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Short and Mid Term Outcomes of Cryopreserved Abdominal Aortic Allografts Used as a Substitute for Infected Prosthetic Grafts in 200 Patients

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1 **Short- and mid-term outcomes of cryopreserved**
2 **abdominal aortic allografts used as a substitute for**
3 **infected prosthetic grafts in 200 patients**

4
5 **Short title: Short- and mid-term outcomes of aortic allografts**

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22

23 **What this paper adds:**

24 This large and homogeneous series of patients allowed quantifying the complication rate of
25 surgery for abdominal aortic graft infection and the rate of allograft-related complications.

26 Despite acceptable results of allografts used as a substitute for infected aortic prostheses, early
27 ruptures were observed, due to allograft to reinfection. Anastomotic prosthetic graft

28 pseudoaneurysm upon presentation, regardless of the microorganism involved, was identified
29 as a predictive factor for allograft rupture. Moreover, a bacteriological confirmation of

30 infection before initiation antibiotics and a rigorous imaging follow-up are recommended.

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34

35 **Introduction**

36 The incidence of aortic graft infections (AGI) is low (0.5-6%)¹⁻³ but is associated with high
37 morbidity and mortality rates of 10-50%³⁻⁷. Standard treatment remains controversial ranging
38 from radical surgery with complete excision of the graft and infected tissues and iterative
39 vascular repair, to conservative strategies. Some substitutes with infection-resistant properties
40 are available, including femoral veins, antibiotic- or silver-coated grafts. However, the
41 substitute showing the best resistance to infection and the best long-term results remains a
42 matter of debate.

43 Radical surgery using cryopreserved arterial allografts (CAAs) for the iterative repair is our
44 preferred strategy since the 1980s because several experimental and clinical studies have
45 shown the resistance of CAAs to colonization by most microorganisms involved in vascular
46 infections⁸⁻¹¹. Moreover, CAA is considered a safe¹¹ and even mechanically ideal material for
47 arterial repair, at least in the short term, with good outcomes¹². However, the benefit of such a
48 strategy remains to be demonstrated in the long term and in large series. Despite the recent
49 recommendations provided by the European Society of Vascular and Endovascular Surgery¹³,
50 there is a lack of evidence due to the heterogeneity and small sample sizes of the published
51 series.

52 This study provided a large database from which solid conclusions could be drawn. Its aim
53 was to investigate the early and late outcomes of patients with arterial graft infection treated
54 with complete excision of the infected graft and iterative arterial repair using a CAA starting
55 from the infrarenal aorta.

56

57 **Patients and methods.**

58

59 **Patients**

60 All consecutive patients treated with CAA for infrarenal aortic repair in prosthetic arterial
61 infections in our vascular department between January 1997 and December 2013 with a
62 follow-up until January 2016 were included in a monocentric study. Data were recorded in a
63 prospectively maintained database and were analyzed retrospectively¹⁴.

64 Demographics, cardiovascular risk factors, comorbidities and techniques including the CAA
65 features were recorded.

66 When a diagnosis of graft infection was suspected a Computed Tomography (CT)-scan was
67 systematically performed to identify a periprosthetic abscess, graft-enteric fistula or
68 pseudoaneurysm (PA).

69

70 **Bacteriological diagnosis**

71 The microorganisms responsible for infection were identified in bacteriological samples
72 collected preoperatively by drainage or CT-guided puncture of perigraft pus drainage or in
73 blood cultures or were directly collected intraoperatively. The analyzed intraoperative
74 samples included intraprosthetic and PA thrombus, perigraft collection or the graft itself. Our
75 institutional algorithm recommended to systematically perform bacteriological samples before
76 initiating antibacterial treatment.

77 The diagnosis of AGI was ascertained using the MAGIC classification¹³ if one major criterion
78 or at least two minor clinical, radiological or biological criteria were present. Infection was
79 defined as early if it occurred after <4 months and late if it occurred after >4 months¹³.

80 Then, broad-spectrum antibiotics were initiated before secondary targeted antibiotics after
81 identification of the microorganism by infectious disease specialists.

82 All survivors underwent CT and/or duplex ultrasound examinations before discharge and
83 were followed with a clinical examination and a new imaging at one and six months and
84 yearly thereafter.

