Cryopreserved arterial allograft reconstruction for peripheral graft infection

Yves Castier, MD,a Fady Francis, MD,a Pierre Cerneau, MD,a Mathieu Besnard, MD,a Jérome Albertin, MD,a Laurent Foulhe, MD,a Olivier Cerneau, MD,a Pierre Albaladejo, MD,a and Guy Lesèche, MD,a

Clichy, France

Objective: This prospective, observational study evaluated the safety and efficacy of cryopreserved arterial allograft reconstruction in the management of major peripheral arterial graft infections.

Methods: From April 1996 to May 2003, data from patients with major peripheral arterial graft infection who underwent graft excision and cryopreserved arterial allograft reconstruction were prospectively collected. Arterial allografts were harvested from multiple organ donors and cryopreserved at −80 °C. The patients were observed for survival, limb salvage, persistence or recurrence of infection, and allograft patency. The results were calculated with the Kaplan-Meier method.

Results: During the 7-year study period, 17 patients (14 men, 3 women; mean age, 68 years) with major peripheral graft infection underwent graft excision and cryopreserved arterial allograft reconstruction. Eight patients (47%) had systemic sepsis, 5 (29%) had acute ischemia at the time of the allograft reconstruction, and 9 (53%) had experienced anastomotic rupture. Allograft reconstruction was performed as an emergency procedure in 7 patients (41%). There were no perioperative deaths or early amputations. Two patients had allograft ruptures in the groin during the early postoperative period. The mean follow-up period was 34 months (range, 8 to 80 months). There was no persistent or recurrent infection, and none of the patients received long-term (>3 months) antibiotic therapy. Reoperation for allograft revision, excision, or replacement was performed in 2 patients. The 18-month primary and secondary allograft patency rates were 68% and 86%; the overall limb salvage rate was 82% at 2 years.

Conclusion: Our experience with cryopreserved arterial allograft in the management of major peripheral bypass graft infection suggests that this technique seems to be a useful option for treating one of the most dreaded vascular complications. (J Vasc Surg 2005;41:30-7.)

Major peripheral arterial graft infection is an uncommon but severe and potentially devastating complication of vascular surgery that is associated with significant mortality and high amputation rates.1-3 The basic goal of therapy in patients with lower-extremity graft infection is to eradicate infection and maintain adequate perfusion. Radical excision of infected perioperative tissue is the recommended treatment to eradicate infection and is mandatory in cases of systemic sepsis, anastomotic disruption, or graft occlusion.4-8 Autologous saphenous veins are considered the best arterial substitute for lower-extremity revascularization in infected fields, but they are often unavailable or unsuitable in these patients.6

Having been faced with this dilemma and encouraged by good long-term results obtained with cryopreserved arterial allograft reconstructions in infected prosthetic grafts and mycotic aneurysms of the abdominal aorta,7,8 we investigated cryopreserved arterial allografts in the management of major peripheral arterial graft infection. This prospective observational study evaluated the safety and efficacy of cryopreserved arterial allograft reconstruction in the latter indication. The main variables studied were patient survival, freedom from persistent or recurrent infection, allograft patency, and avoidance of major amputation.

PATIENTS AND METHODS

From April 1996 to May 2003, data from patients with major peripheral bypass graft infection treated by graft excision and cryopreserved arterial allograft reconstruction in the Department of Vascular and Thoracic Surgery at our institution were prospectively collected. These data included demographics, atherosclerotic risk factors, original procedures, modes of presentation, surgical details, perioperative morbidity, and bacteriologic findings.

The diagnosis of peripheral bypass graft infection was made using clinical criteria, ultrasound scanning, computed tomographic scanning, and bacteriology tests. Indications for graft excision were systemic sepsis, disrupted anastomosis (infected pseudoaneurysm or hemorrhage), graft occlusion, infection due to virulent gram-negative organisms, infection of the entire graft, or a combination of these criteria.

