SURGERY FOR ADULT CARDIOVASCULAR DISEASE

CRYOPRESERVED ARTERIAL ALLOGRAFTS IN THE TREATMENT OF MAJOR VASCULAR INFECTION: A COMPARISON WITH CONVENTIONAL SURGICAL TECHNIQUES

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Objective: Recent findings with cryopreserved heart valve allografts in the treatment of infectious endocarditis suggest that the use of cryopreserved arterial allografts may improve the outcome in patients with vascular infections. **Methods:** Seventy-two patients with mycotic aneurysms (n = 29) or infected vascular prostheses (n = 43) of the thoracic (n = 26) or abdominal aorta (n = 46) were treated with in situ repair and extra-anatomic reconstruction using prosthetic material (n = 38) or implantation of a cryopreserved arterial allograft (n = 34). Disease-related survival and survival free of reoperation were assessed. Morbidity, cumulative lengths of intensive care, hospitalization, antibiotic treatment, and costs were calculated per year of follow-up. **Results:** The use of cryopreserved arterial allografts was superior to conventional surgery in terms of disease-related survival ($P = .008$), disease-related survival free of reoperation ($P = .0001$), duration of intensive care per year of follow-up (median 1 vs 11 days; range 1 to 42 vs 2 to 120 days; $P = .001$), hospitalization (14 vs 30 days; range 7 to 150 vs 15 to 240 days; $P = .002$), duration of postoperative antibiotic therapy (21 vs 40 days; range 21 to 90 vs 60 to 365 days; $P = .002$), incidence of complications (24% vs 63%; $P = .005$), and elimination of infection (91% vs 53%; $P = .001$). In addition, costs were 40% lower in the group treated by allografts ($P = .005$). **Conclusions:** The use of cryopreserved arterial allografts is a more effective treatment for mycotic aneurysms and infected vascular prostheses than conventional surgical techniques. (J Thorac Cardiovasc Surg 1998; 116:965-72)

The treatment of mycotic aneurysms and infected vascular prostheses is one of the most challenging problems in cardiovascular surgery. Although a variety

of treatment modalities have been developed and overall results have improved in recent years, mortality rates of up to 50% and amputation rates of up to 60% are reported.^{1,2} Conventional procedures usually encompass prosthetic in situ repair or complete removal of infected parts of the vessel or the infected prosthesis and reconstruction with an extra-anatomic bypass graft. Both techniques are associated with distinct technical problems and considerable mortality and morbidity resulting from reinfection and suture line problems leading to multiple reoperations and prolonged antibiotic treatment.

The use of fresh vascular allografts was first reported 50 years ago.³ However, because of their high rate of thrombosis, spontaneous rupture, and formation of anastomotic aneurysm, allografts were considered

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Table I. Preoperative patient data (1990-1996; n = 72)

	Homograft		Prosthesis		P value
	No.	%	No.	%	
Age (yr)					
Median	61		63		.8
Range	40 to 85		48 to 81		
Mycotic aneurysm	16	47	13	34	
Infected vascular prosthesis	18	53	25	66	.3
Thoracic aorta	12	35	14	37	
Abdominal aorta	22	65	24	63	.9
Preoperative sepsis	24	71	20	53	.12
Positive blood culture	24	71	10	26	.001
Preoperative antibiotic therapy	27	79	13	34	.001
<i>Mycobacterium tuberculosis</i> , fungi, or multidrug-resistant bacteria	8	24	9	24	.99
Peripheral arterial vascular occlusion	22	65	13	34	.01
Atrial fibrillation	7	21	2	5	.05
Renal insufficiency	6	18	14	37	.07
Chronic obstructive lung disease	20	59	18	47	.3
Diabetes mellitus	10	29	12	32	.8
Serum creatinine ($\mu\text{mol/L}$)	127 $\pm$ 74		127 $\pm$ 90		.99
Coronary artery disease	20	59	19	50	.4
Emergency surgery	21	62	27	71	.4

unsuitable to serve as vascular substitutes.⁴ In recent years, excellent results in the treatment of infectious endocarditis have been obtained with cryopreserved allograft valves.⁵ In addition, the long-term performance of cryopreserved allograft heart valves proved to be markedly superior to freshly implanted allograft valves.⁶ This led us to use cryopreserved arterial allografts for in situ repair in patients with major vascular infection.⁷ Although the initial results were promising, experience with this new technique is limited^{7,8} and direct comparison with conventional surgery has not been performed.

