From the Society for Vascular Surgery

Treatment and outcomes of aortic endograft infection

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Objective: **This study examined the medical and surgical management and outcomes of patients with aortic endograft infection after abdominal endovascular aortic repair (EVAR) or thoracic endovascular aortic repair (TEVAR).**
Methods: **Patients diagnosed with infected aortic endografts after EVAR/TEVAR between January 1, 2004, and January 1, 2014, were reviewed using a standardized, multi-institutional database. Demographic, comorbidity, medical management, surgical, and outcomes data were included.**
Results: **An aortic endograft infection was diagnosed in 206 patients (EVAR, n = 180; TEVAR, n = 26) at a mean 22 months after implant. Clinical findings at presentation included pain (66%), fever/chills (66%), and aortic fistula (27%). Ultimately, 197 patients underwent surgical management after a mean of 153 days. In situ aortic replacement was performed in 186 patients (90%) using cryopreserved allograft in 54, neoaortoiliac system in 21, prosthetic in 111 (83% soaked in antibiotic), and 11 patients underwent axillary-(bi)femoral bypass. Graft cultures were primarily polymicrobial (35%) and gram-positive (22%). Mean hospital length of stay was 23 days, with perioperative 30-day morbidity of 35% and mortality of 11%. Of the nine patients managed only medically, four of five TEVAR patients died after mean of 56 days and two of four EVAR patients died; both deaths were graft-related (mean follow-up, 4 months). Nineteen replacement grafts were explanted after a mean of 540 days and were most commonly associated with prosthetic graft material not soaked in antibiotic and extra-anatomic bypass. Mean follow-up was 21 months, with life-table survival of 70%, 65%, 61%, 56%, and 51% at 1, 2, 3, 4, and 5 years, respectively.**
Conclusions: **Aortic endograft infection can be eradicated by excision and in situ or extra-anatomic replacement but is often associated with early postoperative morbidity and mortality and occasionally with a need for late removal for reinfection. Prosthetic graft replacement after explanation is associated with higher reinfection and graft-related complications and decreased survival compared with autogenous reconstruction. (J Vasc Surg 2016;63:332-40.)**

With widespread use of aortic endograft placement for treatment of aortic pathology, complications of endografts are being increasingly reported. Infection of an endograft placed during abdominal endovascular aortic repair (EVAR) or thoracic endovascular aortic repair (TEVAR) is one of the most complex and morbid of these complications and is reported to be rare, with an incidence in small series of 0.2% to 5%[1-9]; however, there are currently no large multi-institutional studies.

Although complete removal of the infected endograft is the optimal approach for aortic graft infection treatment,[10,11] in many cases EVAR or TEVAR are used in patients who are unfit for open procedures, and therefore, the decision to perform an explantation with thoracic aorta or pararenal aortic cross-clamping is associated with a high risk of operative complications or death, or both. In addition, because of the low incidence of infection, diagnosis may be delayed, resulting in sepsis and other systemic complications. Optimal management of aortic endograft infection, whether medical with antibiotic therapy or surgical, is unknown, as is the optimal surgical reconstruction technique. This multi-institutional study was conducted to define the morbidity and mortality in patients with endograft infection and determine the optimal treatment strategies for this disease.

METHODS

Patients with EVAR or TEVAR infection who were diagnosed between 2004 and 2014 were included. Patients were identified using pre-existing investigator databases in addition to the following procedural and diagnosis

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codes: Current Procedural Terminology (American Medical Association, Chicago, Ill) code 35907 (excision of infected abdominal endograft), and International Classification of Diseases, Ninth Revision codes 996.62 (infection and inflammatory reaction due to other vascular device, implant, or graft), 996.74 (other complications due to other vascular device, implant, or graft), 998.59 (other postoperative infection), and 996.52 (mechanical complication due to other tissue graft, not classified elsewhere).