85 **Cryopreservation protocol.**

86 All CAAs were provided by the tissue bank of our institution (Banque de Tissus de
87 l'Assistance Publique Hôpitaux de Paris, Hôpital Saint-Louis, Paris, France). Allografts were
88 obtained from brain-dead multiorgan donors and transported at a temperature between +3 and
89 +10°C to the bank in 500 mL of gelatin (Plasmion) solution containing antibiotics (160 mg of
90 gentamicin, 250 mg of vancomycin, 300 mg of Clindamycin or Lincomycin). After 36 hours
91 in this solution, they were placed in a cryopreservation solution composed of 50 mL of
92 dimethyl sulfoxide (DMSO) and 350 mL of tissue preservation fluid (Solution de
93 Conservation des Organes et Tissus, SCOT 30, Macopharma, Mouvaux, France). Allografts
94 were then frozen in a controlled-rate nitrogen vapor freezing chamber at a rate ranging
95 between -1°C and -2°C/minute up to -40°C and of -5°C/minute from -40°C to -150°C. CAAs
96 were then stored in a nitrogen vapor container (-150°C) until their use.

97

98 **Surgical technique.**

99 Exhaustive excision of all synthetic material whether or not macroscopically infected, was
100 performed in all cases. Aggressive debridement of the surrounding periprosthetic infected
101 tissues was performed to obtain a macroscopically normal surgical field. Arterial repair was
102 then performed using one or more CAAs. The allograft was systematically separated from the
103 bowels using a retroperitoneal tissue or bovine pericardial patch (Edwards Lifesciences,
104 Irvine, CA, USA) or by omentoplasty.

105 In all cases with graft-to-enteric fistula, the digestive part of the procedure was performed by
106 a gastrointestinal surgeon as previously described¹⁵. The digestive procedure ranged from a
107 simple suture of the bowel to resection and anastomosis with the third portion of the
108 duodenum depending on the tissue loss and fistula location.

109 Perioperative surgical data and CAA features were collected (intervention duration, blood loss,

110 number of allografts used, clamping level, need for vasoactive drugs, surgical procedure).

111

112 **Postoperative parameters**

113 Postoperative (at 30 day and in-hospital) mortality and systemic morbidities were recorded.

114 In-hospital complications requiring revision surgery were also collected. During the follow-up,

115 the need for allograft-related revision surgery, aneurysmal degeneration and thrombosis,

116 reinfection, survival and limb salvage were recorded. Ruptures were considered a reinfection

117 if no mechanical factors were found after reviewing the operative reports.

118

119 **Outcomes**

120 The primary outcome was the allograft-related revision surgery rate. Secondary outcomes

121 were the rates of 30-day mortality, survival, primary patency, limb salvage and infection

122 recurrence.

123

124 **Statistical analysis.**

125 Data are presented as a frequency (percentage) for qualitative variables and a mean \pm standard

126 deviation for quantitative variables. Statistical analysis was performed using SAS software

127 (version 9.4, SAS Institute, Cary, NC).

128 The analysis of the long-term mortality, primary patency, and graft-related complication-free

129 survival was performed using the Kaplan-Meier method. Potential risk factors for early

130 mortality were identified using univariate and multivariate logistic regression analysis.

131 Univariate factors associated with a p-value $<.20$ were included in the multivariate analysis

132 using a stepwise selection. Odds ratios (OR) with their respective 95% confidence intervals

133 (CI) were computed. Risk factors for short-term septic complications and long-term

134 complications were analyzed using a Cox model according to the method of Fine and Gray.

135 For the long-term risk factors, patients who died, were lost to follow-up or underwent
136 allograft explantation before 6 months were excluded from the analysis. For both analyses,
137 hazard ratios (HR) with their 95% CI were computed. A p-value <.050 was considered
138 significant. The conduct of this study was approved by our institutional review board under
139 the number 20190906192459.

140

141 **Results**

142 Patient demographics and clinical presentation

143 Over the study period, 200 patients with a mean age of 64.2 ± 9.4 years were included (**Table**
144 **1**). The indication for primary surgery was a non-infected aneurysmal or occlusive disease in
145 65 and 135 cases, respectively. The mean time between initial surgery and the diagnosis of
146 infection was 58 ± 65 months. In 51 cases (25.5%), infection occurred less than 4 months
147 after initial surgery.

