Surgical management of infrainguinal arterial prosthetic graft infections: Review of a thirty-five–year experience

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Purpose: The purpose was to determine the early and late mortality and morbidity rates associated with infrainguinal arterial prosthetic graft infection (IAPGI) and to identify optimal methods of management.

Methods: The study included 53 men and 14 women (mean age, 61 years) in whom a total of 68 IAPGIs developed in the years 1959 to 1993. IAPGI involved 58 femoropopliteal grafts (85%), six femorodistal grafts (9%), and four other grafts or synthetic patches (6%). Graft material was dacron in 36 (53%), polytetrafluoroethylene in 28 (41%), and human umbilical vein in four (6%). Sixteen IAPGIs (24%) involved limbs that had required amputations before IAPGI was diagnosed. Twenty-six (38%) of the 68 grafts were thrombosed, and 14 (88%) of the 16 amputees had occluded grafts.

Results: Staphylococcal organisms were isolated from 34 (58%) of the 59 IAPGIs for which culture data were available. The median intervals until IAPGI was diagnosed were 3 months after implantation and 1 month after the last procedure involving the original graft. Initial management consisted of local measures only in 13 (19%), partial removal or in situ graft replacement in 15 (22%), and total graft excision in 40 (59%). Total excision was performed in 15 (94%) of the 16 patients with prior amputations and in only 25 (48%) of the 52 intact limbs. The overall postoperative mortality rate was 18%; seven (58%) of the 12 early deaths were related to sepsis, and all 12 occurred within the group of 51 patients (24%) for whom limb salvage was still being attempted ($p = 0.056$). IAPGI ultimately led to amputations in 21 (40%) of 52 intact limbs within the first year. Twenty-three (82%) of the 28 IAPGIs managed with incomplete graft removal required subsequent operations for continued sepsis, compared with five (13%) of the 40 treated with complete excision ($p < 0.001$). The cumulative 5-year survival rate (77%) for 53 patients who survived operation was less than that (89%) for the normal, age-matched U.S. male population.

Conclusions: IAPGI is associated with substantial early mortality and amputation rates. Complete excision of infected graft material results in a significant reduction in the incidence of recurrent sepsis. (J VASC SURG 1995;21:782-91.)

One of the most serious complications associated with the use of prosthetic material for vascular reconstruction is infection involving the synthetic graft. The reported incidence of infrainguinal arterial prosthetic graft infection (IAPGI) is 2.5%,[1] yet IAPGI is associated with mortality and amputation rates of 17% and 41%, respectively.[1] Therefore, although the incidence of IAPGI is relatively low, the frequency with which lower extremity revascularization procedures are performed and the devastating consequences associated with IAPGI underscore its importance. Despite a clear consensus concerning its objectives (i.e., control of infection and limb salvage), there is an element of controversy regarding the optimal management of IAPGI. Some authors have advocated excision of the entire infected graft followed by revascularization with autogenous tissue and/or extraanatomic bypass.[2-4] Others have suggested local measures without removal of the graft,[5-7]

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whereas partial or complete graft removal and in situ revascularization with another synthetic graft also have been recommended.[8-11] Still others have suggested early primary amputation.[12]

To determine the early mortality and morbidity rates and the late survival rate for this complication and to clarify its management, we have reviewed our entire experience with IAPGI, which encompassed the last 35 years.

PATIENTS AND METHODS

We collected retrospective data from the hospital records of 67 consecutive patients who underwent some form of surgical treatment for 68 IAPGIs from 1959 through 1993. Long-term information was obtained during subsequent office visits or by a telephone canvass of the patients, their immediate families, or their local physicians. The end point of data collection was defined as death or follow-up within 3 months of study closure. Follow-up was complete for 57 patients, but the remaining 10 were considered lost to follow-up at a median interval of 66 months (mean, 89 months; range, 3 days to 280 months). Only three patients, however, were lost to follow-up within the 4 years after surgical intervention for their IAPGI. The median follow-up period for the entire series was 4 years (mean, 6 years; range, 0 to 28 years).