Primary study end points included morbidity and morality of surgical and nonsurgical treatment, and patient survival. Secondary end points included freedom from persistent sepsis, recurrent infection, graft explant, and limb loss.

Vascular Low-Frequency Disease Consortium and database management. The Vascular Low-Frequency Disease Consortium is a multi-institutional program that aims to improve the clinical care of patients with low-frequency or uncommon vascular diseases where only small series or discrepancies in management recommendations exist within the published literature.

Obtaining Investigational Review Board (IRB) approval was the responsibility of the principal investigator at each institution. Patient consent was waived by all IRBs due to the minimal risk and retrospective nature of the study. After IRB approval, patients were identified, and data were collected, then deidentified and transmitted to the Vascular Low-Frequency Disease Consortium at the University of California, Los Angeles.

The submitted data were examined for accuracy and completeness, with incomplete, inconsistent, or abnormal entries verified by the patient's institution using their unique patient identifiers. The principal investigator from each institution was responsible for the validity and completeness of all data submitted. The data were stored in a password-encrypted central database. All study investigators reviewed the collective data before abstract submission, presentation, and manuscript submission.

Statistics. Data were collected and maintained in an Excel 14 database (Microsoft Corp, Redmond, Wash). Statistical analysis was performed with SPSS Statistics 21 software (IBM Corp, Armonk, NY) and Prism 6.0 software (GraphPad Software, La Jolla, Calif). Continuous variables are presented as mean ± standard deviation unless noted otherwise. Differences between subgroups were analyzed using independent Student *t*-test, Kruskal-Wallis test, Mann-Whitney *U* test, and analysis of variance test. Unless numeric values are given, percentages are not inclusive. Differences between subgroups of noncontinuous variables were analyzed using the χ^2 test or the Fisher exact test. Multivariable analysis was performed using binary and multinomial logistic regression models. Time-dependent variables were analyzed using Kaplan-Meier life tables. For all comparative tests and analysis, a value of $P < .05$ was considered significant.

RESULTS

Patient demographics and comorbidities. A total of 206 patients (78% male) were treated for infected aortic stent grafts, 180 (87%) EVAR and 26 (13%) TEVAR, at 19 institutions (range, 1-27 patients per institution). The mean age was 68 years (range, 35-88 years), and the average body mass index was 26.6 kg/m^2 (range, 17-43 kg/m^2). Hypertension was the most common comorbidity, occurring in 174 patients (84%), with other cardiovascular risk factors present in a significant portion (Table I). Diabetes mellitus was present in 54 patients (26%), 15% of patients had a history of chronic infections, and 4% had a history of immunosuppression.

Table I. Patient demographics, comorbidities, and initial endovascular aortic repair (*EVAR*) and thoracic endovascular aortic repair (*TEVAR*) grafts

Variable	*No. (%) or mean ± SD (N = 206)*
Sex	
Male	161 (78)
Female	45 (22)
Age at diagnosis, years	68 ± 9
Comorbidities	
Hypertension	174 (84)
Smoking	119 (58)
Renal insufficiency	62 (30)
Diabetes mellitus	54 (26)
Congestive heart failure	45 (22)
Peripheral arterial disease	33 (16)
Chronic infection	31 (15)
Initial graft[a]	
EVAR	(n = 180)
Cook Zenith	42 (23)
Gore Excluder	35 (19)
Medtronic AneuRx	23 (13)
Gore TAG	20 (11)
Medtronic Endurant	12 (7)
Endologix	8 (4)
Medtronic (unknown type)	7 (4)
Guidant Ancure	5 (3)
Medtronic Talent	4 (2)
Gore Viabahn	2 (1)
Unknown	22 (12)
TEVAR	(n = 26)
Gore TAG	14 (54)
Medtronic Talent	5 (19)
Cook Zenith	3 (11)
Bolton Relay	2 (8)
Endologix	1 (4)
Unknown	1 (4)

SD, Standard deviation.
[a]Bolton, Sunrise, Fla; Cook, Bloomington, Ind; Endologix, Irvine, Calif; Guidant, Indianapolis, Ind; Medtronic, Minneapolis, Minn; W. L. Gore and Assoc, Flagstaff, Ariz.