We compared the use of cryopreserved arterial allografts with in situ repair and extra-anatomic reconstruction using prosthetic material in the treatment of mycotic aneurysms and infected vascular prostheses of the thoracic or abdominal aorta that were implanted between 1990 and 1996 at our institution.

Methods

Patients. Seventy-two patients (Table I) with mycotic aneurysms (n = 29) or infected vascular prostheses (n = 43) of the thoracic (n = 26) or abdominal aorta, with (n = 24) or without (n = 22) pelvic or groin vessel involvement, were treated either with conventional surgery (n = 38) or with implantation of a cryopreserved arterial allograft (n = 34). Median age was 62 years (range 40 to 85 years). Surgery was performed urgently within 24 hours after admission in 46 patients (64%), within 3 days in 18 (25%), and electively in 8

(11%). Twenty-five patients (35%) had fistulas from the aorta to different organs: 8 to bronchi, 5 to the esophagus, 11 to intestines, and 1 to the urinary tract. Forty-six patients (64%) had previously received antibiotic therapy; of these, 61% had received multiple antibiotics.

Patients treated by implantation of allografts had more frequent peripheral arterial vascular disease and atrial fibrillation than the conventionally treated group. In addition, patients with an allograft were more likely to have had positive blood culture and to have received antibiotic therapy before the operation.

Selection of vascular graft. The procurement of arteries from organ donors and the cryopreservation of vascular segments similar to the technique used for heart valve allografts was first started in 1990. Thus availability of cryopreserved allografts was limited in the early phase of this report. Although not randomized, the selection of the surgical technique was dependent only on the presence of a cryopreserved allograft and not on the preoperative status of the patient. After 1994, procurement of allografts, subject to the usual organ donor shortage, became familiar and allografts were implanted more often than prostheses. Hence patients with conventional treatment have a median follow-up time of 34 months (range 10 to 84 months), whereas patients with allografts have a median follow-up time of 24.5 months (range 10 to 83 months) ($P > .2$).

Operative technique. The preparation of allografts and the operative technique have been described in detail.^{7,9} In brief, arteries were procured from organ donors who fulfilled heart valve selection criteria according to the European standards for cryopreserved heart valve allografts.¹⁰ The arteries were

prepared in the European Homograft Bank, Brussels, Belgium, where they were decontaminated, dipped in ice-cold cryoprotective solution (10% dimethylsulfoxide), frozen in liquid nitrogen to -100°C , and stored in the vapor phase of liquid nitrogen at -180°C . The grafts were thawed immediately before implantation.

For infection of the ascending aorta and aortic arch, a median sternotomy was made; cardiopulmonary bypass, cold blood cardioplegic solution, and, if indicated, deep hypothermic circulatory arrest (16°C) and retrograde cerebral perfusion were used. The descending aorta was approached through a left posterior thoracotomy. Partial venoarterial bypass at moderate hypothermia (30°C) was instituted via the left groin vessels. A standard midline incision was made in patients with mycotic aneurysms of the abdominal aorta and a retroperitoneal approach was used to replace infected infrarenal prosthetic grafts.

Mycotic aneurysms or infected grafts were excised, and the allografts were inserted end to end to the normal aorta with the use of single, running polypropylene sutures. Extended periaortic, perigraft, mediastinal, or chest wall debridement was not performed. Neither viable tissue such as omentum or muscle flaps nor autologous arteries or veins were used; if buttressing was necessary, additional allograft tissue was used.