148 The diagnosis of infection was made based on major clinical or radiological criteria in 167
149 cases (83.5%) (prosthetic-digestive fistula, periprosthetic abscess, cutaneous fistula). In case
150 of minor criteria (PA or graft thrombosis), the diagnosis was confirmed by collecting
151 microorganisms from the explanted grafts or intra-operative specimen or inflammatory
152 syndrome according to the MAGIC classification¹³. Among the patients with major criteria,
153 14 also had a PA.

154 Bacteriology

155 Microbiological findings are reported in **Table 2**.

156 All patients received antibiotics postoperatively and 172 (86%) preoperatively. The mean
157 duration of antibiotherapy was 57.3 ± 91 days.

158 The bacteriological samples were negative in 35 patients. Among them, 30 had received an
159 empirical antibiotherapy prior to bacteriological sampling. In these 35 patients, the diagnosis

160 of graft infection was based on the presence of a periprosthetic abscess (n=13), a cutaneous
161 fistula (n=9), a prosthetic-digestive fistula (n=5), a PA and an inflammatory syndrome (n=7), a
162 periprosthetic urinoma and an inflammatory syndrome (n=1).

163

164 **Operative Data**

165 Per-operative data concerning the surgical technique is reported in [Table 3](#).

166 Regarding patients who underwent a 2-stage surgery: all cases of bleeding were treated with
167 local repair (direct suture or a short graft interposition). In case of severe sepsis upon
168 presentation, an abscess drainage was performed before graft explantation. In case of acute
169 ischemia secondary to septic thrombosis, embolectomy was systematically performed.

170 A mean number of 8.6 ± 7 blood units were transfused, corresponding to a mean blood loss of
171 3.7 ± 3.7 L per patient.

172 A mean number of 2 CAAs were used per patient. The cryopreserved arterial segments used
173 were the descending thoracic aorta, the aortic bifurcation and one iliofemoral artery in 40.0,
174 43.5 and 50.5% of patients, respectively. One or more calcifications were present in 44.7% of
175 CAAs. The mean age of donors was 39 ± 13.3 years. These factors were not predictive of
176 long-term degeneration of the allograft.

177

178 **Postoperative Outcomes**

179 The 30-day mortality rate was 11% (n=22). The overall mortality rate was 14% (n=28) before
180 discharge (the causes of death are listed in [table 4](#)). This rate was even much higher in
181 patients with aorto-enteric fistulas (21%). Early reinfections (<1 month) were associated with
182 a significantly higher rate of in-hospital mortality compared to late reinfections (>1 month),
183 with mortality rates of 27.6% and 11.7%, respectively (OR=0.35 [0.13-1.04], $p=.030$).

184 The in-hospital morbidity rate was 57.5% (the postoperative complications are listed in [Table](#)

185 4). In-hospital revision surgery was needed in 59 patients (29.5%) (detailed in Table 5) of
186 whom 14 died. Among the 59 cases of revision surgery, 15 were related to the allograft (7.5%)
187 and led to the death of 3 patients (Table 6).

188 The predictive factors for post-operative death identified in the multivariate analysis were: the
189 age (OR = 2.9 [1.5-5.5] for 10 years, $p=.001$), the presence of postoperative acute renal failure
190 (OR = 3.8 [1.3-11.2], $p=.014$) and the number of transfused blood units (OR = 4.2 [1.8-9.8],
191 $p<.001$) (Table 7).

192 Among the 172 patients who survived during the early postoperative period, the mean follow-
193 up was 4.1 ± 3.9 years (median = 2.9 years, IQR 4.8 years). Fifty-three patients (26.5%) were
194 lost to follow-up, of whom 38 during the first 3 years. Fifteen were still alive at 3 years but
195 were lost to follow-up thereafter.

196 The 1-, 3- and 5-year survival rates were respectively 76%, 66% and 56% (Figure 1).

197 During the follow-up, 59 other patients died after the early postoperative period. The most
198 common causes were cancer (n=16), extravascular infectious disease (n=11), heart disease
199 (n=6). Six allograft-related deaths due to a rupture were reported (Table 6).