Index aortic procedure: Technical factors and possible sources of infection. Infected EVAR and TEVAR stent grafts removed included multiple commercial devices (Table I). The index procedure used femoral cutdown access in 66% of patients, and 65% of the index aortic procedures were performed at hospitals other than the institutions that removed the infected endografts. An infection complicated the initial aortic operation in 70 patients (34%). with the most common being urinary tract infection (Table II), and the original operation was

Table II. Sources of possible endograft infection

Possible source of infection	*No. (%) (N = 205)*
Infection at index operation	70 (34)
Groin infection	14 (7)
Urinary tract infection	16 (8)
Other infection	40 (19)
Contaminated index operation	29 (14)
Endoleak at index operation	52 (25)
No intervention	23 (11)
With intervention	29 (14)
Interval procedure	69 (34)
Interval known infection	78 (38)

Table III. Symptoms and findings at diagnosis of aortic endograft infection

Presenting symptom	*No. (%) (N = 206)*
Pain	137 (66)
Back	71 (52)
Abdominal	47 (34)
Groin	8 (6)
Chest	7 (5)
Flank	4 (3)
Fever/chills	137 (66)
Aortic fistula	55 (27)
Endoleak	50 (24)
Rupture	23 (11)
Asymptomatic	10 (5)

contaminated in 29 patients (14%). An endoleak was initially detected in 52 patients (25%), with 29 (56%) undergoing subsequent intervention. Interval operative procedures for nonaortic-related pathology were performed in 69 patients (34%). Infections were documented in 78 patients (38%) between the time of stent graft placement and the diagnosis of stent graft infection that included sinusitis, infected hematoma, liver abscess, spine abscess, tooth abscess, vertebral infection, Q-fever, and endocarditis.

Symptoms/presentation and diagnosis. Common symptoms at presentation included pain in 137 patients (66%) and fever/chills in 137 (66%; Table III). Endoleak was present in 50 patients (24%), and an aortic fistula was identified in 55 (27%). Patients with infected TEVAR were more likely to have a fistula than those with an infected EVAR (12 of 26 vs 43 of 180; $P = .02$), with the most common being aortoesophageal. Only 10 patients (5%) were asymptomatic and identified incidentally.

The average time between the initial endograft placement and the detection of infection was 22 months (range, 0.2-158 months; Fig 1), with thoracic stent grafts detected earlier, at a mean of 18 months (range, 0.6-70 months), and abdominal stent graft infections identified at 24 months (range, 0.2-158 months; $P = .067$). Imaging identified the infection in 196 patients (95%), most commonly with computed tomography (CT) scan, in which 167 patients (81%) had findings of infection. In addition, 71 (34%) had a positive indium 111 leukocyte scan and eight (4%) had findings suggestive of aortic infection on magnetic resonance imaging. Preoperative blood cultures were positive in 123 patients (63%).

Medical management. Medical management with broad-spectrum antibiotics was undertaken initially in most patients; however, 197 patients (96%) ultimately underwent surgical explantation (Fig 2). Five patients (19%) in the TEVAR group never underwent surgical treatment, compared with only four patients (2%) in the EVAR group (mean follow-up, 4 months). Four patients (80%) in the TEVAR group died at a mean of 56 days after endograft infection diagnosis, and two (50%) of the EVAR group died of graft-related causes.