All patients had undergone prior leg revascularization with prosthetic material, and both the proximal and distal anastomoses of their grafts had been performed below the inguinal ligament. The diagnosis of IAPGI was based on conventional criteria including the presence of exposed synthetic material, the presence of purulence or a draining sinus contiguous with the prosthetic graft, or the isolation of microorganisms from excised graft material in conjunction with pseudoaneurysm formation, anastomotic disruption, or adjacent soft tissue sepsis (Szilagyi grade 3 infections).[13] Infection of a prosthetic graft developed in the contralateral lower extremity of one patient 4 years after graft sepsis had resolved in the other leg. This episode was defined as a separate event, yielding a total of 68 IAPGI in 67 patients. Nevertheless, the reappearance of clinical infection at the site of previous graft involvement was considered to represent a continuation of the original septic process and was classified as recurrent graft sepsis.

The study group consisted of 53 men and 14 women, with a mean age of 62 years (median, 62 years; range, 37 to 91 years). Forty-eight patients (72%) were cigarette smokers, 40 (60%) had clinical evidence of coronary artery disease, 31 (46%) had hypertension, 21 (31%) had diabetes, and 10 (15%) were noted to be obese. Forty-nine (72%) of the 68 infected grafts had been constructed at our center, whereas the remaining 19 (28%) had been implanted elsewhere. The IAPGIs involved 58 femoropopliteal grafts (85%), six femoroinfrapopliteal grafts (9%), two common femoral interposition grafts (3%), and two femoral endarterectomy patches (3%). The synthetic material was pure, Dacron in 35 IAPGI (51%), polytetrafluoroethylene (PTFE) in 27 (40%), and human umbilical vein in four (6%). The remaining two IAPGIs (3%) involved composite grafts composed of PTFE and human umbilical vein in one case and PTFE and Dacron in the other.

Fifteen (22%) of the IAPGIs occurred in extremities that previously had required proximal (aortoiliofemoral) reconstruction, and a total of 22 IAPGIs (32%) occurred in grafts that had been implanted during vascular reoperations. The initial site of infection was the groin in 39 extremities (57%). Sixteen IAPGIs (24%) developed in extremities for which major amputations had been performed after the original bypass procedure but before the onset of graft sepsis. Thirteen of these amputations were above the knee, whereas the remaining three were below the knee.

At the time of diagnosis of IAPGI, 26 (38%) of 68 grafts in the entire series were thrombosed, 37 (55%) were patent, and the patency status of the remaining five (7%) could not be determined. The grafts were known to be occluded in 14 (88%) of 16 previously amputated limbs. Within this subgroup, one additional graft was known to be patent, but the patency status of the remaining graft was undetermined.

Because the median age of the study group was 62 years and because men outnumbered women by a factor of more than 3.5 to 1 in the series, the cumulative 5-year survival for the normal U.S. male population at age 62 years was calculated from U.S. census data for comparison purposes. For this calculation the life-table method was used. Furthermore, it was assumed that the U.S. Census Bureau follow-up was complete and that the decrease in patient population at each year of age reported by the census data was caused entirely by the deaths in the interval.[14]

Statistical comparisons were made with Fisher's two-tailed exact test or with the chi square test when appropriate. Cumulative late survival for the study group was calculated by use of the Kaplan-Meier method.[15]

Table I. Summary of available culture results for 59 graft infections*

	Predominant growth		*Individual bacteria*	
	per individual	*IAPGI (n = 59)*	*isolated*	*(n = 86)*
Microorganism	*No.*	*%*	*No.*	*%*
No growth	1	2	NA	NA
Staphylococcus	**34**	**58**	**35**	**41**
aureus	26	44	26	30
epidermidis	8	14	9	10
Gram-negative rods	**16**	**27**	**35**	**41**
Pseudomonas	7	11	10	12
Proteus	4	7	7	8
Escherichia coli	3	5	10	12
Enterobacter	1	2	4	5
Serratia	1	2	2	2
Bacteroides	0	0	1	1
Klebsiella	0	0	1	1
Streptococci	4	7	10	12
Enterococci	3	5	5	6
Gram-positive cocci	1	2	1	1

NA, Not applicable.
*Culture data unavailable for nine IAPGIs.