200

201 **Allograft-related events**

202 Seven late major amputations were reported during the follow-up, 2 were related to the
203 allograft.

204 The 1-, 3- and 5-year primary patency rates were respectively 92%, 84% and 80% (Figure 1).

205 The 5-year limb salvage rate was 90% (Figure 1).

206 The rates of patients free from allograft-related revision surgery were 85%, 77% and 70% at 1,
207 3 and 5 years, respectively (Figure 1) and the 30-day rate of allograft revision surgery was 6%.

208 The rate of allograft-related mortality was 3% (n=6 deaths).

209 All allograft-related complications are reported in Table 6.

210 Each allograft-related complication was reviewed: 27 patients required revision surgery
211 during the first 6 months (Table 6). Seventeen patients experienced a complete or partial (PA)
212 rupture of the allograft and 3 experienced an anastomotic tear or collateral bleeding. Among
213 these 17 patients, 5 died (including 2 before revision surgery) and 4 experienced successive
214 ruptures. The bacteriological samples collected during revision surgery were positive or
215 multiple ruptures occurred in all cases except one. A total of 22 interventions were performed.
216 Redo surgery consisted in a partial replacement with a new segment of allograft (n=13),
217 saphenous vein (n=3), *in situ* rifampicin-bounded prosthesis (n=3), stent-graft (n=1),
218 resection-anastomosis (n=1) and total resection + axillo-bifemoral prosthetic bypass (n=1).
219 All *in situ* prostheses except one were secondarily infected and explantation was needed. The
220 first revision surgery was performed after less than 6 weeks in 13 out of the 17 patients.

221 In the multivariate analysis, diabetes (HR = 4.18 [1.74-10.01], $p = .001$) and pseudo-
222 aneurysm upon presentation (HR = 2.92 [1.18-7.23], $p = .020$) were the only predictive
223 factors for allograft rupture before 6 months. The type of microorganisms and bowel fistulas
224 were not associated with an increased risk of rupture (Supplementary Table 1).

225 After 6 months, 25 patients (18%, n=25/139) experienced an allograft-related complication
226 (Table 6). Two ruptures were consecutive to two late allograft-related enteric fistulas (at 12
227 and 20 months) responsible for 1 death. PA occurred later in 6 patients (1 at 7 months, 2 at 3
228 years, 3 at 10 years). The PA that occurred at 7 months was a recurrence of a previous PA that
229 occurred after less than 6 months.

230 The 1-, 3- and 5-year CAA reinfection rates were 10, 12 and 12%, respectively.

231

232 Discussion

233 This series of patients allowed quantifying the complication rate of surgery for abdominal
234 aortic graft infection, in particular allograft-related complications from a homogenous cohort

235 of patients. Despite the acceptable results achieved with allografts used as a substitute for
236 infected aortic prostheses, a significant rate of early failures was observed, leading to an
237 increased risk of mortality.

238 The early mortality rate found in this study was acceptable (11%) compared to that reported
239 by Antonopoulos¹² (14.9%) although the rate of enteric fistulas upon presentation was higher.
240 Enteric fistulas were not associated with a significantly increased mortality rate contrary to
241 what has been reported in other studies^{6,11,16,17}, probably because of our aggressive
242 intervention at the bowel defect that prevented fistula recurrence¹⁵.

243 The most common risk factors for early death from aortic sepsis treated with *in situ* allografts
244 reported in the literature are the age of the patient^{6,7,18}, the need for emergent surgery^{7,11,17},
245 and enterobacteria and *Candida* infections^{3,19}. However, the only significant independent
246 predictors for death identified in our multivariate analysis were the age of the patient, the
247 presence of post-operative acute renal failure, and the number of transfused blood units
248 reflecting the invasiveness of such a surgery.

249 Our results confirmed that AGI remains a huge surgical challenge with a high morbidity rate
250 (57%) falling within the range of values reported in Antonopoulos meta-analysis¹². The septic
251 and hemorrhagic context of AGI, the physiological consequences of the surgical procedure,
252 and frequent age-related comorbidities could explain such a high complication rate. That is
253 why a high-volume center with a specialized intensive care unit is crucial for the management
254 of such patients.

255

256 **Short-term Allograft-Related Complications**

257 Our rate of allograft-related revision surgery during the first 6 post-operative months was 13.5%
258 (n=27). Among these cases, 3 were due to collateral bleeding and 7 to early thrombosis or
259 stenosis. However, the most worrisome causes of allograft-related revision surgery were

260 ruptures (n=17, 8.5%) since they were responsible for 5 deaths (2.5%).

