Cryopreserved arterial homografts vs silver-coated Dacron grafts for abdominal aortic infections with intraoperative evidence of microorganisms

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Objective: **The gold standard for the treatment of abdominal aortic infections remains controversial. Cryopreserved arterial homografts and silver-coated Dacron grafts have both been advocated as reasonable grafts. Direct clinical or experimental comparisons between these two treatment options have not been published before. This study compared cryopreserved arterial homografts and silver-coated Dacron grafts for the treatment of abdominal aortic infections in a contaminated intraoperative field.**

Methods: **From January 2004 to December 2009, 56 patients underwent in situ arterial reconstruction for an abdominal aortic infection. Patients with negative intraoperative microbiologic specimens were excluded. We compared 22 of 36 patients (61%) receiving cryopreserved arterial homografts (group A) vs 11 of 20 (55%) receiving a silver-coated Dacron graft (group B). Primary outcomes were survival and limb salvage; secondary outcomes were graft patency and reinfection. Direct costs of therapy were also calculated.**

Results: **Thirty-day mortality was 14% in group A and 18% in group B ($P > .99$), and 2-year survival rates were 82% and 73%, respectively ($P = .79$). After 2 years, limb salvage was 96% and 100%, respectively ($P = .50$), whereas graft patency was 100% for both groups. Major complications were an aneurysmal degeneration in group A and graft reinfection in group B (n = 2). Median direct costs of therapy (in US $) were $41,697 (range, $28,347-$53,362) in group A and $15,531 (range, $11,310-$22,209) in group B ($P = .02$).**

Conclusions: **Our results show comparable effectiveness between cryopreserved arterial homograft and silver-coated Dacron graft in the contaminated operative field with respect to early mortality and midterm survival. Graft-inherent complications, aneurysmal degeneration for homografts, and reinfection for silver graft, were also observed. The in situ arterial reconstruction with homografts is nearly three times more expensive than with silver graft. (J Vasc Surg 2011; 53:1274-81.)**

The changing epidemiology of vascular infections, with increased evidence of highly virulent microorganisms (eg, *Pseudomonas aeruginosa*), has made the in situ revascularization after arterial or prosthetic graft excision in the setting of infection a challenging surgical task associated with considerable mortality rates of 20% to 75%.[1,2] Several grafts and surgical approaches have been developed to gain long-term durability, a less-traumatic surgical procedure, and the prevention of infection recurrence.[1] The standard of care advocated from most surgeons remains the proximal and distal ligation of the abdominal aorta and the implantation of an extra-anatomic axillobifemoral prosthetic bypass.[1] Antibiotic-bonded grafts (eg, rifampin-bonded Dacron graft)[3] and superficial femoropopliteal veins[4] have been considered as durable alternatives as well.

Recent studies have presented the silver-coated Dacron graft (SCG) as a reasonable option for treatment of abdominal aortic infection (AAI) treatment. The availability of the graft and the relatively low rates of initial secondary procedures are its important advantages.[2] From the other side, there has been a renewed interest in the cryopreserved arterial homograft (CAH) for the treatment of vascular graft infections, with favorable outcomes even against highly virulent microorganisms.[5-9] However, SCG and CAH are associated with specific early or late complications such as aneurysmatic degeneration, occlusion, and reinfection.[1,2,5]

Because of the small number of recognized aortic (graft) infections and priorities for graft selection and local treatment at single institutions, most publications deal only with small numbers of patients.[1,2] In addition, the very low prevalence of vascular graft infections (<3%)[1,10] impedes a statistically reasonable comparison of different graft materials in a randomized controlled trial.[11] For example, >3000 patients are needed to address a statistically significant reduction from 4% to 2% of infection recurrence rates. Neither national health care agencies nor the device industry are likely to get involved in such a large multicenter study at present.

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As a consequence, we initiated a study to retrospectively compare the effectiveness of CAH vs SCG, trying to assess a first trend. Here, the short-term and medium-term outcomes using CAH or SCG for the in situ reconstruction of the infected abdominal aorta were documented. We hypothesized that the postoperative outcomes would favor CAH, because the elimination of the infectious focus seems more likely in the absence of alloplastic material.

MATERIALS AND METHODS

The study design and the follow-up protocol were approved by the local Ethics Committee (No. 660/2010/01/22).

Patients. A retrospective review of our prospectively collected data for AAI from January 2004 through December 2009 identified 56 patients undergoing in situ reconstruction of the abdominal aorta after suspicion or diagnosis of vascular infection. To compare both grafts in a uniform and, more important, contaminated environment, only patients with positive intraoperative microbiologic specimens were included. Thus, 22 of 36 patients (61%) undergoing CAH implantation (group A) and 11 of 20 patients (55%) undergoing SCG implantation (group B) in the abdominal aorta were considered. Patient characteristics and comorbidities are reported in Table I.

Indications for CAH or SCG implantation. Indications for surgery were (1) prosthetic graft infections, (2) prosthesis-enteric (PEF) or prosthesis-ureter fistulas (PUF), and (3) infected aneurysms. The choice of CAH or SCG was constricted due to the limited availability of CAH in case of emergency but was left to the surgeon's discretion. Details regarding CAH preparation and the characteristics of SCGs have been described elsewhere.[2,5-7,11]

Surgical procedure and treatment adjuncts. The surgical technique has been described in previous reports.[5-7] Patients in both groups underwent complete debridement of the surrounding tissues, followed by irrigation of the operative fields with liberal amounts of 7.5% standard povidone-iodine solution (Braunol, B. Braun, Melsungen, Germany) diluted in 0.9%-isotonic NaCl. Both grafts were washed in 5000 IU neomycin/250 IU bacitracin solution (Baneocin pro instillatione, Sandoz, Kundl, Austria) for at least 5 minutes. In nonemergency patients with prosthetic graft infection (PGI), PEF, or PUF, a ureteral splint (J-catheter) was implanted preoperatively to enable better recognition of the ureters for safe debridement of infected tissues. All patients received standard intraoperative antibiotic therapy with cefuroxime. Intraoperative specimens of tissues and excised prosthetic grafts were sent for microbiologic and histologic examination.