Table II. Surgical management of 68 IAPGIs in 67 patients

Group	*Original graft disposition/surgical management*	*No.*	*% IAPGI*
A	Complete removal without in situ graft replacement	**40**	**59**
	No revascularization	33	49
	Synthetic extraanatomic bypass graft	2	3
	In situ autogenous	5	7
B	Complete removal with in situ graft replacement	**2**	**3**
	In situ homograft	1	1
	In situ dacron graft	1	1
C	Partial removal	**13**	**19**
	No revascularization	12	18
	Synthetic extraanatomic bypass graft	1	1
D	No removal	**13**	**19**
	Local care	12	18
	Pseudoaneurysm suture	1	1
Total		68	100

RESULTS

By definition, all IAPGIs were heralded at least by local findings, and 20 (29%) caused systemic manifestations. The most common sign of graft infection was drainage from a wound or sinus tract in 50 IAPGIs (74%), followed by bleeding or pseudoaneurysm formation in 27 (40%), induration or tenderness each in 23 (34%), and graft exposure in 12 (18%). The symptoms and physical findings were confined to the groin in 39 extremities (57%). One additional patient was discovered to have purulent material around the prosthetic graft at the time of midthigh amputation. Systemic symptoms included fever or chills accompanying 18 IAPGIs (26%) and anorexia accompanying two (3%). The median interval between the initial implantation of the prosthetic graft and the clinical diagnosis of IAPGI was 3 months (mean, 16 years; range, 0 to 187 months). The median interval since the last procedure done on the graft, such as thrombectomy, revision, or an amputation that transected the graft, was 1 month (mean, 6 months; range, 0 to 110 months).

Because of the length of the study period, culture data were available for only 59 IAPGIs (87%). *Staphylococcus* species was the predominant pathogen isolated, either alone or in combination with other microorganisms, from 34 (58%) of these 59 infections. Multiple organisms were isolated from 22 infections (37%), yielding a total of 86 documented pathogens from the 59 infections (Table I). Although microorganisms could not be isolated from one

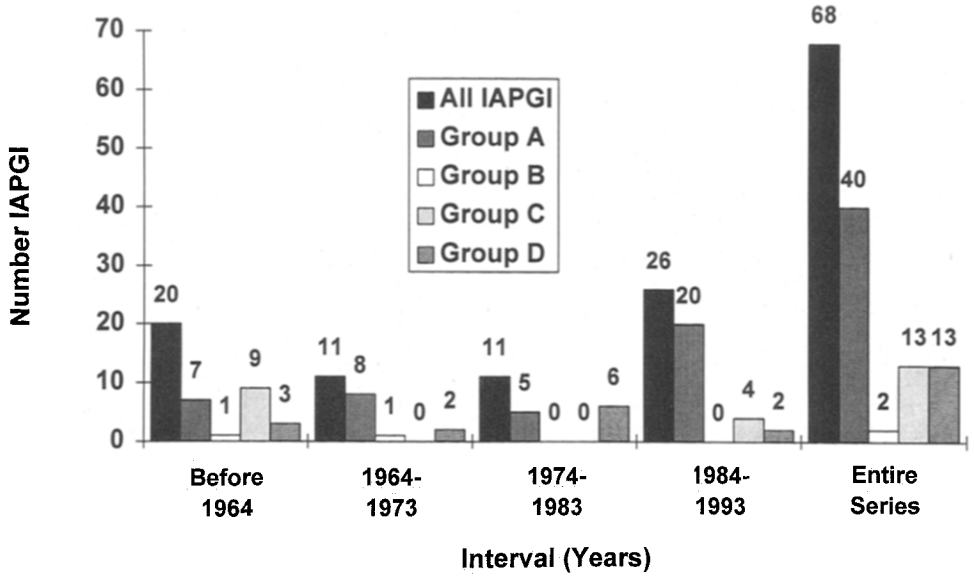

Fig. 1. Graphic representation of frequency of IAPGI and treatment methods used during each decade of study of 68 graft infections in 67 patients.

clinical graft infection, staphylococcus organisms represented 41% (35/86) of the individual pathogens. Nine IAPGIs yielded cultures positive for *Staphylococcus epidermidis*. Whereas two cultures grew *S. epidermidis* alone, the remaining seven yielded multiple organisms, one of which was *S. aureus*. Consequently, in our series, only three of 59 IAPGI for which culture data were available (4%) were low-virulence infections, caused by either *S. epidermidis* alone or an organism that failed to grow in standard culture media. Gram-negative rods accounted for 41% (35/86) of the isolated organisms but were predominant in only 27% (16/59) of the available cultures (Table I).