261 Similarly, the resistance to infection and technical safety have been questioned due to a
262 relatively high rate of early ruptures of 5.9% in a recent meta-analysis¹². Subadventitial
263 rupture can occur as a result of a default in the freezing/thawing process, leading to
264 microcracks in CAA structure as shown in some historical reports when the process was still
265 immature^{20,21}.

266 However, after reviewing all cases of postoperative rupture or PA, we observed that among
267 the 17 patients for whom redo surgery was needed, all except one had positive bacterial
268 samples or multiple ruptures, supporting CAA infection rather than mechanical rupture
269 induced by cryopreservation.

270 CAAs have shown their resistance to colonization by the microorganisms involved in AGI in
271 *in vitro*²², *in vivo*^{8-10,23} and clinical¹² studies. But CAA ruptures secondary to persistent
272 infection are poorly defined in the literature.

273 We did not identify any pathogen that could be more prone to induce rupture, unlike some
274 studies that have identified *P. aeruginosa* or *Candida spp* as necrotizing organisms¹³. But we
275 showed that infections leading to PA of the native artery, regardless of the microorganism
276 involved, appeared to be associated with a higher risk of early allograft rupture. The
277 systematic collection of data on bacterial phenotypes involved in AGI is a promising field of
278 investigation since some of them could be more likely to induce a disruption of the aortic wall,
279 but unfortunately it was not included in our protocol. From this perspective, a proteomic
280 analysis could be proposed in the future to compare bacterial strains responsible for rupture.

281 In addition, 8 other patients experienced a rupture or a PA of the CAA, but they occurred 3-10
282 years after CAA implantation, supporting a degenerating process rather than the consequence
283 of persistent infection. In summary, a recurrence of CAA rupture mainly occurred within six
284 months of surgery and was related to infection recurrence and was found in about 8.5% of our

285 patients. Special care should be taken in case of PA upon presentation, for which a close
286 imaging monitoring is needed during the first 6 months. A duplex ultrasound examination
287 should be performed weekly for the first 6 weeks and then monthly thereafter to early detect a
288 CAA rupture. In case of successive ruptures, allograft explantation combined with prosthetic
289 extra-anatomic bypass should be considered.

290 The recommended duration of targeted postoperative antibiotherapy varies from 2 weeks to 6
291 months or even lifelong¹³. However, most authors, including us, recommend a 6-week
292 duration²⁴, especially since most (13/17) CAA ruptures occurred during this period.

293 Harlander-Locke et al.³ have found that the partial excision of the infected graft was a
294 significant predictor for failure, confirming our doctrine consisting in systematically resecting
295 all synthetic material and tissues, grossly infected or not, before allografting as
296 recommended¹³.

297 Although the lack of bacteriological confirmation has not been associated with a pejorative
298 predictive factor, effort should be made to avoid it, in order to provide appropriate
299 antibiotherapy¹³. In this case, our institutional protocol recommends the use of antibiotics
300 targeting Gram-negative bacillus for 5 days and Gram-positive cocci for 12 days after graft
301 removal. This protocol is based on the bacteriological spectrum we identified.

302

303 **Mid-term Allograft-Related Complications**

304 Allografts are known to degenerate over time. In our experience as in that of others, late
305 occlusive degeneration is nowadays much more frequent than aneurysmal degeneration (0-
306 11.1% and 0-4.9%, respectively)^{3-5,7,12,25}. Our conclusion was that the continuous
307 improvement of the methods for obtaining and preserving CAAs will probably eradicate late
308 aneurysmal degeneration. Even if an occlusive disease is easily treated using endovascular
309 techniques⁷, such a high rate remains a concern. Because of the limited life expectancy of

310 patients and the small size of series, the rate of late occlusive degeneration remains imprecise.
311 In our subgroup of patients still alive at five years, the rate of late occlusive degeneration
312 requiring revision after 6 months was 18% and involved the iliofemoral segment of the CAA
313 in 61.5% of cases. The etiology of late CAA degeneration remains controversial with several
314 theories, including a chronic immune rejection as reported in the arteries of transplanted
315 organs²⁶ or a lower resilience to mechanical stress than native tissues as suggested for the
316 mechanisms of late calcification of valvular allografts²⁷. Thus, CAA do not appear as an ideal
317 arterial substitute if their late complications are taken into account.