Postoperative management and follow-up examination. Intravenous antibiotics were administered during the parenteral nutrition, and oral administration of organism-specific oral antibiotics was continued for at least 2 weeks after discharge.[13] Caloric requirements were delivered orally as soon as feasible.

All patients were seen in our department 3 and 6 months after surgery and biannually thereafter. Postoperative outcomes were evaluated with ultrasound imaging or computed tomography scan. We also contacted our patients by telephone to obtain information about late complications at the time of analysis.

Table I. Patient demographics, comorbidities, and preoperative characteristics

Variable	*Group A No. or mean ± SD*	*Group B No. or mean ± SD*	P
Total	22	11	
Gender			
Male	21	11	
Female	1	0	>.99
Age, years	68 ± 8	61 ± 16	.16
Comorbidity			
Hypertension	15 (68)	6 (55)	.47
COPD	4 (18)	4 (36)	.39
Coronary disease	10 (45)	4 (36)	.71
Myocardial infarction <6 months	4 (18)	3 (27)	.66
Hypercholesterolemia	6 (27)	3 (27)	>.99
Diabetes mellitus	6 (27)	4 (36)	.69
Body mass index, kg/m^2	24.7 ± 3.51	22.8 ± 3.50	.16
CKD-EPI GFR[a]	69.59 ± 31.62	69.54 ± 26.35	.99
Dialysis	2 (9)	1 (9)	>.99
ASA score			
II	1 (5)	1 (9)	
III	14 (63)	4 (36)	
IV	6 (27)	5 (46)	.37
V	1 (5)	1 (9)	
Positive pre-op bloodstream cultures	5 (23)	1 (9)	.63
Antibiotic pre-op treatment	14 (64)	5 (46)	.45

ASA, American Society of Anesthesiologists; *CKD-EPI*, Chronic Kidney Disease Epidemiology Collaboration; *COPD*, chronic obstructive pulmonary disease; *GFR*, glomerular filtration rate; *SD*, standard deviation.
[a]The CKD-EPI GFR is an estimate of the glomerular filtration rate using serum creatinine and demographic factors. It is a relatively new equation proposed to be superior to the Modification of Diet in Renal Disease GFR equation.[12]

Definitions. The criteria of Centers for Disease Control and Prevention (CDC) were used to define PGI.[14] All radiologic findings were evaluated separately by an experienced independent radiologist and two vascular surgeons. An infected aortic aneurysm was defined as aortic dilation with a diameter of >3 cm, on the basis of clinical evidence of infection by fever and leukocytosis in accordance with CDC criteria and periaortic soft-tissue infiltration demonstrated by contrast-enhanced CT scan.[15]

Study design. Group A was compared with group B in comorbidities, preoperative clinical condition as determined by the American Society of Anesthesiologists (ASA) score, and operation time to exclude any undue differences that might introduce bias. Primary outcomes were survival and limb salvage. Secondary outcomes were reinfection (according to CDC criteria) and graft patency. Perioperative complications and cost-effectiveness were also addressed.

Statistical analysis. All analyses were performed and graphs were created with MedCalc 9.4.2.0 software (Mariankerke, Belgium). Categoric variables are presented as percentages. Normally distributed continuous variables are presented as mean ± standard deviation and the respective not normally distributed are presented as medians with the interquartile range. The distribution of continuous variables was determined by Kolmogorov-Smirnov test. Ordinal data with two categories were compared with Pearson χ^2 test and with more than three categories (eg ASA score) with χ^2 for trend. Normally distributed continuous variables were compared with the *t* test for independent variables, and the Mann-Whitney test was performed for the respective not normally distributed data. Survival, limb salvage, and graft patency rates were calculated using the Kaplan-Meier method. Hazard ratios (HR) are presented with 95% confidence intervals (CIs). Patients were censored at their last known date of follow-up. A value of $P \leq .05$ was considered statistically significant for individual tests.

RESULTS

Indications for surgery in group A were PGI in 8, PEF in 10, PUF in 1, and infected aneurysms in 3 patients. Comparably, indications in group B were PGI in 1 ($P = .21$), PEF in 2 ($P = .13$), and infected aneurysms in 8 patients ($P = .001$). A synopsis of symptoms at the time of presentation, CT scan findings, responsible microorganisms and outcomes is presented in Table II (online only).

The most common microorganisms in group A were *Staphylococcus aureus, Enterococcus faecalis,* and *E faecium* (18% each one). Methicillin-resistant *S aureus* (MRSA) was found in three patients (14%) and *P aeruginosa* in two patients (9%). In group B, the most common agents were *P aeruginosa, S epidermidis,* and *Escherichia coli* (18% each one). MRSA was found in one patient (9%).

Eight patients (36%) in group A and seven patients in group B (64%) underwent an urgent operation ($P = .26$) without any cardiac resuscitation. Purulent tissues were found intraoperatively in 11 patients (50%) in group A and in 2 patients (18%) in group B ($P = .13$). Aortic graft configurations in group A were aortic tube grafts in 5 (23%) aortobiiliac in 6 (27%), aortobifemoral in 5 (23%) and aortobiprofundal in 6 (27%). The configurations in group B were aortic tube graft in 5 (45%), aortobiiliac in 5 (45%), and aortobifemoral in 1 (10%). Preoperative ureteral splinting was required in 10 patients in group A (45%) and in 1 patient in group B (10%). No patients sustained a ureter injury.