Four general approaches to the initial surgical management are summarized in Table II. Complete excision was defined as removal of all of the original synthetic graft material, whereas partial excision indicates that a segment of the original graft was left undisturbed. Because the exact amount of residual graft material often could not be determined retrospectively, the excision was classified as partial if any of the original graft remained in place. Forty infections, representing 59% of the 68 limbs in the entire series, were treated by complete removal of the original graft with no synthetic replacement in the contaminated bed (group A). Two infections (3%) were managed with complete removal of the original graft and simultaneous in situ revascularization with another nonautogenous graft (group B). Thirteen infections (19%) were treated by partial removal of the original graft, the remaining segment presumably being uninfected (group C). Thirteen infections (19%) were managed by use of local measures only, such as incision and drainage, debridement, and dressing changes (group D). In one of these patients a pseudoaneurysm was repaired by primary suture of the involved anastomosis. None of the original graft material was removed initially from group D limbs. The frequency of IAPGI relative to the decade of the study is summarized in Fig. 1. Twenty-six (38%) of the 68 IAPGIs were managed in the most recent decade of the study. Total excision was performed for 77% (20/26) of the IAPGIs in this decade but in only 48% (20/42) of all prior IAPGIs.

The results of each method of initial management are summarized in Table III. Only five recurrent infections (13%) developed after all synthetic material had been excluded from the contaminated field in 40 IAPGIs (group A), whereas recurrent infections occurred in 23 (82%) of the 28 limbs ($p < 0.001$) in the other three treatment groups. The thirteen IAPGIs in group D that were treated locally without graft resection are of particular interest. Four of these (31%) were associated with systemic symptoms of sepsis. Six grafts in group D were patent (46%) at the time of diagnosis of IAPGI, whereas four were occluded (31%) and the patency status of the remaining 3 could not be determined. Of the six patent grafts, one had developed a pseudoaneurysm

Table III. Recurrent graft sepsis and deaths for each treatment group for 68 IAPGIs in 67 patients

				Subsequent operation for sepsis		*Perioperative deaths*	
Excision method	*Group*	*n (IAGPI)*	*n (Patients)*	*No.*	*% (IAPGI)*	*No.*	*% Patients*
Complete	A	**40**	**39**	**5**	13	7	18
	B	2	2	2	100	1	50
	C	13	13	8	62	3	23
	D	13	13	13	100	1	8
Incomplete	B + C + D	**28**	**28**	**23**	82	5	18
Total		68	67	28	41	12	18

Table IV. Amputation incidence for each treatment group for 68 IAPGIs in 67 patients

	Total (n = 68)		*Group A (n = 40)*		*Group B (n = 2)*		*Group C (n = 13)*		*Group D (n = 13)*	
Amputation	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Prior	16	24	15	38	0	0	1	8	0	0
Subsequent(s)	23	34	12	30	1	50	5	38	5	38
Level										
Above-knee	(12)	(52)*	(5)	(42)	(1)	(100)	(3)	(60)	(3)	(60)
Below-knee	(10)	(43)	(6)	(50)	(0)	(0)	(2)	(40)	(2)	(40)
Unknown	(1)	(5)	(1)	(8)	(0)	(0)	(0)	(0)	(0)	(0)

*Numbers in parentheses are subsequent amputations.

and two others presented with hemorrhage. Nonexcisional treatment was never successful for group D limbs, and all of these grafts eventually required complete excision for the control of sepsis. In situ revascularization with nonautogenous grafts was attempted on only two occasions (group B), but both required reoperation for infection.