318 Nevertheless, in the published studies with the longest follow-up, the 5-year survival rate
319 ranges between 50% and 64%^{3,4,11,25,28}. In our study, with a mean survival of 7.6 years, this
320 rate was 57%. Thus, it could be assumed that the sustainability of CAAs is in line with such a
321 survival. Cryopreservation definitely did not prevent the need for late revision surgery, with a
322 rate of 25% at 5 years in our study and of 20% in the study by Harlander-Locke et al.³ in 220
323 patients. The quality of the CAA was also investigated: we concluded that the age of the
324 donor, but also the presence of calcifications were not predictive factors for long-term
325 complications. This result could support an extension of the criteria for artery harvesting in
326 order to compensate the low availability of CAA. However, late revision surgery consists
327 generally in limited “house-keeping” interventions associated with fairly low mortality and
328 morbidity rates.

329 The limitations of our study include its retrospective design and the inherent inaccuracy that it
330 implies, in particular with regard to antibiotic treatments: as a matter of fact, treatment
331 duration and the precise time between the detection of a microorganism and the initiation of
332 targeted antibiotics were poorly documented. Also, the lack of bacteriological confirmation in
333 35 patients could have led to an analysis bias due to the inability to administer an adapted
334 antibiotic. In addition, data from patients who were not candidates for surgery were not

335 collected in this study. But non-eligibility criteria were based on patient age and general
336 condition regardless of the septic event, as for any standard aortic surgery. Moreover, the
337 number of patients lost to follow-up could also have induced a bias for the long-term results
338 of CAA.

339

340 **Conclusion**

341 CAAs provide acceptable results to treat aortic graft infection despite early graft-related
342 reinfections. For that reason, it is recommended to bacteriologically confirm infection before
343 initiating antibiotherapy and to perform a rigorous imaging follow-up. This study showed that
344 this type of surgery is associated with a high morbidity due to patients' comorbidities and
345 surgery invasiveness and a high-volume center is thus needed to performed it. Mid-term
346 allograft-related complications were quite common but associated with low mortality and
347 amputation rates.

348

349

350 **Conflict of Interest/Funding:** None

351

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Figure Legends

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439 Figure 1

440 Cumulative Kaplan-Meier estimates with 95% confidence intervals of (A) survival, (B)

441 primary patency, (C) freedom from allograft reintervention, (D) limb salvage after use of

442 cryopreserved abdominal aortic allografts as a substitute for infected prosthetic grafts in 200

443 patients.

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Copy editors: please note that only the critical style editing has been made to these tables.
 Full copy editing is still needed. I have used green background color to highlight the edits that should be repeated in the following rows in the same column. After having moved the percentages from the last column to the previous column, please delete the last column.
 Please note that the hierarchy for the first column should be created by italics and indenting, not by bolding the texts.

Tables

Variable	Patients (n=200)	
Demographics		
Age - years	64.2 ± 9.4	-
Male	184 (92)	
Female	16	(8)
Cardiovascular risk factors		
Hypertension	122	(61)
Diabetes	29	(14.5)
Dyslipidemia	98	(49)
Smoking	181	(90.5)
Comorbidities		
COPD	46	(23)
Chronic renal disease	33	(16.5)
Dialysis	5	(2.5)
Coronary artery disease	54	(27)
PAD	144	(72)
ASA score		
I	1	(0.5)
II	95	(47.5)
III	97	(48.5)
IV	7	(3.5)
Indication for allograft		
<i>Prostheto-digestive fistula</i>	56	(28)
<i>Periprosthetic abscess</i>	68	(34)
<i>Cutaneous fistula</i>	43	(21.5)
<i>Graft thrombosis + microbio (+)</i>	6	(3)
<i>PA + microbio (+)</i>	20	(10)
<i>PA + inflam syndrome</i>	7	(3.5)
Initial bypass		
Aorto-femoral	139	(69.5)
Aorto-iliac	30	(15)
Aorto-aortic	17	(8.5)
Ilio-femoral bypass	4	(2)
Axillo-bifemoral bypass	3	(1.5)
Cross-over femoro-femoral bypass	3	(1.5)
EVAR	2	(1)
Aorto-popliteal bypass	1	(0.5)
Aorto-aortic + Aorto-birenal bypass	1	(0.5)

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Table 1: Preoperative characteristics of 200 patients with aortic graft infection.