Mean duration of operation was 279 ± 96 minutes in group A and 172 ± 60 minutes in group B ($P < .001$). The median number of blood cell components administrated during the operation was 8 (range, 5.75-10.25) in group A vs 6 (range, 4.25-7.50) in group B ($P = .56$).

Mean length of hospital stay amounted to 24 ± 14 days in group A and to 16 ± 12 days in group B ($P = .06$). The 30-day mortality was 14% (3 of 22 patients) in group A and 18% (2 of 11 patients) in group B ($P > .99$). Sepsis-related multiple organ failure (MOF) was the cause of death in both groups (Patients 1, 2, 20, 32, 33; Table II, online only). In-hospital mortality was 14% in group A and 27% (3 of 11 patients: 24, 32, and 33) in group B ($P = .38$). Perioperative complications are presented in Table III. Graft-related complications were observed in two patients in each group (group A: 9% vs group B: 20%, $P = .57$). No patients died of a graft-related complication.

Mean follow-up was 27 ± 21.5 months in group A and 18 ± 18.7 months in group B ($P = .24$). Except for patient 33, who died of sepsis-related heart failure in the intermediate care unit on the same day, all patients were included in the follow-up surveillance (Table II, online only). The postoperative survival rates are illustrated as a Kaplan-Meier curve in Fig 1. Two-year survival rates were 82% in group A and 73% in group B (HR, 0.82; 95% CI, 0.26-5.64; $P = .80$). Reasons for late (>30 days) death in group A were myocardial infraction in patients 7 and 13 and sepsis-related MOF due to endocarditis in patient 21. In group B, patient 25 died of late sepsis-related MOF. This patient underwent SCG implantation 5 months after heart transplantation to treat a contained rupture of a 10-cm common iliac aneurysm. He was taking immunosuppressants, and *P aeruginosa* septicemia was documented before the aneurysm rupture.

The 2-year limb salvage rate was 96% in group A and 100% in group B ($P = .50$), and 2-year graft patency amounted to 100% for both groups. However, the cumulative graft patency rates decreased to 75% for group B ($P = .09$) after 3 years.

Evidence of reinfection (ongoing or recurrent) was raised in no patients in group A and in two patients (20%) in group B ($P = .09$). Patient 25, diagnosed with spondylodiscitis and HIV infection, underwent a ^{18}fluorodeoxyglucose (FDG) positron-emission tomography (PET) computed tomography (CT) scan 39 months postoperatively. The examination showed an increased ^{18}FDG uptake (maximum standardized uptake value, 6.0) around the SCG (Fig 2). A CT-guided perigraft fluid aspiration in 2009 showed evidence of *Mycobacterium avium*; this microorganism was found also in the intraoperative specimens. The patient complained of persistent back pain but has rejected any further surgical intervention. Long-term tuberculostatic treatment has been initiated instead. Patient 30 presented with a graft-enteric fistula on postoperative day 19 with evidence of *E coli*. This patient underwent a CAH implantation and had an uneventful postoperative course.

The treatment costs from admission to discharge were calculated in each group and compared to the reimbursement according to diagnosis-related group. Median direct costs of therapy (in US $) were $41,697 (range, $28,347-$53,362) in group A and $15,531 (range, $11,310-$22,209) in group B ($P = .02$). More interestingly, the median contribution margin was –$13,272 (range, –$16,790 to –$5,065) in group A and $1290 (range, –$24,372 to $12,975) in group B ($P = .01$).

Table III. Perioperative complications and respective treatment for each group

Complications	*Treatment*	*No. (%)*
Group A: Cryopreserved arterial homografts		
Graft related		
Anastomotic bleeding	Reoperation and repair	1 (5)
Aneurysmatic degeneration	Homograft reconstruction with Dacron patch	1 (5)
Operation related		
Hematoma	Open surgical drainage/temporary abdominal closure	2 (9)
Spleen rupture	Splenectomy	2 (9)
Pancreatitis (necrotizing)	Duodenopancreatectomy	1 (5)
Wound infection (lymphocele)	Vacuum-assisted wound closure[a]	1 (5)
Other		
Acute limb ischemia[b]	Tibial amputation on both sides	1 (5)
Atrioventricular block, 3rd degree	Heart pacemaker implantation	1 (5)
Cholecystitis	Cholecystectomy	1 (5)
Group B: Silver-coated Dacron graft		
Graft related		
Occlusion	Thrombectomy	1 (9)
Prosthetic-enteric fistula	CAH implantation	1 (9)
Operation related		
Wound dehiscence	Wound repair	2 (18)
Cardiac arrest	Cardiac resuscitation	1 (9)
Pancreatitis	Relaparotomy with drainage	1 (9)
Other		
Cholecystitis	Cholecystectomy	1 (9)
Visceral ischemia	Aortovisceral bypass	1 (9)

CAH, Cryopreserved arterial homograft.
[a]V.A.C Therapy Unit; KCI Concepts, San Antonio, Tex.
[b]Caused by high rates of catecholamines (septic shock).