This report includes only 10 IAPGIs for which standard cultures yielded no organisms (one infection) or *S. epidermidis* either alone (two infections) or in combination with other bacteria (seven infections). Consequently, only three of the 68 IAPGIs in our series (4%) were caused by a low-virulence pathogen, which either failed to grow in conventional culture media or consisted of *S. epidermidis* alone. Infection recurred in one patient who had no growth and who was treated with only local measures, but infection did not recur in two others who had growth of *S. epidermidis* and were treated with complete graft excision.

Twenty-three extremities required major amputations, including a hip disarticulation in one patient (Table IV). Twenty-three (44%) of the 52 limbs that were intact at the time IAPGI was discovered subsequently were amputated, 12 of these above the knee. Twenty-one of the 23 amputations were necessary within the first year after IAPGI was diagnosed. Some type of vascular reconstruction was attempted in 10 of the 52 intact limbs. Although only two (20%) of these required major amputations, compared with 19 (45%) of the 42 limbs for which no revascularization was performed, this difference did not achieve statistical significance ($p = 0.174$).

Eleven patients died within 30 days after their initial operations for IAPGI. One additional patient died of bleeding from a ruptured mycotic femoral pseudoaneurysm at the site from which an infected graft had been removed 35 days earlier, and this death also was considered to represent a related postoperative event. Therefore the postoperative mortality rate was 18% (12/67). Seven (58%) of the 12 early deaths were caused by uncontrolled sepsis or secondary hemorrhage (Table V). Two additional patients were lost to follow-up in the early postoperative interval. There were no fatal complications among the 16 patients with prior amputations, compared with twelve deaths (24%) within the group of 51 patients who had intact limbs at the onset of graft sepsis ($p = 0.056$). Fifteen (94%) of the 16 amputated limbs initially were treated by complete removal of the infected graft, but this approach was taken in only 25 (48%) of the 52 intact limbs ($p = 0.001$).

The results of treatment methods with respect to graft patency at the time of IAPGI discovery are summarized in Table VI. Only one IAPGI (3%) among 37 patent grafts was associated with prior amputation, whereas 14 infections (54%) occurring in 26 occluded grafts involved previously amputated limbs ($p < 0.001$). However, incomplete excision was associated with increased rates of reoperation for

Table V. Cause of death after surgical treatment of 68 IAPGIs in 67 patients

	Cause	*No.*	*%*
Early deaths (3-35 days)	Hemorrhage	5	42
	Sepsis/multisystem failure	2	17
	Congestive heart failure	2	17
	Gastrointestinal bleeding	1	8
	Stroke	1	8
	Acute kidney failure	1	8
Total		12	100
Late deaths (7 mo–28 yr)	Unknown	11	38
	Cardiac	10	35
	Cancer	3	10
	Stroke	2	7
	Aortic aneurysm	1	3
	Pneumonia	1	3
	Vasculitis	1	3
Total		29	100

Table VI. Summary of treatment results with respect to graft patency at the time of discovery of 68 IAPGI in 67 patients

						Amputation					
				Subsequent operation for sepsis		*Prior*		*Subsequent*		*Perioperative deaths*	
Graft status	*Excision method*	*n (IAPGI)*	*n (Patients)*	*No.*	*% (IAPGI)*	*No.*	*% (IAPGI)*	*No.*	*% (IAPGI)*	*No.*	*% (Patients)*
Patent	Complete	21	21	2	10	1	5	11	52	6	29
	Incomplete	16	16	12	75	0	0	7	44	4	25
Total		37	37	14	39	1	3	18	49	10	27
Occluded	Complete	17	16.5*	2	12	13	76	1	6	0	0
	Incomplete	9	8.5*	8	89	1	11	3	33	1	12
Total		26	25	10	38	14	54	4	15	1	4
Unknown	Complete	2	2	1	50	1	50	0	0	1	50
	Incomplete	3	3	3	100	0	0	1	33	0	0
Total		5	5	4	80	1	20	1	20	1	20

*One patient had two IAPGIs; one was completely excised and the other incompletely excised.

sepsis irrespective of graft patency at presentation, however (75% vs 10% for patent grafts, $p < 0.001$; 89% vs 12% for occluded grafts, $p = 0.0002$). The perioperative mortality rate was higher for patients presenting with patent grafts (27%) than for those with occluded grafts (4%) ($p = 0.038$).