Surgical management. Stent graft infection was surgically managed in 197 patients (96%). Urgent or emergency surgery was performed in 37 (19%); of whom, 18 (49%) had rupture, 16 (43%) had endoleak, and 9 (24%) had aortic fistula. The mean time from diagnosis to procedure was 18 days. The interval between diagnosis and definitive repair in the remaining 169 patients was 153 days (range, 1-1012 days). Aortic replacement with a Dacron (DuPont, Wilmington, Del) graft was performed in 75 patients (38%), cryopreserved allograft in 54 (27%), polytetrafluoroethylene graft in 36 (18%), femoropopliteal neoaortoiliac system (NAIS) in 21 (11%), and extra-anatomic bypass in 11 (6%). Before implantation, 56 of the 75 Dacron replacement grafts were soaked in antibiotics, but only five of 36 polytetrafluoroethylene grafts received antibiotic impregnation.

Supraceliac clamping was required in 61 patients (35%), clamping above the superior mesenteric artery was required in 15 patients (9%), a suprarenal clamp was required in 59 (34%), and clamping above one renal artery was required in 9 (5%). In only 33 patients (19%) was infrarenal clamping performed. Seven of the TEVAR infection group (27%) required left heart bypass.

The mean operative time was longer for patients undergoing NAIS (543 minutes; range, 415-744 minutes) or cryopreserved allograft (502 minutes; range, 243-1029 minutes) procedures than those undergoing extra-anatomic (320 minutes; range, 201-465 minutes) or prosthetic (359 minutes; range, 230-682 minutes) bypass (Table IV). Mean blood loss was 4067 mL, with no statistical difference between procedure types. At least one additional procedure was needed in 71 patients at time of infected graft explant (Table V).

Intraoperative cultures identified gram-positive organisms in 42 patients (22%), with *Streptococcus* the most prevalent bacteria. Gram-negative organisms were found in 25 patients (13%), with *Escherichia coli* and *Prevotella* (bacteroides) the most common. Fungus was identified in eight patients (5%). Cultures were polymicrobial in 66 patients (35%) and negative in 56 (30%). Intraoperatively, perigraft abscess was present in 87 patients (44%), biofilm was present in 31 (16%), and graft-bowel erosion was present in 27 (14%). Postoperative antibiotic therapy was continued indefinitely in 122 patients (62%), and the

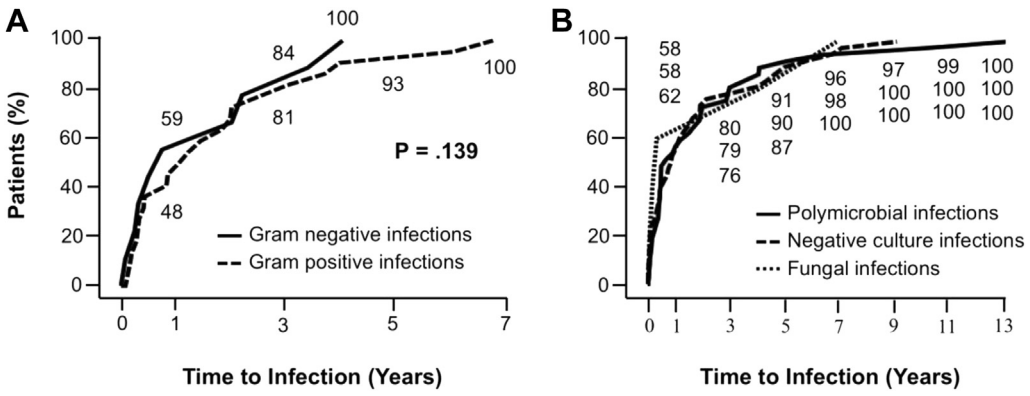

Fig 1. Time from the initial endograft placement in endovascular aortic repair (EVAR) or thoracic endovascular aortic repair (TEVAR) to the diagnosis of aortic endograft infection in **(A)** patients with gram-positive and gram-negative infections and **(B)** those with polymicrobial, fungal, and negative culture infections.