Data are presented as *n* (%) or mean ± standard deviation. COPD = Chronic Obstructive Pulmonary Disease; PAD= Peripheral Arterial Disease, ASA= American Society of Anesthesiologists; PA=Pseudo-aneurysm VGI = Vascular Graft Infection; EVAR = endovascular aneurysm repair.

Microorganism	Patients (n = 200)	
<i>Staphylococcus Aureus</i>	62 (31.6) †	
<i>Escherichia Coli</i>	42 (21.4)	
Coagulase-negative <i>Staphylococcus</i>	32	(16.3)
<i>Enterococcus</i>	29	(14.8)
<i>Pseudomonas Aeruginosa</i>	28	(14.3)
<i>Candida</i> sp.	24	(12.2)
<i>Streptococcus</i>	25	(12.8)
Other enterobacteria	19	(9.7)
Anaerobes	12	(6.1)
<i>Proteus</i> sp.	11	(5.6)
<i>Klebsiella</i> sp.	10	(5.1)
<i>Citrobacter</i>	4	(2)
Other yeasts	2	(1)
Number of microorganisms per patient*		
None	35	(17.9)
1	74	(37.8)
2	35	(17.9)
3 or more	52	(26.4)

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465 **Table 2:** Microorganisms responsible for infection, identified in local samples (periprosthetic
466 abscess or graft) or blood cultures in 200 patients with aortic graft infection.

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470 Data are presented as *n* (%). Sp. = Species.

471 *4 with missing data

472 † 23 Methicillin-resistant *Staphylococcus Aureus*

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	Patients (n = 200)	
One-step emergent surgery	15 (7.5)	
Two-step emergent surgery	68	(34)
Hemostasis first	33	(16.5)
Abscess drainage first	30	(15)
Revascularization first (for acute ischemia)	5	(2.5)
Separation of the allograft from the bowels	200	(100)
Retroperitoneal tissue	126	(63)
Omentoplasty	69	(34.5)
Pericardial patch	5	(2.5)
Sartorius plasty	26	(13)
Duodenum fistula repair	36	(18)
Direct suture	22	(11)
Resection/anastomosis	14	(7)
Small bowel fistula repair	12	(6)
Direct suture	6	(3)
Resection/anastomosis	6	(3)
Colonic fistula repair	8	(4)
Direct suture	1	(0.5)
Resection	7	(3.5)

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Table 3: Peroperative features according to the surgical technique in 200 patients with aortic graft infection.

Data are presented as *n* (%).

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	Morbidity - n		Deaths - n
Cardiac	36 (18)		
Myocardial infarction	17	(8.5)	1
Cardiac arrhythmia	10	(5)	0
Acute pulmonary edema	4	(2)	0
Cardiac arrest	3	(1.5)	0
Cardiogenic shock	2	(1)	1
Pulmonary	45	(22.5)	
Pneumopathy	34	(17)	2
Atelectasis	10	(5)	0
ARDS	1	(0.5)	1
Pulmonary embolism	1	(0.5)	1
Digestive	30	(15)	
Ischemic colitis	14	(7)	3
Digestive bleeding	5	(2.5)	0
Bowel occlusion	4	(2)	0
Pancreatitis	4	(2)	0
Cholecystitis	3	(1.5)	0
Renal	63	(31.5)	
Acute renal failure	49	(24.5)	0
Acute renal failure with dialysis	14	(7)	0
Septic shock	21	(10.5)	8
Hemorrhagic shock	10	(5)	6
Multiorgan failure	5	(2.5)	5

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Table 4: Morbidity and causes of death during the postoperative in hospital period in 200 patients with aortic graft infection.

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Data are presented as n (%). ARDS: Acute Respiratory Distress Syndrome.