The median follow-up interval for the remaining 53 patients who survived operation was 5 years (mean, 7.5 years; range, 50 days to 28 years). Twenty-nine patients died during this period, none of persistent sepsis (Table V). Cumulative Kaplan-Meier 5- and 10-year survival rates for all 67 patients in the entire series were 63% (SE = 6.4%) and 40% (SE = 7.4%), respectively. The corresponding actuarial survival rates for the 53 survivors of operation were 77% (SE = 6.4%) and 49% (SE = 8.6%), respectively (Fig. 2). The comparable 5-year life-table survival rate calculated for the normal male U.S. population at age 62 years is 89% (SE = 0.11%). The corresponding 5-year life-table survival rates calculated for survivors of operation (78%) and for the entire series (64%) are significantly less ($p < 0.0001$ for each comparison) than that of the normal, age-matched U.S. male population (89%).

DISCUSSION

The optimal management of IAPGI is problematic. Early diagnosis, at a time when treatment is most likely to be effective, is often difficult. Moreover, because the indications for the original graft often included limb-threatening ischemia, some type of alternative revascularization usually is necessary to avoid amputation, if the infected graft is not already occluded. As a practical matter, however, suitable autogenous conduits rarely are available, or they would have been employed during the original revascularization procedure. Treatment is further confounded by the variable biologic be-

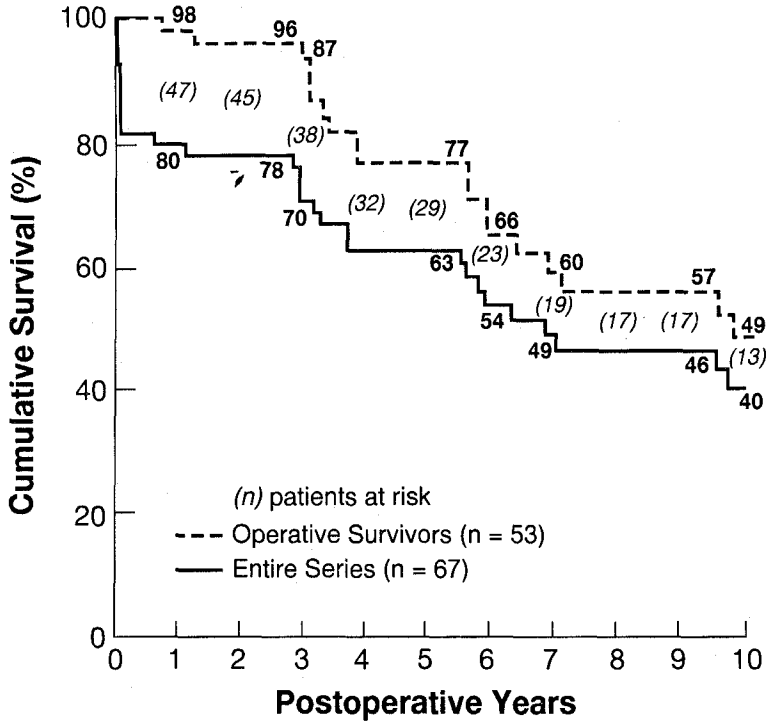

Fig. 2. Graphic representation of cumulative survival (Kaplan-Meier method) calculated for all 67 patients in entire series *(solid line)* and 53 survivors of operation *(dotted line)*.

havior of different pathogens that may colonize graft infections.[5,8,9,11,16-18]

Early attempts at nonresectional methods of management of IAPGI generally were disappointing. Recurrent infections with systemic sepsis, pseudoaneurysm formation, and anastomotic hemorrhage were common and could be encountered even late in the postoperative period.* Consequently, excision of the prosthetic material and either revascularization with autogenous tissue or the placement of a new synthetic graft in clean anatomic planes is now the preferred surgical approach at many centers.[2-4,21,22] Nevertheless, the mortality and morbidity rates associated with IAPGI have remained formidable despite aggressive therapy.[12,19,20] For this reason the fact that some authors have described successful results in selected patients with IAPGI without complete removal of the involved graft has attracted considerable attention.[6,8-11,13-16,20] Many of these reports comprise relatively small series of patients with limited follow-up; yet they appear to demonstrate that IAPGI occasionally may be confined to a glycoprotein biofilm coating the synthetic material that can be excised and successfully replaced with a new prosthetic graft in the same bed.[8,11,14,15,17] This is an important concept, but it may apply only to infections caused by organisms having intrinsically low virulence (e.g., *S. epidermidis*).