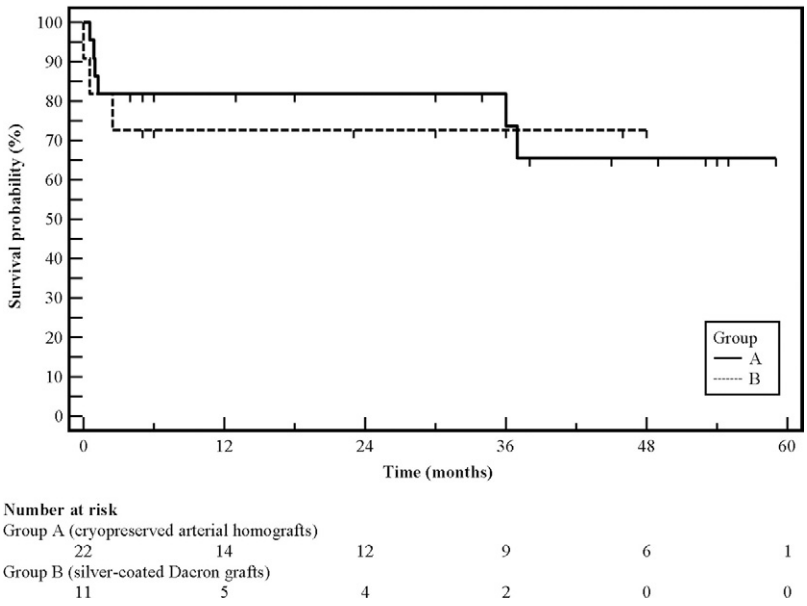

Fig 1. Kaplan-Meier life-table analysis comparing the survival rates after in situ reconstruction of the infected abdominal aorta with cryopreserved arterial homografts (*group A*) and silver-coated Dacron grafts (*group B*). The standard error (SE) is <10% in group A at 1.2 months, 11% at 36 months, and 12% at 37 months. SE is <10% in group B at 0.01 months, 12% at 0.56 months, and 13% at 2 months.

DISCUSSION

SCGs showed comparable 2-year survival and limb salvage rates compared with CAHs. The one observed limb loss in group A was caused by limb ischemia related to high doses of catecholamines in a patient with severe septic shock. Regarding the secondary end points, we observed considerable higher reinfection rates in the SCG group (20%), whereas no evidence for reinfection was raised in the

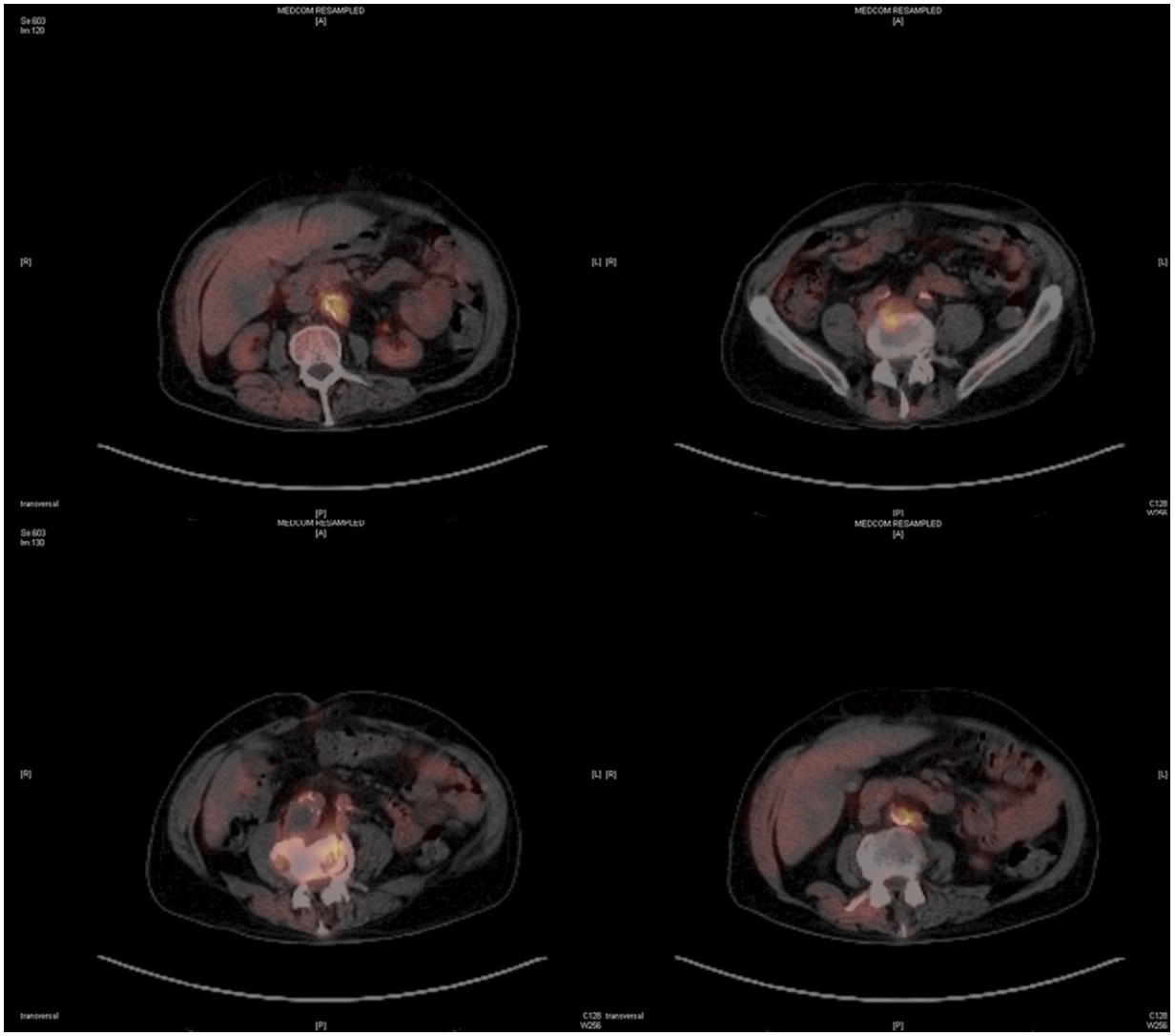

Fig 2. [18]Fluorodeoxyglucose positron-emission tomography-computed tomography scan of patient 25 shows the ongoing infection of the silver-coated graft caused by concomitant spondylodiscitis. *Mycobacterium avium* was the responsible microorganism.