The decision to perform revascularization in patients whose limbs were salvageable and whose vessels could be reconstructed was made on indication for initial peripheral bypass grafting, clinical presentation at the time of allograft reconstruction, and arteriographic findings. A cryopreserved arterial allograft was used after first considering revascularization with autologous greater saphenous veins.
Surgical technique. Bacteriologic culture tests were performed on the perigraft fluid and the infected graft. Wounds were carefully excised to obtain macroscopically normal tissue. To make sure that all infected involved tissue was completely resected, the anastomotic and perianastomotic regions were dissected and exposed thoroughly during surgery.

Dissection of popliteal and tibial arteries was restricted to the presenting aspect only, with no circumferential dissection and without the use of arterial clamps (Esmarch bandage). The arterial allografts were implanted using polypropylene sutures for proximal and distal anastomoses. The allograft was tunneled using the previous pathway (in situ) or a new pathway, depending on the location of the sepsis. To allow close surveillance, the arterial allograft was routed subcutaneously when possible.

Once reconstruction had been completed, arteriography was routinely performed when the allograft extended into an infrageniculate outflow site, any technical errors or problems were corrected immediately, and another radiograph was taken to confirm a satisfactory situation. All incisions were drained, and the skin was closed primarily in all cases. Fasciectomy was routinely performed in patients who presented with acute limb ischemia.

Arterial allograft. Harvesting, preservation, and preparation of allografts have been previously described.8,9 Arterial allografts (aortic bifurcation, iliac, femoral, and popliteal arteries) were carefully harvested from brain-dead multiple-organ donors. Informed consent was given by the donor’s family, in accordance with French law. Bacteriology and virology tests were performed for all donors.

After harvesting, arterial allografts were flushed with heparinized saline solution to eliminate any residual intraarterial blood and stored at 4 °C in M199 medium (Gibco Laboratories, Gaithersburg, Md) containing gentamicin (0.50 mg/mL) and amphotericin B (0.25 mg/mL). The delay before freezing did not exceed 18 hours in all cases. Cryopreserved arterial allografts were ABO compatible with the recipient in 14 patients (82%) and mismatched in 3 patients. None of the patients received immunosuppression therapy.

Table I. Clinical characteristics of the 17 patients with peripheral graft infection

<table>
<thead>
<tr>
<th>Clinical characteristics</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>68 ± 8.75</td>
</tr>
<tr>
<td>Range</td>
<td>50-83</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>14 (82)</td>
</tr>
<tr>
<td>Female</td>
<td>3 (18)</td>
</tr>
<tr>
<td>Cigarette smoking</td>
<td>14 (82)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>12 (70)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>5 (29)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>9 (53)</td>
</tr>
<tr>
<td>Cerebrovascular event</td>
<td>2 (12)</td>
</tr>
<tr>
<td>Obesity</td>
<td>3 (18)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>4 (23)</td>
</tr>
<tr>
<td>Malignancy</td>
<td>1 (6)</td>
</tr>
<tr>
<td>Steroid use</td>
<td>1 (6)</td>
</tr>
<tr>
<td>Malnutrition‡</td>
<td>3 (18)</td>
</tr>
</tbody>
</table>

‡Malnutrition was defined as recent weight loss of greater than 15% body weight, a body weight below ideal body weight by at least 15%, or both.

Postoperative management and follow-up examination. Intravenous antibiotics were administered for 2 weeks, and culture-determined oral antibiotics were continued for 6 weeks. After discharge, routine late follow-up included a clinical and duplex scanning examination at 1 month and every 6 months thereafter. Late arteriography was performed depending on the results of duplex scanning. Patients were routinely prescribed daily low-dose aspirin (100 mg). For the purposes of this report, the status of all survivors was updated in April 2004. Patency, limb salvage rate, and survival were determined with the Kaplan-Meier method.