The increased rate of recurrent infection associated with incomplete graft excision in our series may reflect not only the advanced stages of graft infection among our patients at the time of treatment but also the practical difficulty in making the diagnosis of limited, nonvirulent IAPGI suitable for conservative treatment in the usual clinical setting. Our report concerns infections that were well established at the time of their initial treatment. Only three IAPGIs (4%) in our experience involved apparently low-virulence organisms. Two resolved after complete graft excision, but one recurred despite local care. Although the predominant pathogen in this series was *Staphylococcus* species, infections caused by gram-negative rods also were quite common and often occurred in the presence of mixed flora. Gram-negative IAPGIs are recognized to be more invasive than is the case with biofilm infections,[5,17] and because the interval from graft implantation to the diagnosis of IAPGI was only 3 months, the infections

*References 2, 3, 5, 12, 13, 19, and 20.

in our series were comparatively virulent. Furthermore, deep infection involving the arterial wall has been associated with an increased incidence of suture line disruption, and its undetected presence may have been a factor in the failure of incomplete excisional treatment in some of our patients.[9,22]

Conceding the liabilities of a retrospective study, we believe our experience with established IAPGI generally indicates that aggressive treatment provides better results, at least until more reliable diagnostic methods are available. The incidence of recurrent infection was significantly lower when complete graft excision was performed. The early postoperative mortality rate was 18%, but 58% of these deaths were related to uncontrolled sepsis. No perioperative deaths occurred among patients who presented with prior amputations, yet the early mortality rate was 24% for those patients who had intact limbs at the time they were discovered to have IAPGI. This difference may be related to the fact that 94% of the IAPGIs that occurred in amputated extremities were treated by complete graft excision, compared with about half of IAPGIs in the intact limbs. The 5-year life expectancy for survivors of operation was less than that of an age-matched, normal U.S. male population, suggesting that their long-term survival is probably compromised by other factors associated with systemic atherosclerosis even when the septic process is controlled. IAPGI is associated with a significant risk for limb loss, however. Nearly half (40%) of the intact limbs with IAPGI in our series required amputations within 1 year of diagnosis, and more than half of these were above the knee. Nevertheless, revascularization of the ischemic extremity at the time of treatment for IAPGI was rewarded with twice the limb salvage rate as was the case when revascularization either was not attempted or was not feasible.

Although incomplete graft excision may be acceptable for some carefully selected patients with IAPGI, we advise caution in its application. In addition to specific antibiotic therapy, we conclude that complete removal of all involved prosthetic material with adequate debridement of infected tissues is usually necessary for the management of established IAPGI. If the limb is severely ischemic after graft removal, autogenous revascularization should be attempted if at all possible. In the absence of autogenous material, extraanatomic bypass with another synthetic graft may be considered; but it becomes increasingly difficult if the original infected graft already extends below the knee. Incomplete graft removal has been only infrequently successful in our experience, and we believe it requires careful long-term surveillance for recurrent infection whenever it is attempted.

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DISCUSSION

Dr. Jonathan B. Towne (Milwaukee, Wis.). This paper demonstrates the high morbidity and mortality rates associated with lower limb graft infections. It appears to me that the study group actually represents three different groups of graft infections.

The first is early infections, which I define as occurring less than 3 months after the implantation of the graft and which are often, in my experience, related to wound healing complications in which coagulase-positive staphylococcus is a principal organism. Because in this series the mean time from insertion of the graft to occurrence of infection was 3 months, I suspect many of these patients fall into this group.