The conventional surgical techniques comprised in situ reconstruction ($n = 20$) with a new vascular prosthesis or removal of infected vascular sections or graft material together with extra-anatomic bypass grafting ($n = 18$).

Intraoperative findings. Despite the higher incidence of preoperative antibiotic therapy, pus was visible during the operation in 11 patients (32%) in the allograft group but in only 4 patients (11%) in the conventional surgery group ($P = .04$). The types of infectious agents could be identified in 59 patients (82%) and did not differ between the 2 groups. In 13 of 59 patients (22%), 2 or more responsible agents could be found (Table II). Fistulas from the aorta to esophagus, bronchi, bowels, and urinary tract were equally frequent, 35% in the allograft group and 34% in the conventional surgery group.

Patients in the allograft group were more likely to receive bi-iliac anastomoses, 17 of 22, whereas 17 of 24 patients in the conventionally treated group had extra-anatomic bypass grafts requiring bifemoral anastomoses ($P = .001$).

Clinical assessment and follow-up. Medical history was derived from reports from the referring hospitals and our institution. Blood cultures were taken and the usual hematologic and clinical indices of infection were determined before and after the operations. Intraoperatively, appropriate culture media for aerobes, anaerobes, fungi, and mycobacteria were taken. Location and extent of infection, as well as presence of fistulas, were noted. Rapid Gram staining was performed in all. Duration of artificial respiration, time in intensive care, hospitalization, and the postoperative use of antibiotic therapy were assessed and cumulatively calculated for the entire follow-up time. In addition, perioperative mortality (mortality within 30 days after the operation or within the same hospitalization), disease-related survival, and survival free from

Table II. Frequency of responsible infectious agents in patients with major vascular infection (1990-1996; $n = 72$)

Infectious agent	Homograft	Prosthesis
<i>Staphylococcus aureus</i>	12	10
<i>Staphylococcus</i> , coagulase negative	5	3
<i>Streptococcus pneumoniae</i>	1	5
<i>Pseudomonas aeruginosa</i>	1	3
<i>Enterococcus</i>	1	2
<i>Escherichia coli</i>	2	4
<i>Candida albicans</i>	3	—
<i>Candida parapsilosis</i>	1	2
<i>Aspergillus fumigatus</i>	2	—
<i>Mycobacterium tuberculosis</i>	2	—
<i>Propionibacterium acnes</i>	1	5
<i>Salmonella typhi</i>	3	—
<i>Treponema pallidum</i> *	—	2

**Treponema pallidum* was detectable in aortic tissue; both patients had concomitant superinfection with coagulase-negative *Staphylococcus*.

reoperation were assessed. Disease-related survival was defined as survival free from perioperative death or death during follow-up resulting from recurrence of infection, reoperation, or graft-related complications. Patients were followed up yearly by the referring physician, the referring hospital, and/or by our institution. At the end of follow-up, 87% of patients treated by implantation of allografts were followed up by magnetic resonance imaging angiography ($n = 15$), computed tomography ($n = 7$), conventional angiography ($n = 7$), or transesophageal echocardiography ($n = 7$).

In addition, approximate costs per patient for the operation, anesthesia, hospitalization, and antibiotic therapy were cumulatively calculated, time-adjusted for the differences in follow-up, and compared between the two groups per day of hospitalization. Immunohistochemical examinations of explanted allografts were available in 3 of 4 patients who had died.

Postoperative antibiotic treatment. Patients with allografts received postoperative intravenous antibiotic treatment for 4 to 6 weeks, based on the experience gained with the use of cryopreserved valve allografts in the treatment of aortic valve endocarditis.¹¹ In addition, patients with difficult-to-treat infectious agents, eg, mycobacteria or fungi, had oral antibiotics for 3 months ($n = 6$). None of the patients received long-term or life-long antibiotic treatment.

Patients with conventional surgical therapy were treated with intravenous antibiotics for 6 weeks, followed by oral antibiotics for 3 months in case of negative and 6 months in case of positive arterial wall culture findings.¹² For high-risk patients oral suppressive antibiotics were recommended indefinitely ($n = 4$).¹³ For statistical purposes, indefinite postoperative antibiotic treatment was defined as treatment for 365 days.