RESULTS

Patients and initial procedures. During the 7-year study period, 17 patients (14 men, 3 women; mean age of 68 years, range, 50 to 83 years) who had major peripheral graft infection underwent graft excision and cryopreserved arterial allograft reconstruction. The baseline characteristics of the patients are shown in Table I. Systemic risk factors for infection, including diabetes mellitus, malignancy, steroid use, and malnutrition were present in 7 patients (41%).

The indications for initial peripheral bypass grafting were critical leg ischemia in 10 (59%) patients, severe claudication in 5 (29%), and popliteal aneurysm in 2 (12%). The types and indications of initial peripheral reconstructions with infection are described in Table II. Prosthetic femoropopliteal bypass was the most frequently infected reconstruction. Graft material was polytetrafluoroethylene (PTFE) in 10 patients, Dacron in 3, and autologous saphenous vein in 4.

The median time from placement of the bypass to the initial symptom of graft infection was 22 days (range, 10
Table II. Types and indications of peripheral reconstructions with infection in 17 patients

<table>
<thead>
<tr>
<th>Reconstruction</th>
<th>Material</th>
<th>n</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axillofemoral</td>
<td>Dacron</td>
<td>1</td>
<td>CLI</td>
</tr>
<tr>
<td>Crossover</td>
<td>PTFE</td>
<td>1</td>
<td>Claud</td>
</tr>
<tr>
<td>Femorofemoral</td>
<td>PTFE</td>
<td>1</td>
<td>Claud</td>
</tr>
<tr>
<td>Iliofemoral</td>
<td>PTFE</td>
<td>1</td>
<td>Claud</td>
</tr>
<tr>
<td>Iliofemoral patch</td>
<td>Dacron</td>
<td>1</td>
<td>Claud</td>
</tr>
<tr>
<td>Angioplasty</td>
<td>PTFE</td>
<td>1</td>
<td>Claud</td>
</tr>
<tr>
<td>Iliofemoral patch</td>
<td>Dacron</td>
<td>1</td>
<td>CLI</td>
</tr>
<tr>
<td>Angioplasty + femoropopliteal (AKPA)</td>
<td>PTFE</td>
<td>1</td>
<td>CLI</td>
</tr>
<tr>
<td>Femoropopliteal (AKPA)</td>
<td>PTFE</td>
<td>1</td>
<td>CLI</td>
</tr>
<tr>
<td>Femoropopliteal (BKPA)</td>
<td>PTFE</td>
<td>4</td>
<td>CLI (2)/Fempop Aneur (2)</td>
</tr>
<tr>
<td>Femorotibial*</td>
<td>PTFE</td>
<td>1</td>
<td>CLI</td>
</tr>
<tr>
<td></td>
<td>GSV</td>
<td>3</td>
<td>CLI</td>
</tr>
</tbody>
</table>

*Including 1 patient with tibial nerve compression and neurologic deficit.

BKPA, Below-knee popliteal artery; AKPA, above-knee popliteal artery; PTFE, polytetrafluoroethylene; GSV, greater saphenous vein; Ilio, external iliac artery; CLI, critical limb ischemia; Claud, claudication; Fempop aneur, femoropopliteal aneurysm.

*Site of proximal anastomosis was an aortofemoral graft in 1 patient.

days to 52 months); this time was less than 30 days in 11 (65%) of the 17 patients. The median time from graft placement to definitive treatment of the graft infection was 31 days (range, 10 days to 72 months). Six (35%) of these 17 patients had been initially operated on in our center, whereas 11 (65%) were referred to us after a mean of 2.1 ± 1.3 operations (range, 1 to 5) had been performed elsewhere.

Manifestation and preoperative diagnosis. The clinical events in 17 patients with an infected peripheral graft are described in Table III. One false aneurysm developed at the below-knee popliteal level and resulted in a neurologic deficit due to tibial nerve compression. Because of arterial status, failed reoperations, or end-to-end bypasses, restoration of lower-limb arterial circulation was required to salvage the limb after removal of the infected patent graft in the 12 patients without acute ischemia.