CAH group during surveillance. Patency was 100% in CAH and 75% in SCG after 3 years. In the CAH group, aneurysmal degeneration was the major complication. Any additional subclinical aneurysmal degeneration was excluded using duplex ultrasound imaging and contrast-enhanced CT scans. Major complications in the SCG group were an early PEF and a late graft occlusion.

Encouraging outcomes have been reported with both grafts.[1-5,8] However, almost all publications represent observational studies with only one type of treatment, and the definition of graft infection in these studies is debatable because they also included patients with negative intraoperative microbiologic specimens.[1-9] In contrast, the present study is the first, to our knowledge, to compare two different graft types for AAI treatment. Although the method leads to a decreased sample size, we included only patients with a bacterial graft or arterial infection documented by positive microbiologic specimens, resulting in an objective comparison between the grafts. Some of the data for group A patients were reported previously in our single-center 8-year experience with CAH.[5]

Looking carefully at the indications for operation, there were more PGIs and PEFs in group A, whereas most group B patients presented with an infected aneurysm. This fact reflects our previous institution policy regarding the graft choice. We preferred CAH implantation in patients with the diagnosis of AAI without an acute life-threatening status (eg, gastrointestinal bleeding, free aneurysm rupture, cardiogenic shock). Most patients in group B underwent SCG implantation due to an unexpected intraoperative

field with suspicion of infection (eg signs of purulence, contained rupture with preoperative clinical signs of infection, spondylodiscitis, nondiagnosed fistula; Table II, online only) or due to an urgent operation and unavailable CAH. Also noteworthy is the longer mean operation time in group A ($P < .001$), which was most likely related to the higher proportion of PGI and PEF in group A. Adhesiolysis and precise debridement of the infected tissues extend the operation time significantly.

Our results rejected our hypothesis that patients undergoing total removal of any artificial material show better outcomes and support the theory that in case of vascular arterial infection, there is no gold standard for treatment between CAH and SCG. All types of available grafts and techniques (vein grafts, CAHs, SCGs, antibiotic-bonded grafts, extra-anatomic bypass) have drawbacks.[1] Especially regarding CAH and SCG, it is well-known that CAH have a risk of aneurysmal degeneration, although the exact mechanism is a matter of debate and has been discussed extensively in other reports.[1,2,5,7] SCG patients are said to exhibit high rates of recurrent or ongoing infections.[2,16] Both complications were observed in our study populations.

Another important issue remains the costs of therapy. To our knowledge, we are the first to calculate the costs of treatment, including all events during the postoperative course, for both groups. Interestingly but as expected, CAH treatment costs were notably and statistically significantly higher than costs in group B. Although costs of therapy should not influence the quality of a patient's treatment and the surgeon's strategy when one treatment is superior to another, this issue should be given serious consideration in cases of comparable effectiveness between different types of therapy.

In the literature, autogenous veins remain the most effective method to avoid any reinfection. Important factors limiting their applicability are extended surgical trauma (risk of wound infection) and longer operation time.[1,2,4] CAH are associated with lower rates of reinfection (no evidence of reinfection in our study), but limited availability and durability remain their drawbacks. Our study also adds the costs of therapy as a main disadvantage.[1,2,5] Late dilation rates amounted to 17% (5% in our study) and late occlusion rates to 32% (0% in our study).[2] In contrast, a late occlusion was observed in the SCG group, although prosthetic grafts rarely led to late occlusions.[2] An important risk factor for graft occlusion remains the distal flow path, especially in aortofemoral and small-caliber grafts.[17]

SCG failed to prevent graft infection in several clinical and experimental studies, and the risk of reinfection remains a concern.[2,15,18,19] Its availability in different types and sizes, its ease of use, its durability, and the lower costs (vs CAH due to our results) remain important advantages.[2,15]

Finally, the use of extra-anatomic bypass and antibiotic-bonded grafts as reasonable treatment options has been challenged from recent studies, respectively, due to the considerable reinfection rates and to the development of antibiotic resistance with graft failure.[1,2] Interestingly however, is that antibiotic-bonded grafts (mostly rifampin-bonded) were more effective at preventing graft infection compared with SCG (polyester prosthesis) in experimental studies.[18]

Consequently, the successful treatment of AAI depends on a variety of parameters and factors and not only on the choice of the most effective graft. The patient's condition, comorbidities, appropriate antibiotic treatment, precise infectious tissue debridement, and intra-abdominal lavage are equally important contributors.

Antibiotic treatment is mostly organism-specific. It is noteworthy that no guidelines are available for this issue, and it remains to be addressed.[13] It is proposed, generally, that when the diagnosis of vascular graft infection is obvious, empiric broad-spectrum parenteral therapy should be instituted rapidly before the initial surgical exploration or reconstruction.[13] The most-preferred antibiotic agents are daptomycin for gram-positive coverage coupled with piperacillin-tazobactam, cefepime, or levofloxacin for gram-negative coverage.[13,20] Vancomycin or linezolid (we prefer linezolid)[5] is an alternative for staphylococcal and MRSA coverage.

