all these criteria are examined before therapy, standardization is feasible and successful outcomes will become more predictable and routine even in the face of this rapidly evolving pathological process.

There were several limitations in this study. Surgeons selected which procedures

would be performed on each patient in a non-randomized manner. The surgeon's past experience and comfort level will often determine choice of procedure. The clinical assessment of severity of infection may also differ among surgeons, and this was controlled for by the use of a unified grading system. Another factor that may influence the choice of intervention is the presence of a working relationship between the vascular surgeon and a plastic surgeon. Not all vascular surgeons have a strong relationship with a plastic surgeon, whereby they may not opt for vascular graft salvage using muscle flaps when indicated. The study will be strengthened if it can be repeated in a prospective fashion, with greater than three institutions involved, and a larger sample size.

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