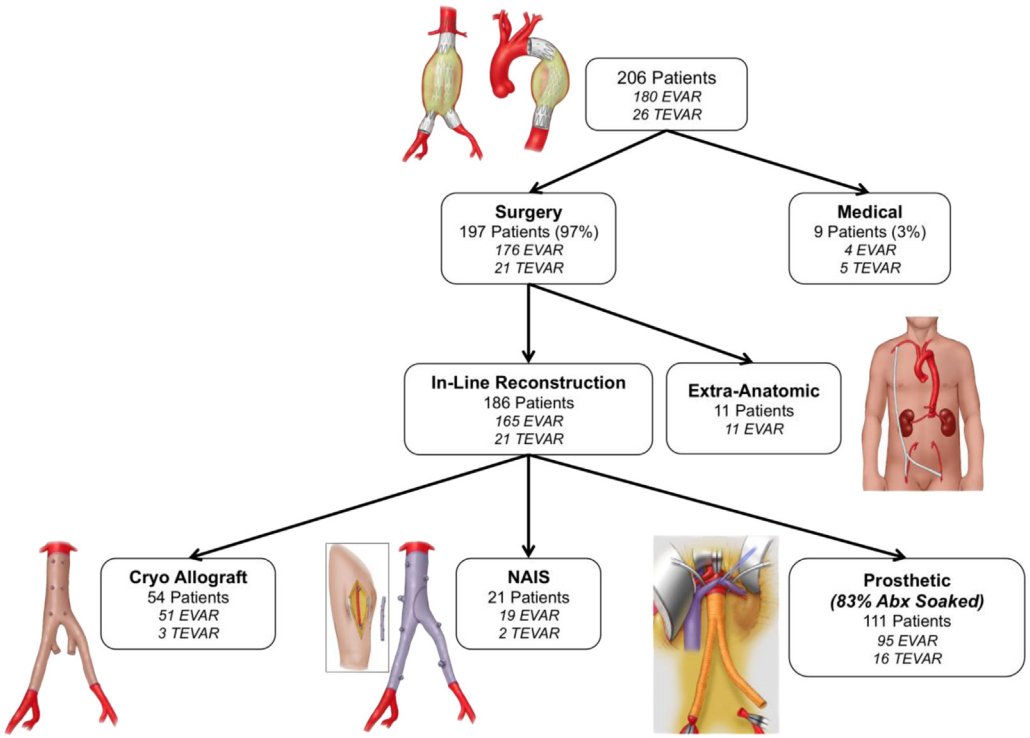

Fig 2. Flow chart details the management of patients with aortic endograft infection. *Abx*, Antibiotic; *EVAR*, endovascular aortic repair; *NAIS*, neoaortoiliac system; *TEVAR*, thoracic endovascular aortic repair.

remaining patients were treated for a mean of 165 days (range, 11-1825 days).

Perioperative complications occurred in 69 patients (35%), the most common of which was persistent sepsis in 27 (14%; Table VI). Outcomes were independent of institution and volume. Variables that were predictive of persistent sepsis included use of a prosthetic graft for aortic replacement, polymicrobial infection, and groin infection after the initial aortic procedure. The replacement graft ruptured in five patients at 7, 13, 35, 39, and 95 days after endograft excision, and all but one subsequently died. Four patients had thrombosis or occlusion of their grafts, but there was no perioperative limb loss. There was no predilection for type of replacement graft in the graft rupture or failure groups.

The 30-day perioperative mortality was 11%, and the mean length of stay after the procedure was 23 days (range, 1-94 days), with no statistical difference between patients with infected EVAR vs TEVAR graft removal. The mean follow-up was 21 months (range, 1-149 months), with

Table IV. Operative data in patients undergoing surgical management of aortic endograft infection

Variable[a]	*Extra-anatomic bypass (n = 11)*	*Prosthetic (n = 111)*	*Cryoallograft (n = 54)*	*NAIS (n = 21)*	P *value*
EBL, mL	3909 ± 1539	4142 ± 524	3588 ± 374	4986 ± 752	NS
Operative time, min	320 ± 99	359 ± 22	502 ± 54	543 ± 38	<.001
Perioperative mortality	2 (18)	14 (13)	4 (7)	2 (10)	.103
Complications	7 (64)	40 (36)	14 (26)	7 (33)	.046

EBL, Estimated blood loss; *NAIS*, neoaortoiliac system; *NS*, not significant.
[a]Continuous data are shown as the mean ± standard deviation and categoric data as number (%).