Patients with invasive or cavitary infections and those treated by in situ replacement (prosthetic or allograft) or graft preservation techniques require 4 to 6 weeks of parenteral antibiotics.[11] We prefer switching the patient to oral administration early, if his or her general condition allows it and the clinical chemical inflammation parameters have normalized or greatly improved, particularly if the active substance has high oral bioavailability (eg fluoroquinolones, clindamycin, and linezolid). A randomized trial for abdominal infections showed that conversion of intravenous antibiotic therapy to oral administration appears as effective as continued intravenous therapy.[21] Several institutions augment therapy by using antibiotic-loaded beads in their wound sterilization algorithm.[11]

Finally, the role of a thorough debridement of all infectious tissues with irrigation of the operative field with liberal amounts of antiseptic or antibiotic agents (in this study, povidone-iodine solution) remains decisive. Different agents have been examined in similar intra-abdominal (peritonitis-associated) infections in general surgery but not in vascular infections.[22-28] A number of clinical and many experimental studies showed a decrease of infectious complications and death after irrigation with solutions containing antibiotics.[22,23] A current meta-analysis addresses the superior value of antibiotics in lavage in experimental peritonitis, although the authors recognize the interval between the onset of an experimental peritonitis and the start of lavage treatment was usually only 1 or 2 hours, which is not representative of the clinical situation.[23]

The effectiveness of antiseptic agents such as povidone-iodine and chlorhexidine in this setting is a matter of debate. Toxic effects on host peritoneal cells led to a significant increase in death, whereas another study observed that povidone-iodine solutions enhanced peritoneal defense mechanisms.[25-27] In a prospective randomized

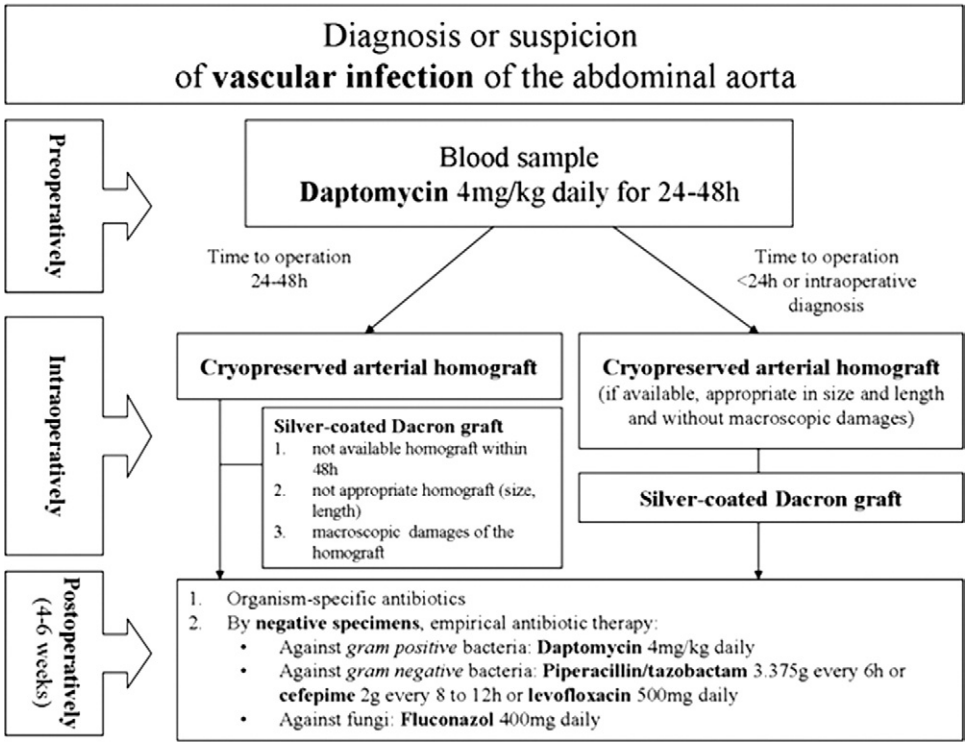

Fig 3. Schematic presentation of the algorithm we used for the treatment of vascular infections of the abdominal aorta.

study,[28] however, the use of diluted povidone-iodine solution as an intraperitoneal irrigant was significantly superior to saline irrigation in preventing the development of intra-abdominal abscesses.

In our opinion, important treatment adjuncts are also (1) ureteral drainage for safe debridement of infectious tissues and (2) the impregnation of the grafts with neomycin, a bactericide antibiotic (transfer of the antibiotic to the perigraft tissues and prevention of graft colonization with microorganisms).[5] CAHs may thus have an enhanced inherent antimicrobial activity compared with conventional grafts because they are stored in antibiotic solution, and this remains a great advantage.[5,6] Both antibiotic loading and neomycin impregnation could explain the absence of any reinfection in the respective group.

Taking under consideration all of the aforementioned factors, we strongly suggest that antibiotic treatment and intra-abdominal lavage are prerequisites for successful treatment. Guidelines for "best medical treatment" are mandatory. Our treatment algorithm is presented in Fig 3. Although the effectiveness of SCG in PGI or fistulas (few cases in the respective group) is not clearly demonstrated in this study, SCG seem a reasonable therapy for an infected aneurysm. We still favor CAH, despite the financial disadvantage, in cases of highly virulent microorganisms. However, we propose the use of SCG as a primary treatment in hospitals that have no access to a tissue bank or are not familiar with this technique.

We recognize further limitations of this single-center work. The retrospective design and the limited number of patients in both groups reduce the statistical power of the results and may introduce bias. Although abdominal aortic aneurysms may be contaminated without signs of infection,[29] infection in this study was confirmed through a combination of clinical, radiologic, and intraoperative signs of infection (Table II, online only) and in accordance with the CDC criteria.

Although we included only patients with contaminated intraoperative specimens to reduce heterogeneity, the indications were still very different between the two groups. However, this work represents a first attempt to derive information about the most efficient graft material in similar microbiologic circumstances.

Finally, the results may not apply to all cases of aortic infection, and several situations might arise in which neither of these techniques is optimal; for example, a neoaortic reconstruction using autogenous femoral vein in a young healthy patient may be preferential.