The second group is what I would call late infections. These infections usually are defined as occurring more than 3 months after the insertion of the prosthesis and often months and years later in the follow-up period. These are often graft biofilm infections caused by coagulase-negative staphlococci.

The third group is an interesting group. These infections occur in previously occluded grafts in limbs that had undergone a previous major amputation. In this group the question is what factor did the infection play in the overall scheme of things? I would like to know how many of those occluded grafts that became secondarily infected were related to wound healing complications that occurred at the time of the major amputation. It is our policy to do subtotal graft excisions in any patient on whom we do a major amputation. We dissect out the groin but go a little distal to the groin and remove the remainder of the graft.

The bottom line is to get some sense of the Cleveland Clinic's algorithm for treating these grafts. If you look at the data in this paper, only seven of the 40 patients who had complete excision had some sort of extraanatomic bypass. Because the amputation and mortality rates were incredibly high, we have to ask ourselves what should you do? When do you do a bypass? What do you bypass? And how often do you do a primary major amputation? Because the incidence of amputation in patients with an intact limb at the time of the infection was 44% and because the mortality rate was 18% in approximately half of these above-knee amputations, can you determine whether the surgical results have improved over the 34-year span of this study. For example, in the last 5 years, have the results improved, and to what do you attribute that improvement?

Dr. Patrick J. O'Hara. I have tried to determine why we cannot successfully treat grafts in situ or replace them in situ very often, because I believe it certainly would be a much easier thing to do. Part of our problem might be in correctly diagnosing low virulence infections. Considering the algorithm question first, among the grafts that were reported, the diagnosis of infection was very clear. Some grafts that were more mildly infected may have been missed, but the ones that were clearly infected and that had advanced infections at presentation were unlikely to have been helped without taking out the graft. As a result, usually we obtained arteriography and planned revascularization with autogenous or extraanatomic tissue ahead of time. Often the remaining options were very limited, which perhaps might account for our amputation rate. The 40% figure for amputation seems to be fairly constant, at least in reports of infrainguinal graft infection.

I tried to analyze the data to determine whether our results have improved over time. However, this is a retrospective study. The study interval—35 years—was very long, and the numbers, although substantial, are still small. The result is that we could not demonstrate a difference. I suspect the high morbidity and mortality rates reflect the small number of patients with serious problems.

Concerning the subgroup of patients with infections related to previous amputations, most of these probably were secondarily infected at the time of amputation. Because 52 of the 68 patients had previously intact limbs, the amputation group is a relatively small subset.

Dr. Bhagwan Satiani (Columbus, Ohio). I notice that you also included the exposed grafts. I wonder if you would separate the treatments by exposed grafts versus infected grafts. Exposed grafts are usually infected early on, when wound separations occur, typically in obese patients with diabetes. Would you recommend leaving such grafts and treating them with local coverage (versus an infected graft with gross purulence and positive cultures, etc.)?

Dr. O'Hara. We have done what you have proposed only rarely. When we have tried to rotate flaps over such grafts, they have often become infected. I believe our study should be viewed as a cautionary note in such situations. I

also think that, if this is attempted, the patient deserves very close long-term follow-up because recurrence of infection is not uncommon in such situations.

Dr. Kevin James (Cincinnati, Ohio). Some recent reports have documented good results with rotational muscle flaps and long-term administration of antibiotics. Was muscle flap coverage and prolonged antibiotic therapy part of your local treatment, and if so, was your choice of treatment based on the type of infection, that is, gram-negative versus gram-positive infections?

Dr. O'Hara. Again, we tried your method over a long period of time, in a relatively few patients. I think 13 were in one group and two were in another group. We were unsuccessful, and unable to figure out why. Part of the reason may be that we saw a high incidence of gram-negative infections and staphyloccal infections, and were unable to make the diagnosis of low virulence infections well or early enough to discern which grafts we could treat in situ.

Dr. Mark Adams (Milwaukee, Wis.). Have you ever considered using fresh cadaveric artery to replace segments that are infected or prostheses that you remove? It is not that difficult to get these days, and I do not think immunosuppression is necessary because the short duration of time that you would need it, such as to substitute for autogenous vessel.

Dr. O'Hara. No we have not, and I appreciate the recommendation.