Graft infection was localized to the area of the proximal anastomosis in 4 patients (23%), to the area of the distal anastomosis in 4 (23%), and involved the entire graft in 7 (41%). Two patients (12%) had isolated areas of infections involving a portion of a prosthetic graft distant from both anastomotic sites. According to the classification of graft infection from the Montefiore Medical Center,2 all the patients in this series had major graft infections at the time of presentation:

- 2 patients with group III (infections involved the body of the graft but not an anastomosis);
- 2 patients with group IV (infections surrounded an exposed anastomosis but bacteremia or anastomotic bleeding had not occurred); and
- 13 patients with group V (infections involved a graft-to-artery anastomosis and were associated with septicemia, anastomotic bleeding, or both).

Because of acute bleeding in 2, a severe neurologic deficit in 1, and severe acute ischemia in 4, allograft reconstruction was performed as an emergency procedure in 7 patients (41%), whereas it was a planned procedure in 10 patients (59%).

Treatment. Bacteriology cultures were positive in all cases and are listed in Table IV. A single organism was identified in 10 (59%) cultures and multiple organisms in 7 (41%). Infection was due to a variety of organisms, most frequently Staphylococcus aureus followed by Pseudomonas aeruginosa.

In 14 patients (82%), the greater saphenous veins were not available either because they had already been used in other revascularizations or had been stripped. In 2 patients, the saphenous vein was present but was deliberately not used because of a discrepancy between the diameter of the vein and the external iliac artery. A unique greater saphenous vein was used in 1 patient for a femorofemoral crossover in addition to allograft reconstruction. During the study period, 7 patients were treated with greater saphenous vein reconstruction for peripheral graft infection (3 crossover, 1 iliofemoral, and 3 femoropopliteal bypasses).

At surgery, removal of the entire graft was felt to be mandatory in 100% of patients with infected prosthetic grafts and in 50% with infected saphenous grafts. In the latter 2 patients, the distal end of the saphenous was preserved as a “cuff” for a distal allograft anastomosis. Types of arterial allograft reconstruction for all 17 patients are detailed in Table V.

The proximal anastomosis was located at the same level in 7 patients (41%) and was different in 10 (59%). The distal anastomosis was located at the same level in 9 patients (53%) and was more distal in 8 (47%). Reconstruction was performed in situ in 6 patients (35%) and ex situ in 11 (65%). Of the 3 patients with iliofemoral infection, the allograft was placed in situ in 2 cases and a crossover was made in 1. Subcutaneous routing was performed in 13 patients (76%).
Additional procedures included fasciotomy in 4, local fibrinolysis of the tibial arteries during the procedure in 2, and surgical drainage of suppurative arthritis of the knee in 1. No myoplasty was performed. The mean duration of the procedures was 306 minutes (range, 200 to 440).

**Early outcome (<3 months).** There were no perioperative deaths, no early occlusions of the allograft reconstruction, and no early amputation in this series. Five patients (29%) had complications that were not related to the allograft: transient renal failure in 2, delirium tremens in 1, neurologic postischemic sequelae of the limb in 2, and congestive heart failure in 1.

Two patients had allograft ruptures in the groin on postoperative days 20 and 45. The previously infected groin in these two patients had been re-exposed and no myoplasty had been performed during allograft reconstruction. Healing was delayed and skin necrosis occurred, resulting in arterial allograft exposure and subsequent rupture. Both patients underwent emergency surgery with an uneventful recovery.

The first patient had undergone a femorofemoral and a distal extension to peroneal artery allograft reconstruction. Infection of the initial arterial graft was due to S. aureus, and the patient was treated with an oral antistaphylococcus regimen (oxacillin) at the time of rupture. After the proximal end of the distal extension ruptured, the distal extension of the allograft was reimplanted in the profunda femoral artery and a myoplasty was performed.