Explant studies. Explanted cryopreserved allografts were studied by macroscopic, histologic, and immunohistochemical examinations. Hematoxylin-eosin and van Gieson elastin

Table III. Postoperative course in patients with major vascular infection (1990-1996; *n* = 72)

	Homograft		Prosthesis		P value
	No.	%	No.	%	
Thirty-day mortality	2	6	7	18	.12*
Total surgery or infection-related mortality	4	12	12	32	.008†
Reoperation	3	9	17	45	.001†
Infection completely eliminated	31	91	20	53	.001‡
Postoperative sepsis	6	18	15	40	.05*
Tracheotomy required	2	6	10	26	.05*
Postoperative hemofiltration	1	3	10	26	.01*
Secondary wound closure	3	9	16	43	.005*
Time on respirator postoperatively (d)§					
Median		0.4		4.5	
Range		1-28		2-60	.001
Time in intensive care unit (d)§					
Median		1		11	
Range		1-42		2-120	.002
Duration of hospitalization (d)§					
Median		14		30	
Range		7-150		15-240	.02
Duration of postoperative antibiotic therapy§					
Median		21		40	
Range		21-90		60-365	.002

*Two-tailed Fisher's exact test.

†Cox regression analysis, adjusted for dissimilarities between the 2 groups.

‡Kaplan-Meier analysis.

§Cumulative duration per year of follow-up.

||Mann-Whitney U test, adjusted per year of follow-up.

stains were used. Gram staining was used to detect bacterial invasion. Immunohistochemical techniques were performed to differentiate inflammatory cells: CD45 for leukocytes, CD45RO, CD3, and CD43 for T-cell lymphocytes, CD20 for B-cell lymphocytes, and CD68 for macrophages. Results were compared with immunohistochemical examinations of nonimplanted and explanted cryopreserved valve and vascular allografts.^{9,11}

Statistical analyses. Data are presented as median (range) and as frequencies (percent). Categorical data were assessed by means of the Pearson χ^2 test or Fisher's exact test to compare preoperative patient data and postoperative complications of all patients unrelated to the follow-up time. Continuous data were compared by means of the Mann-Whitney U test and were time-adjusted per year of survival. Disease-related survival, survival free of reoperation, and the persistence of complete elimination of infection were calculated by means of Kaplan-Meier analysis; the log-rank test was used to compare groups. Hazard ratio for disease-related survival and disease-related survival free of reoperation was assessed by univariate Cox regression analysis adjusting dissimilarities between the 2 groups. The assumption of proportional hazards was assessed graphically by log minus log survival plots. A stepwise Cox regression analysis was performed to assess independent predictors of outcome including all preoperative patient data (Table I) differing between groups by at least $P < .1$. All calculations were performed with the use of the statistical package SPSS for Windows 6.0 (SPSS, Inc, Chicago, Ill).

Results

Mortality, survival, and reoperation. Nine deaths occurred in the perioperative period, 7 in the prosthesis group (18%) and 2 in the allograft group (6%). The 30-day mortality tended to be lower in the group treated by allografts ($P = .15$) because of the lower perioperative morbidity (Table III), as discussed below. During the follow-up time, 3 patients in the allograft and 2 in the conventional surgery group died of causes unrelated to infection, surgery, or vascular grafts and 2 patients in each group were lost to follow-up, all patients being free of infection at the latest time of contact. Including perioperative deaths, there were 4 disease-related deaths in the allograft group (12%) and 12 in the conventional surgery group (32%) during the entire period of observation. Thus for the conventional surgery group the hazard ratio for disease-related death, adjusted for dissimilarities between groups, was 10.2 (95% CL 3.3–24.3; $P = .008$). In addition, conventionally treated patients had a worse disease-related survival free of reoperation ($29\% \pm 9\%$ vs $79\% \pm 7\%$) (Fig 1), with an adjusted hazard ratio for disease-related reoperation during the follow-up time of 16.8 (95% CL 6.8–38.3; $P = .0001$) (Table III).