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Complications requiring revision surgery	Patients (n = 200)	
Related to the allograft	15 (7.5)	
Rupture	6	(3)
Pseudoaneurysm	2	(1)
Tear or collateral bleeding	3	(1.5)
Thrombectomy	2	(1)
Stenosis	2	(1)
Not related to the allograft	46	(23)
Major amputation	9	(4.5)
Minor amputation	2	(1)
Lower limb revascularization	8	(4)
Wound infection drainage	5	(2.5)
Deep abscess drainage	6	(3)
Hemostasis	5	(2.5)
Colectomy (ischemic colitis)	12	(6)
Cholecystectomy	3	(1.5)
Bowel occlusion	2	(1)
Nephrostomy	2	(1)
Enteric fistula repair	1	(0.5)
Jejunostomy closure	1	(0.5)
Evisceration	1	(0.5)

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Table 5: Inpatient complications requiring revision surgery during the postoperative hospital stay after allograft implantation for aortic graft infection in 200 patients. A given patient could experience several complications.

Data are presented as *n* (%).

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Complication	<6 months (n = 200)				>6 months (n = 139)	
	In-hospital		0-6 months		Patients	Deaths
	Patients	Deaths	Patients	Deaths		
Rupture	6 (3)	3 (1.5)	10 (5)	5 (2.5)	2 (1.4)	1 (0.7)
Pseudoaneurysm	2 (1)	0	7 (3.5)	0	6 (4.3)	0
Tear or collateral bleeding	3 (1.5)	0	3 (1.5)	0	0 (0)	0
Thrombosis	2 (1)	0	5 (2.5)	0	11 (8)	0
Stenosis	2 (1)	0	2 (1)	0	4 (2.9)	0
Aneurysm	0 (0)	0	0 (0)	0	2 (1.4)	0

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Table 6: Allograft-related complications and mortality during follow-up in 200 patients with aortic graft infection.

Data are presented as *n* (%).

Parameters	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p value	OR (95% CI)	p value
No bacteria in samples	*	.006		
Pseudomonas Aeruginosa	2.02 (0.73-5.58)	.22		
MRSA	2.01 (0.68-5.98)	.20		
Candida	3.32 (1.22-9.02)	.023		
Anaerobia	1.33 (0.28-6.46)	.66		
Enterobacteria	2.33 (1.01-5.38)	.043		
Age	2.58 (1.15-5.82)	.019	2.90 (1.53-5.50)	.001
ASA score	0.03 (0.42-2.07)	.86		
Preoperative antibiotics	0.72 (0.23-2.23)	.56		
Antibiotics		.95		
- Non selective vs selective	1.19 (0.45-3.13)			
- No antibiotics vs selective	0.82 (0.27-2.45)			
Hypertension	0.85 (0.37-1.95)	.70		
Diabetes	0.67 (0.19-2.39)	.78		
CKD	1.46 (0.54-3.95)	.42		
COPD	1.14 (0.45-2.87)	.78		
Coronaropathy	0.70 (0.27-1.84)	.47		
Emergency surgery	5.4 (1.86-15.7)	.004		
Digestive fistula	2.12 (0.93-4.81)	.070		
Preoperative hemorrhagy	1.43 (0.44-4.57)	.52		
Clamping level		<.001		
- Infra renal	1			
- Inter renal	0.59 (0.16-2.23)			
- Supra renal	5.10 (1.98-13.10)			
- Coeliac	2.23 (0.42-11.83)			
Intraoperative shock	6.05 (2.5-14.64)	<.001		
Postoperative ARF	3.87 (1.67-8.94)	<.001	3.84 (1.32-11.20)	.014
Postoperative dialysis	4.12 (1.26-13.4)	.027		
Amputation	1.81 (0.36-9.21)	.62		
Major medical complication	4.56 (1.64-12.7)	<.001		
Preoperative septic shock	4.33 (0.69-27.18)	.14		
Hypogastric reimplantation	2.17 (0.55-8.58)	.38		
Number of transfused blood units	4.4 (2.2-8.7)	<.001	4.23 (1.83-9.78)	<.001
Early revision surgery	3.43 (1.41-8.30)	.011		

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Table 7. Uni- and multivariate analysis of early mortality in 200 patients treated with cryopreserved abdominal aortic allograft for aortic graft infection.

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556 *MRSA : Methicillin-Resistant Staphylococcus Aureus ; ASA : American Society of*
557 *Anaesthesiologists ; CKD : Chronic Kidney Disease ; COPD : Chronic Obstructive Pulmonary*
558 *Disease ; ARF : Acute Renal Failure .*

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560 **: OR cannot be calculated in the absence of event*

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