The second patient had undergone a complex allograft reconstruction associating an iliofemoral and a femorofemoral crossover plus femoropopliteal revascularization. Infection of the initial arterial graft was due to S. aureus associated with *P. aeruginosa*, and the patient was treated with an oral antibiotics regimen (pristinamycin and ciprofloxacin) at the time of rupture. After the proximal end of the femorofemoral crossover ruptured, the femorofemoral crossover was ligated and a prosthetic (PTFE) axillofemoral was performed as an inflow conduit for the femoropopliteal allograft. At the time of reoperation, there were no clinical or biological signs of persistent infection and bacteriology cultures from surgery were negative in both cases. The two allografts that ruptured had been stored for a period of 27 and 53 days.

Blood transfusion was required in 10 patients (59%) with a mean of 4.8 red blood cell units (range, 2 to 10 units) per patient. Mean duration of hospitalization was 24 ± 12.6 days.

**Late outcome.** All patients were available for follow-up (mean, 34 months; range, 8 to 80 months). Six patients died during late follow-up in postoperative months 8, 9, 18, 22, 30, and 52, none for treatment-related reasons. Causes of later deaths were myocardial infarction in 4, prostate cancer in 1, and pulmonary embolism in 1. The cumulative survival rate was 88% at 1 year and 74% at 2 years.

Four allografts thrombosed during follow-up at 6, 7, 12, and 20 months. The 3 patients whose grafts occluded at 7, 12, and 20 months did not undergo surgery because of a very poor runoff. Two of them had occlusion of a femorotibial extension with a patent femorofemoral crossover and required below-knee amputation. The third patient had a thrombosed femoropopliteal reconstruction that resulted in critical limb ischemia. The fourth patient underwent successful thrombectomy at 6 months (which was still patent at 23 months).

Aneurysmal deterioration of the cryopreserved allograft occurred twice in 1 patient, graft requiring 2 segmental

---

**Table IV.** Bacteriology of peripheral graft infections in 17 patients

<table>
<thead>
<tr>
<th>Organisms (No.)</th>
<th>Single organism</th>
<th>Multiple organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients (%)</td>
<td>10 (59)</td>
<td>7 (41)</td>
</tr>
<tr>
<td>Organisms (No.)</td>
<td><em>Staphylococcus aureus</em> (8)</td>
<td><em>Staphylococcus aureus</em> (4)</td>
</tr>
<tr>
<td></td>
<td><em>Staphylococcus epidermidis</em> (2)</td>
<td><em>Pseudomonas aeruginosa</em> (4)</td>
</tr>
<tr>
<td></td>
<td><em>Proteus mirabilis</em> (1)</td>
<td><em>Bacteroides fragilis</em> (1)</td>
</tr>
<tr>
<td></td>
<td><em>Enterobacter cloacae</em> (1)</td>
<td><em>Enterobacter facalis</em> (1)</td>
</tr>
<tr>
<td></td>
<td><em>Morganella morganii</em> (1)</td>
<td></td>
</tr>
</tbody>
</table>

**Table V.** Types of arterial allograft reconstructions with infection in 17 patients

<table>
<thead>
<tr>
<th>Reconstruction</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subclavian-brachial + axillofemoral*</td>
<td>1</td>
</tr>
<tr>
<td>Crossover femorofemoral</td>
<td>1</td>
</tr>
<tr>
<td>Crossover femorofemoral + iliofemoral + femoropopliteal (BKPA)</td>
<td>1</td>
</tr>
<tr>
<td>Crossover femorofemoral + femorotibial</td>
<td>2</td>
</tr>
<tr>
<td>Iliofemoral</td>
<td>1</td>
</tr>
<tr>
<td>Iliofemoral + femoropopliteal (AKPA)</td>
<td>1</td>
</tr>
<tr>
<td>Iliofemoral + femorotibial</td>
<td>2</td>
</tr>
<tr>
<td>Common iliac-popliteal (BKPA)</td>
<td>1</td>
</tr>
<tr>
<td>Iliotibial</td>
<td>1</td>
</tr>
<tr>
<td>Femoropopliteal (BKPA)</td>
<td>1</td>
</tr>
<tr>
<td>Femorotibial†</td>
<td>5</td>
</tr>
</tbody>
</table>

BKPA, below-knee popliteal artery; AKPA, above-knee popliteal artery; Ilot, external iliac artery.