To determine whether operative technique was an independent predictor for disease-related survival free

Fig 1. Disease-related survival free of reoperation for patients with major vascular infection, treated either by implantation of cryopreserved arterial homografts or by conventional surgery (1990 to 1996; $n = 72$).

Table IV. Univariate and multivariable risk factors for infection-related survival free of reoperation in patients with major vascular infection (1990-1996; $n = 72$) adjusted for dissimilarities between groups (Table I)

	Univariate			Multivariable		
	HR	95% CI	P value	HR	95% CI	P value
Conventional surgery	4.1	1.7-10.0	.005	4	1.6-9.9	.005
Abdominal operation	2.6	1.0-6.4	.05			
Mycotic aneurysm	0.3	0.1-0.8	.05			
Previous operation	3	1.2-7.3	.05			
No. of infected grafts	1.3	1.06-1.6	.05	1.3	1.05-1.7	.05

HR, Hazard ratio; CI, confidence interval.

of reoperation, we introduced preoperative patient data (Table I), differing by a P value $< .1$, into multivariable Cox regression analysis (Table IV). Surgical technique proved the most important risk factor for reoperation (hazard ratio 4.03; 95% CL 1.63-9.92; $P = .005$). The number of infected grafts was the only other variable independently related to this end point (hazard ratio 1.34; 95% CL 1.05-1.72; $P = .05$).

Morbidity. For the entire period of observation, the cumulative duration of artificial ventilation, the time in the intensive care unit, and the duration of hospitalization and antibiotic treatment, time-adjusted per year of survival, were shorter in the allograft group than in the group treated by conventional surgery (Table III). The cumulative incidence of sepsis, need for tracheotomy, hemofiltration, and secondary wound closure were lower in the allograft group, whereas the percentage of persistence of infection was higher in the conventionally treated group ($P = .001$).

Fate of the allograft. Two late allograft-related deaths occurred 10 and 18 months after implantation. Both patients, an 86-year-old man and an 83-year-old woman,

died of an allograft-duodenal fistula with evidence of persistent *Candida albicans* infection in 1. Neither allograft aneurysm, perivascular exudation, unusual scar formation, nor intraluminal mural thrombi could be detected during the follow-up time. One patient had progressive stenosis of an allograft at the descending thoracic aorta after 18 months, which was successfully relieved by percutaneous vascular stent placement.

Immunohistochemical examinations. Explanted cryopreserved allografts were acellular and nonvital, with total desquamation of the endothelial layer, and all showed nonspecific low-grade inflammation and B-cell lymphocyte infiltration. Macrophages or Langerhan's cells could not be found in explanted allografts, and T-cell lymphocytes were identified in only 1. The collagen framework and the glucose-amino-glycan matrix was intact in all, whereas the elastic fibers of the media were partly fragmented.

Costs. The manufacture of allografts is approximately as expensive as that of vascular prosthesis. Considering the charges for anesthesia, surgery, intensive care, use of antibiotics, and hospitalization, the cumulated median

costs in the conventional surgery group were \$392,000 (range \$89,000 to \$580,000) versus \$58,000 (range \$55,000 to \$160,000) in the allograft group ($P < .001$). Thus the time-adjusted median average was \$2000 per day of follow-up for patients treated by allografts and \$3319 for those treated by conventional surgical technique ($P = .005$).

Discussion

The use of cryopreserved arterial allografts provides a safer, cheaper, and more effective treatment for mycotic aneurysms and infected vascular prostheses than conventional surgical techniques. In particular, patients with persistent infection of a previously implanted prosthesis benefit from this procedure.

In situ repair of prostheses is associated with suture line problems and recurrence of infection,^{1,2} and remote extra-anatomic bypass grafts have a lower patency rate than anatomic reconstruction¹⁴ and are associated with the risk of aortic stump blowout.¹⁵ Moreover, despite improvements in surgical techniques and long-term antibiotic therapy,^{16,17} the disappointing results in the treatment of aortic fistulas communicating with the lung, the bowel, or the esophagus have not improved consistently in the 40 years since the problem was recognized.^{18,19} Hence alternative techniques have been sought to overcome these shortcomings.