CONCLUSIONS

The results of this study showed comparable outcomes between CAH and SCG for the treatment of AAI with positive evidence of microorganisms. Major complications were aneurysmatic degeneration for CAH and reinfection for SCG. The costs of therapy were significantly higher for CAH. To improve outcome in these patients, important

treatment adjuncts such as perioperative antibiotic therapy, tissue debridement, and intra-abdominal lavage must be taken under consideration and should be extensively investigated in future studies. Furthermore, a close follow-up schedule enables detection of graft inherent complications such as aneurysmal degeneration in homografts.

AUTHOR CONTRIBUTIONS

Conception and design: TB, OT
Analysis and interpretation: TB
Data collection: TB, MW, OT
Writing the article: TB, OT
Critical revision of the article: TB, AH, OT
Final approval of the article: TB, MW, AH, OT
Statistical analysis: TB,
Obtained funding: TB, OT
Overall responsibility: OT

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Table II (online only). Summary of indications for surgery, symptoms at the time of presentation, computed tomography findings, responsible microorganisms, intraoperative characteristics, reoperations and midterm survival for each patient

Patient	*Graft*	*Diagnosis*	*Symptoms, indications, relevant medical history*	*CT scan, endoscopy and intraoperative findings*	*Microorganisms*	*Specific intra-op characteristics and reoperations (<30 days)*	*Last follow-up*
Group A (Cryopreserved arterial homografts)							
1	CAH	PGI	Fever, acute bilateral groin pain	CR femoral anastomoses (aortobifemoral graft)	*S aureus*	None	POD 15[a]
2	CAH	PEF	Acute abdominal pain, Hb<6 g/dL	Upper GI endoscopy: PEF	*C freundii, Enterococcus* spp, *S epidermidis, S anginosus*	Intra-op: Partial resection of duodenum Reoperations: POD 1: Splenectomy (spleen rupture) POD 8: Cholecystectomy (acute cholecystitis) POD 9: Total duodenopancreatectomy (acute necrotizing pancreatitis), choledochostomy	POD 27[a]
3	CAH	IA	Back pain	CR spondylodiscitis	*P aeruginosa*	None	59 months alive
4	CAH	PEF	Upper GI bleeding, laparotomy for (1) Y-graft due to type I endoleak after EVAR and (2) distal Roux-Y gastric bypass		*E aerogenes*	Massive adhesions	55 months alive
5	CAH	PGI	Wound dehiscence in both femoral regions, fever, leucocytosis	Abscess around the graft, suspicion of spondylodiscitis	*E faecalis, S haemolyticus*	Temporary abdominal closure (uncontrolled bleeding tendency) Reoperation: POD 1: Abdominal closure POD 2: Heart pacer implantation (AV block III°)	54 months alive
6	CAH	PEF	Leucocytosis, weight loss	Expanding perigraft fluid with gas, infection of aortorenal bypass	*Bacteroides* spp, *E coli, E faecalis, E faecium*	Nephrectomy (left kidney without function) Splenectomy (splenic rupture due to splenomegaly)	36th month[a]
7	CAH	PGI	Wound dehiscence in right femoral region, acute ischemia, wet gangrene of right limb	Occlusion of right graft branch and deep abscess in right femoral anastomosis	*S aureus, E cloacae*	POD 11: Open surgical drainage of hematoma	49 months alive
8	CAH	IA	Upper left limb hematoma, leucocytosis	CR spondylodiscitis, abscess in upper limb	*S typhimurium*	None	45 months alive

Table II (online only). Continued.

Patient	*Graft*	*Diagnosis*	*Symptoms, indications, relevant medical history*	*CT scan, endoscopy and intraoperative findings*	*Microorganisms*	*Specific intra-op characteristics and reoperations (<30 days)*	*Last follow-up*
9	CAH	PEF	Abdominal pain, fever, leucocytosis	Expanding perigraft fluid with gas	*Streptococcus*	Partial ileum resection	49 months alive
10	CAH	PGI	Abdominal pain, fever, leucocytosis; pain in both femoral regions	Expanding perigraft fluid with gas, intraoperative diagnosis of fistula	*E faecium*	None	53 months alive
11	CAH	PEF	Lumbago, leucocytosis, anemia	Psoas abscess	*L rhamnosus, E cloacae, E coli*	POD 4: Anastomotic bleeding of homograft, partial duodenum resection POD 5: Tibial amputation on both sides (patient in severe septic shock with high rates of administrated catecholamines) POD 9: Wound repair (dehiscence of amputation wound)	38 months alive
12	CAH	PGI	Skin redness in femoral region, fever, leucocytosis (patient was admitted initially suffering from stroke)	Expanding perigraft fluid with gas	*S aureus*	Limited excision of the infected graft (high perioperative risk – stroke, dialysis, prostate Ca, coronary artery disease)	37th month[a]
13	CAH	PEF	Upper GI bleeding , urgent endovascular stent implant and fistula closure (10 days before CAH implantation)	Upper GI endoscopy	*E. faecium*		34 months alive
14	CAH	PEF	Upper GI bleeding	Upper GI endoscopy	*Propionibacterium* spp, CNS, *S sanguinis*	23rd month: Homograft reconstruction with Dacron patch (aneurysmatic degeneration of the left homograft-femoral anastomosis)	30 months alive
15	CAH	PEF	Ileus (urgent laparotomy in external hospital showed purulence)	Expanding perigraft (silver-coated) fluid with gas; intra-op diagnosis of fistula	MRSA, *E faecalis, K pneumoniae, E coli*	None	6 months alive
16	CAH	PEF	FUO	Psoas abscess-fistula, intra-op diagnosis	*S aureus, S anginosus*	None	13 months alive
17	CAH	PGI	FUO, laparotomy for sigmoid diverticulitis, septicemia (MRSA)	^{18}FDG PET-CT (SUV_{max}: 18)	MRSA, *P aeruginosa, K pneumoniae, P mirabilis, C albicans*	Explantation of occluded femoro-popliteal bypass (artificial material) POD 24-36: VAC therapy: Wound dehiscence (lymphocele) in upper limb	18 months alive

Table II (online only). Continued.