*A femoral allograft conduit was used to perform the axillohumeral bypass, an ilio-femoropopliteal allograft conduit was used to perform the axillofemoral, and great saphenous vein was used for the femorofemoral crossover.

†Site of proximal anastomosis was an aorto-femoral graft in one case.
replacements with PTFE at 24 and 36 months. This patient
died of myocardial infarction 16 months after the last
procedure with a patent allograft.
There was no persistent or recurrent infection, and
none of the patients received long-term (>3 months) or
indefinite antibiotic therapy. The 18-month primary and
secondary allograft patency rates were 68% and 86% (Fig 1).
The overall limb salvage rate was 82% at 2 years (Fig 2).

DISCUSSION

Our experience with cryopreserved arterial allografts in
the management of major peripheral bypass infections sug-
ests that this technique is a useful option for treating one of
the most dreaded vascular complications. Although the num-
ber of cases reported is small, this is the largest surgical series
dealing with cryopreserved arterial allograft in the manage-
ment of peripheral bypass infection described in the literature.
Most patients in this series represent the most desperately ill
patients presenting with peripheral bypass infection. Eight
patients (47%) had systemic sepsis, 5 (29%) had acute ischemia
at the time of allograft reconstruction, and 9 (53%) had
experienced anastomotic rupture. In addition, multiple or-
ganisms were present in 41%, including virulent \textit{P. aeruginosa}
in 35%. Despite these difficulties, there were no perioperative
deaths or early amputations in this series.

The optimal management of major peripheral graft
infection is still controversial. Total graft excision is gen-
erally required if any of the following conditions exist: (1)
signs of systemic sepsis, (2) anastomotic disruption, (3) the
presence of virulent gram-negative organisms on culture,
(4) involvement of the entire graft, or (5) associated graft
thrombosis. All the patients in this series presented one or
more preoperative conditions and required total graft exci-
sion. However at surgery, the distal part of the vein was
judged to be uninfected in 2 patients who had an infected
saphenous graft, and it was successfully preserved as a
“cuff” for allograft anastomosis. All the patients in this
series required arterial reconstruction to preserve limb via-
bility, whereas none had available or suitable saphenous
veins to perform a complete lower-limb arterial reconstruc-
tion.

We embarked on a cryopreserved allograft replacement
program because

- We were dissatisfied with the more conventional treat-
ments in terms of mortality, reinfection, and amputation
rates.
- Cryopreserved arterial allograft reconstruction is highly
applicable in the management of serious graft infection,
even for emergency use.\textsuperscript{8}
- The results of experimental studies and clinical results
suggest that arterial allografts have a good resistance to
infection.\textsuperscript{8,10-12}
- Arterial allografts harvested from brain-dead donors are
available as part of an active, local, multiorgan transplant-
retrieval program.

None of the patients in this series experienced persist-
ent or recurrent infection. Although two allograft ruptures
occurred in 2 patients in the early postoperative period, we
feel that these ruptures were due to allograft exposure
rather than to infection because no objective clinical or
biological signs of persistent or recurrent infection were
found during reoperation and bacteriology cultures from
surgery were negative.

Although another concern could be whether a longer
follow-up period will reveal recurrent infection, the mean
follow-up period of 34 months, with all allografts observed
for at least 8 months, is reassuring. Furthermore, no rein-
fecations occurred in the 2 patients who required implanta-
tion of a new prosthetic graft.
We cannot conclude, however, that in situ allograft replacement is safe for all types of infection. Indeed, caution should be taken when an in situ allograft replacement is planned in a patient with extensive infection and gross purulence or highly virulent gram-negative organisms. Thus, in 11 patients in this series who required complete graft removal, allografts were routed ex situ to avoid placement in an extensively contaminated bed. Moreover, careful wound excision, removal of the entire prosthetic graft, and perioperative intravenous administration of appropriate antibiotics were important factors for successfully eradicating infection in this series.