The root replacement technique for destructive aortic endocarditis, which encompasses the replacement of the proximal part of the ascending aorta—a combined valvular and vascular in situ repair—has occasionally resulted in improved survival, reduced reinfection rates, and decrease in the requirement for postoperative antibiotics as compared with the use of mechanical heart valve prostheses.^{5,11,20} These findings have awakened interest in the use of cryopreserved arterial allografts in patients with major vascular infections.

The current study compares for the first time implantation of cryopreserved arterial allografts with in situ repair and extra-anatomic reconstruction using prosthetic material for the treatment of mycotic aneurysms and infected prosthetic grafts. The results show that the use of allografts requires fewer reoperations to eliminate the vascular infection, which is associated with a lower incidence of complications and, hence, shorter cumulated duration of intensive care, hospitalization, and antibiotic therapy. Despite the higher preoperative risk regarding preoperative sepsis, positive blood cultures, incidence of peripheral arterial occlusive disease, and atrial fibrillation, disease-related survival was higher in the allograft group, stressing the effectiveness of allografts in the eradication of major vascular infection. Patients with implantation of a vascular prosthesis,

although treated according to the current recommendations,^{12,13} had a higher percentage of persistence of infection during the follow-up despite the lesser extent of infection and the more extensive use of postoperative antibiotics. In addition, implantation of cryopreserved arterial allografts was highly cost effective.

Several reasons may be cited for this improved outcome. The most important one is that cryopreserved arterial allografts seem to be resistant to bacterial infections. Possible explanations for this finding are release of antibacterial substances by the graft, the physicochemical properties of the allograft wall, or responses by the recipient's immune system.²¹ Graft viability early after implantation may also be important, possibly allowing antibiotic drugs and immunocompetent cells to diffuse into the allograft, thereby contributing to the defense of the vasculature against bacterial invasion of the arterial wall and the periarterial environment.^{22,23}

In the past, several investigators reported on their experience with fresh vascular allografts.^{3,4} Szilagyi and associates⁴ found a high complication rate (eg, spontaneous rupture, thrombosis, and late aneurysm formation) with fresh vascular allografts. As a result, their use was abandoned for more than 20 years in favor of artificial prostheses. The difference between fresh and cryopreserved arterial allografts may be explained by several mechanisms.^{6,24} The breakdown of freshly implanted allografts is accompanied by a strong immunologic rejection reaction with infiltration of plasma cells and macrophages. This reaction gives rise to progressive degeneration of the elastic fibers and collagen connective tissue, leading to rarification of the tissue and necrosis.²⁵ The result is a loss of mechanical resilience in the freshly implanted allograft accompanied by dilatation, aneurysm formation, and eventually rupture. Indeed, this is exactly the same mechanism that leads to aneurysm formation and rupture in the autologous aorta. A similar course of degeneration is seen in vascular allografts that have been stored at 4°C after treatment with antibiotics.^{6,26} By contrast, cryopreserved allografts showed less infiltration with immunocompetent cells, as supported by our limited explant studies, substantiating the contention that fresh allografts are more antigenic than cryopreserved grafts. Moreover, the addition of a cryoprotectant such as dimethyl sulfoxide has been demonstrated to further reduce the antigenicity of allografts.²⁷

In addition, the preservation of the collagen framework, glucose-amino-glycan matrix, and the elastic fibers of the media seem to form a digestion-resistant barrier that protects the allograft from autogenic lysis and renders it relatively immunologically inert, providing the basis for the greater mechanical strength of cryo-

preserved as compared with fresh vascular allografts.^{28,29} This is consistent with the promising midterm results of our cryopreserved arterial allografts, as well as with the observed long-term maintenance of cryopreserved heart valve allografts.⁶

In conclusion, the use of cryopreserved arterial allografts demonstrates an improved disease-related survival in patients with major vascular infection. Larger clinical studies and a longer follow-up time are necessary to confirm these results. Even though durability of allografts is limited, eradication of infection presumably would enable patients to undergo replacement of the allograft with a prosthesis with a lower risk of reinfection at a later time. However, successful initial control of infection, a prerequisite for survival, is best achieved with cryopreserved arterial allografts.