Patient	*Graft*	*Diagnosis*	*Symptoms, indications, relevant medical history*	*CT scan, endoscopy and intraoperative findings*	*Microorganisms*	*Specific intra-op characteristics and reoperations (<30 days)*	*Last follow-up*
18	CAH	PGI	Skin redness in femoral region, fever, leucocytosis	Expanding perigraft fluid with gas	*S epidermidis, S haemolyticus*	None	4 months alive
19	CAH	PEF	FUO	Expanding perigraft (silver-coated) fluid with gas	*S maltophilia, C krusei*	None	6 months alive
20	CAH	PUF	Acute massive macrohematuria	Suspicion for graft-ureter fistula	*E faecium, E faecalis, C albicans*	Left cutaneous ureterostoma POD 1: Rectal resection (4-cm rectal cancer)	POD 30[a]
21	CAH	IA	Lumbago, concomitant endocarditis of aortic and mitral valve, septicemia (MRSA)	CR in duodenum, psoas abscess, dissection of abdominal and iliac arteries	MRSA	None	POD 33[a]
22	CAH	PGI	Acute right limb ischemia, multiple thrombectomies of right graft branch (femoropopliteal I bypass), fever, leucocytosis	Expanding perigraft fluid with gas	*S epidermidis*	Explantation of the femoropopliteal bypass	5 months alive
Group B (silver-coated Dacron graft)							
23	SCG	IA	Asymptomatic	CT scan nonspecific-intra-op diagnosis of CR spondylodiscitis	*Corynebacterium* spp	None	46 months alive
24	SCG	IA	Fever, leucocytosis, septicemia, immunosuppressive therapy (heart transplantation)	CR of 10-cm iliac aneurysm	*P aeruginosa*	None	2nd month[a]
25	SCG	IA	Lumbago, HIV therapy	CR– intraoperative diagnosis of infection	*M avium*	Isolated organ perfusion	36 months alive
26	SCG	PEF	Critical ischemia of left limb, abdominal pain, laparotomy for rectal cancer 1 year ago	Occlusion of left common iliac artery, intraoperative diagnosis of aortoenteric fistula	*P aeruginosa*, CNS	None	48 months alive
27	SCG	IA	Abdominal pain, fever, leucocytosis, paraesthesia of left limb, hepatitis B and C, i.v. drug abuse	CR of the aneurysm in left psoas muscle, occlusion of left external iliac artery	*C. fetus fetus*	24th month: Thrombectomy of left graft branch and iliac-femoral bypass with SCG (occlusion of the left SCG branch)	30 months alive
28	SCG	IA	Fever, leucocytosis (nephrectomy for pyelonephritis 2 weeks ago)	Nonspecific CT findings intraoperative findings: Massive adhesions	*E coli*	POD 13: Relaparotomy with drainage (pancreatitis and wound dehiscence)	5 months alive

Table II (online only). Continued.

Patient	*Graft*	*Diagnosis*	*Symptoms, indications, relevant medical history*	*CT scan, endoscopy and intraoperative findings*	*Microorganisms*	*Specific intra-op characteristics and reoperations (<30 days)*	*Last follow-up*
29	SCG	PGI	Fever, leucocytosis, acute ischemia of left limb, urinary tract infection	Occlusion of left iliac branch, perigraft fluid	*S epidermidis*	Suprarenal clamping (<5 min)	6 months alive
30	SCG	IA	Abdominal pain, unknown Hb decrease (<7 g/dL), pleura empyema	CR, intraoperative diagnosis	*E. coli*	POD 19: In situ reconstruction with CAH (Pat No15), explantation of SCG (PEF)	6 months alive
31	SCG	IA	No specific symptoms, severe ocular infection (endophthalmitis)	Not specific CT findings- intraoperative diagnosis- massive adhesions	*E faecalis*	POD 8: Relaparotomy and wound repair (fascia and wound dehiscence)	23 months alive
32	SCG	IA	Acute abdominal pain, Hb-decrease, leucocytosis, fever	Type A dissection, cholecystitis, free rupture of abdominal aorta	*E faecalis, S epidermidis*	Cholecystectomy (cholecystitis), temporary abdominal closure POD 1: Second-look laparotomy, mini-thoracotomy (hemothorax) POD 2: Second-look laparotomy POD 5: Aortovisceral bypass (visceral ischemia caused by the dissection membrane) POD 12: Wound closure (laparotomy)	POD 17[a]
33	SCG	PEF	Upper GI bleeding	Diagnosis of PEF in upper GI endoscopy and CT scan	MRSA	Intraoperative cardiac resuscitation	POD 1[a]

CAH, Cryopreserved arterial homograft; CNS, coagulase-negative staphylococci; *CR,* contained rupture; *CT,* computed tomography; *EVAR,* endovascular (infrarenal) aortic repair; *^{18}FDG-PET,* fluorodeoxyglucose positron-emission tomography; *FUO,* fever unknown origin; *GI,* gastrointestinal; *IA,* infected aneurysm; Hb, hemoglobin; MRSA, methicillin-resistant *Staphylococcus aureus*; prosthetic-enteric fistula; *PGI,* prosthetic graft infection; *POD,* postoperative day; *PUF,* prosthetic urinary tract fistula; *SCG,* silver-coated graft.
[a]Indicates the patient died.