Early rupture of the allograft is a potentially devastating and specific complication of allografting. Fractures from cryopreservation and thawing have been reported both clinically and experimentally. Hunt et al provide evidence that the mechanical stresses that build up between −80 °C and −196 °C during the cryopreservation process could be responsible for fractures. Furthermore, clumsy handling during the thawing process could trigger lesions of the extracellular matrix that could be responsible for later ruptures. Exposure of the allograft secondary to wound breakdown had also been reported as a cause for allograft rupture. However, especially for aortic allografts, most early ruptures seemed to be caused by infection. Infection with highly virulent organisms is a logical risk factor for allograft infection and subsequent rupture. This probably accounts, at least in part, for the significantly higher mortality after allograft replacement to treat secondary aortoenteric fistulas.

As 15 (88%) of 17 patients in this series had severe underlying occlusive disease and 5 were referred with acute ischemia, they were obviously at high risk of limb loss. Therefore, it is important to note that that the 18-month primary and secondary allograft patency rates were 68% and 86%, and there were no early amputations and only two late below-knee amputations in our patients. This low amputation rate was consistent with the treatment of policy of immediate revascularization. After a mean follow-up period of 34 months, 5 allografts failed (4 from thrombosis, 1 from aneurysmal dilatation) which resulted in 3 successful, technically uncomplicated interventions.

Despite this relatively good success rate, arterial allograft reconstruction in major peripheral graft infection has some obvious disadvantages:

- Wound healing could not be obtained in 2 patients, and bleeding occurred in 2 because of allograft exposure. As a result, coverage by muscle transposition should be performed in infected groin anastomoses even when allograft reconstruction is performed.
- Allograft failure from thrombosis and aneurysmal deterioration was not uncommon in this series, confirming that these allografts must be closely monitored and that subcutaneous tunneling of the grafts is an important part of the surgical technique.
- With longer follow-up, the incidence of secondary and late aneurysmal deterioration is expected to increase.
- With longer follow-up, the incidence of allograft thrombosis is expected to increase as well. Albertini et al reported a poor long-term patency rate of 42% at 3 years in a group of 148 patients who experienced arterial allograft below-knee bypasses for limb salvage.

In this series, arterial allograft was used after revascularization with autologous greater saphenous veins was first considered. Arm and femoropopliteal veins were not con-
sidered. However, autologous reconstruction is another very relevant option for revascularization in infected fields. Very good revascularization results have been obtained with femoropopliteal or arm veins for aortic or peripheral infection and critical limb ischemia.\textsuperscript{23-26}

Harvesting and preparing these two types of conduits are technically demanding (with the need to perform angiography in the case of an arm vein) and time-consuming procedures. Furthermore, harvesting the femoropopliteal vein in the absence of the greater saphenous vein may lead to venous sequelae. Reconstruction with femoropopliteal or arm veins often necessitates a specialized two-team approach to expedite the operation and to splice the composite vein using venovenostomy to create a vein conduit of sufficient length to allow the performance of the lower-extremity revascularization. Finally, in our opinion, this approach may be difficult in sick and infected patients who need urgent treatment.

Few series reported vascular allograft reconstruction after excision of an infected peripheral bypass graft. After fresh venous allograft reconstruction in 5 patients with patent peripheral prosthetic graft infection, Snyder et al\textsuperscript{27} reported complete resolution of infection in all cases. More recently, Fujitani et al\textsuperscript{28} reported the use of cryopreserved homograft veins to eradicate infection and achieve limb salvage in all 6 patients with infected peripheral prosthetic grafts with a limited follow-up of 9.5 months.