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Discussion

Dr Tirone E. David (Toronto, Ontario, Canada). We are indebted to Dr Vogt and his associates from Zurich for presenting this information on the management of mycotic aneurysms and infected Dacron grafts in the thoracic and

abdominal aorta. Infections in prosthetic grafts are a dreadful complication of surgery and we should always take all measures to prevent them. Unfortunately, such complications occur even in the hands of surgeons who adhere scrupulously to aseptic techniques.

Although we have extensive experience with aortic root abscess in patients with active endocarditis and prosthetic valve endocarditis, our experience with infection in the descending thoracic aorta is more limited. We have done only 8 operations in the past 20 years. Three of the patients had infected grafts and 5 had mycotic aneurysms of the descending thoracic aorta. I do not like operating on these patients and hope I never need to again. However, in all 8 of the patients I operated on, I was able to cure the infection with conventional surgery. I have never used homografts, as you have described.

I firmly believe that extensive debridement of all necrotic and chronically inflamed material is the most important component of these operations. Although we agree that anatomic reconstruction of the aorta is preferable to extra-anatomic bypass, this is not possible in every case. At least it was not possible in all my cases. I was forced to do an extra-anatomic bypass because of the extension of the infection. Finally, in every one of my cases I used a living patch, such as a muscular pedicle or omentum, to cover the area that was infected.

Dr Vogt's data suggest that use of the aortic homograft is better than conventional surgery. That leads me to a few questions.

Do you believe that the 2 groups of patients are comparable? Although the number of patients is small for computing statistical differences, the group who had conventional surgery had a higher preoperative proportion of infected grafts as opposed to mycotic aneurysms and a higher incidence of preoperative renal failure—2 major determinants of operative outcomes.

Second, did you manage to implant the homograft in the anatomic position in all cases, or did you use the homograft in the easier cases and simply ligate the aorta and perform an extra-anatomic bypass in the more complex ones? Those

patients are obviously much sicker than those in whom you can insert a graft in the anatomic position.

Last, you showed that the rate of freedom from reoperation was much higher in the homograft group, but were the patients similar? Were the reoperations the result of complications of extra-anatomic bypass?

Dr. Vogt. Thank you, Dr David, for your kind comments. During the last 3 to 4 decades, more than 1 generation of vascular surgeons have been involved in the treatment of major vascular infections. We cannot assume that the extent of the debridement of necrotic and inflamed material has been their only problem. I think extensive debridement is important, but not the only solution for major aortic infection. Other points help to determine the outcome after vascular infection, such as the properties of the prosthetic graft compared with the homograft wall or the local effectiveness of the perioperative antibiotic treatment on the perigraft space.

Besides the classic aortic stump blowout syndrome, a major cause of late death, in situ repair with the use of homografts also prevents reinfection of extra-anatomic bypass grafts, which occurs in up to 20% of patients. We did not perform any extra-anatomic bypass grafts during this period of observation if a homograft was available. Selection of the operative technique was determined only by the availability of a homograft. Thus the patients of the 2 groups are comparable.

Moreover, in the group treated with homografts, 18 patients, mostly referred in the last 2 to 3 years, had persistence of their vascular infection despite a history of 27 infection-related operations. All 18 patients became free from infection after 1 operation using cryopreserved vascular homografts.

The use of homografts has several advantages as described. I think a decrease of the total disease-related mortality has not yet been proved only because of the small number of patients. However, the number of reoperations, as well as overall costs, is effectively reduced. For us, the cryopreserved arterial homograft is the substitute of choice in the surgical treatment of major aortic infection.