Patency rates reported by many investigators with cryopreserved venous allografts for limb salvage were low, however.\textsuperscript{28,29} The largest experience was reported by Farber et al,\textsuperscript{30} who performed 240 infrainguinal revascularizations for limb salvage and achieved a primary patency rate of 30\% at 1 year and 18\% at 2 years. Our experience was very similar, causing us to abandon this conduit for distal revascularization.\textsuperscript{9,31}

We found 21 documented cases of arterial allograft reconstruction after excision of an infected peripheral bypass graft reported in the English literature.\textsuperscript{16,17,21,32-35} The location of the infected grafts and the outcome of these 21 cases are presented in Table VI. Reported results were good, with no reinfection, one perioperative death, and one early amputation, but it is difficult to draw any conclusion from a group of small series or case reports.

The heterogeneity of patients, the numerous therapeutic strategies, and the general diagnosis of peripheral graft infection make comparisons between series very difficult. Nevertheless, we think that the outcome of the midterm follow-up in our series for mortality, limb salvage, and freedom from reinfection compare favorably to other series using more conventional methods.\textsuperscript{1-3,36} To compare different series of peripheral bypass infections, a system is needed to stratify these patients using standards similar to those that have been developed in other areas of vascular surgery.\textsuperscript{37,38}

**Conclusion.** Although this study presents a small series of patients with limited follow-up, reconstruction with a cryopreserved arterial allograft seemed to be a useful option for treating one of the most dreaded vascular complications. When major peripheral graft infection occurs in patients with severe underlying occlusive disease and autol-

### Table VI. Documented cases of management of peripheral bypass infection with cryopreserved arterial allograft reported in the literature.\textsuperscript{*}

<table>
<thead>
<tr>
<th>Reference</th>
<th>N</th>
<th>Location of infected graft</th>
<th>Material</th>
<th>Partial or total graft removal</th>
<th>Perioperative mortality</th>
<th>Early amputation</th>
<th>Late amputation</th>
<th>Secondary infection</th>
<th>Mean follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bracale et al\textsuperscript{32} (1999)</td>
<td>2</td>
<td>Axillofemoral</td>
<td>PTFE, Dacron</td>
<td>Total/2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13.5</td>
</tr>
<tr>
<td>Locati et al\textsuperscript{113} (2000)</td>
<td>2</td>
<td>Axillolibifemoral</td>
<td>PTFE</td>
<td>Partial/2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>Desgranges et al\textsuperscript{34} (1998)</td>
<td>5</td>
<td>Femoropopliteal (1), Femorofemoral (2), Iliofemoral (1)</td>
<td>SV Prosthetic, Prosthetic</td>
<td>Partial/2 Total/2 Total/2</td>
<td>1/5 (20%)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>20 (18\†)</td>
</tr>
<tr>
<td>Wagstaff et al\textsuperscript{17} (1996)</td>
<td>4</td>
<td>Femoropopliteal (1), Femorotibial (1), Femoropopliteal (1), Crossover</td>
<td>Dacron PTFE, PTFE, Dacron</td>
<td>At least 3 total graft removal</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>24.5 (7\†)</td>
</tr>
<tr>
<td>Nevelsteen et al\textsuperscript{21} (1998)</td>
<td>3</td>
<td>Femorodistal</td>
<td>Prosthetic</td>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24.5 (30\†)</td>
</tr>
<tr>
<td>Lavigne et al\textsuperscript{16} (2003)</td>
<td>4</td>
<td>Femoropopliteal (1), Femorofemoral (1)</td>
<td>Prosthetic</td>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>18 (22\†)</td>
</tr>
<tr>
<td>Locati et al\textsuperscript{35} (2000)</td>
<td>1</td>
<td>Femorotibial</td>
<td>PTFE</td>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
</tr>
</tbody>
</table>

SV, Saphenous vein; PTFE, polytetrafluoroethylene; AV, arm vein.

\textsuperscript{*} Axillolibifemoral or bilateral axillolibifemoral following removal infected aortic prosthetic graft were excluded.

\textsuperscript{†} Mean follow-up of the indicated series that included patients treated for prosthetic aortic graft infection, number of patients in each series is indicated after the dagger.
REFERENCES