Table V. Additional procedures performed during infected aortic endograft explant

Procedure	*No. (%) (N = 197)*
Ureteral stenting	9 (5)
Vertebral body débridement	8 (4)
Aortoduodenal fistula repair	6 (3)
Splenectomy	6 (3)
Esophagus repair	4 (2)
Duodenum repair	4 (2)
Small bowel repair	4 (2)
Omentoplasty	4 (2)
Retroperitoneal abscess drainage	4 (2)
Fasciotomy	4 (2)
Bovine pericardium patch angioplasty	3 (2)
Aortoenteric fistula repair	2 (1)
Cholecystectomy	2 (1)
Colostomy	2 (1)
Renal bypass	2 (1)
Nephrectomy	2 (1)
Groin flap coverage	2 (1)
Thrombectomy	2 (1)
Renal endarterectomy	1 (<1)

Table VI. Postoperative complications in patients managed surgically

Complication	*No. (%) (N = 197)*
Persistent sepsis	27 (14)
Recurrent infection	12 (6)
Perioperative	9 (5)
Long-term	3 (2)
Myocardial infarction	9 (5)
Pneumonia	8 (4)
Acute kidney injury	6 (3)
Stroke	5 (3)
Arrhythmia	5 (3)
Graft rupture	5 (3)
Perioperative	2 (<1)
Long-term	3 (2)
Ischemic colitis	4 (2)
Acute respiratory failure	4 (2)
Anastomotic hemorrhage	4 (2)
Perioperative	3 (2)
Long-term	1 (<1)
Graft thrombosis/occlusion	4 (2)
Perioperative	3 (2)
Long-term	1 (<1)
Urinary tract infection	3 (2)

an overall 5-year survival of 51%. Explantation of the graft placed for open reconstruction was necessary in 19 patients at a postoperative mean of 540 days (range, 36-1253 days), with life-table explantation rates of 6%, 13%, and 16% at 1, 3, and 5 years, respectively. Factors that were predictors of replacement graft explantation on multivariate analysis included procedure duration >540 minutes and use of an extra-anatomic bypass.

Survival was worse in patients with gram-negative infections than in those with gram-positive infections (56% vs 31% survival at 5 years; $P = .011$), and there was a trend for decreased survival with polymicrobial infections, although this was not statistically significant. Patients with abdominal stent graft infections had better survival than those with thoracic stent graft infection (52% vs 29% survival at 5 years; $P = .038$), with most of the additional deaths occurring during the perioperative period (Fig 3). Survival was significantly different when autogenous reconstructions were compared with prosthetic reconstructions, with NAIS (65%) and cryopreserved (72%) in-line reconstruction together having overall 5-year survival of 71% compared with 53% in patients with antibiotic-soaked prosthetic and 12% in those treated with bare prosthetic grafts.

Univariate analysis identified several factors associated with graft and all-cause mortality (Table VII). Multivariate predictors of all-cause mortality included uncontrolled hypertension, renal insufficiency, chronic infection, endoleak with no intervention, procedure duration >540 minutes, blood loss >8000 mL, aortic fistula, and polymicrobial infection.

DISCUSSION

Fortunately, infection after EVAR or TEVAR is a rare problem. Previous publications, consisting of small single-center studies with only a small number of patients,[2-4,6,9,12-14] show that the overall incidence of infection after endograft placement is estimated to occur in <1% of cases. Our series represents a multicenter experience during a 10-year period and therefore cannot provide data on the incidence of endograft infection, because more patients were referred to treatment centers from other institutions, but our study provides an analysis of a large number of patients managed for infected EVAR or TEVAR. The differences between performing a standardized review over a meta-analysis are that there

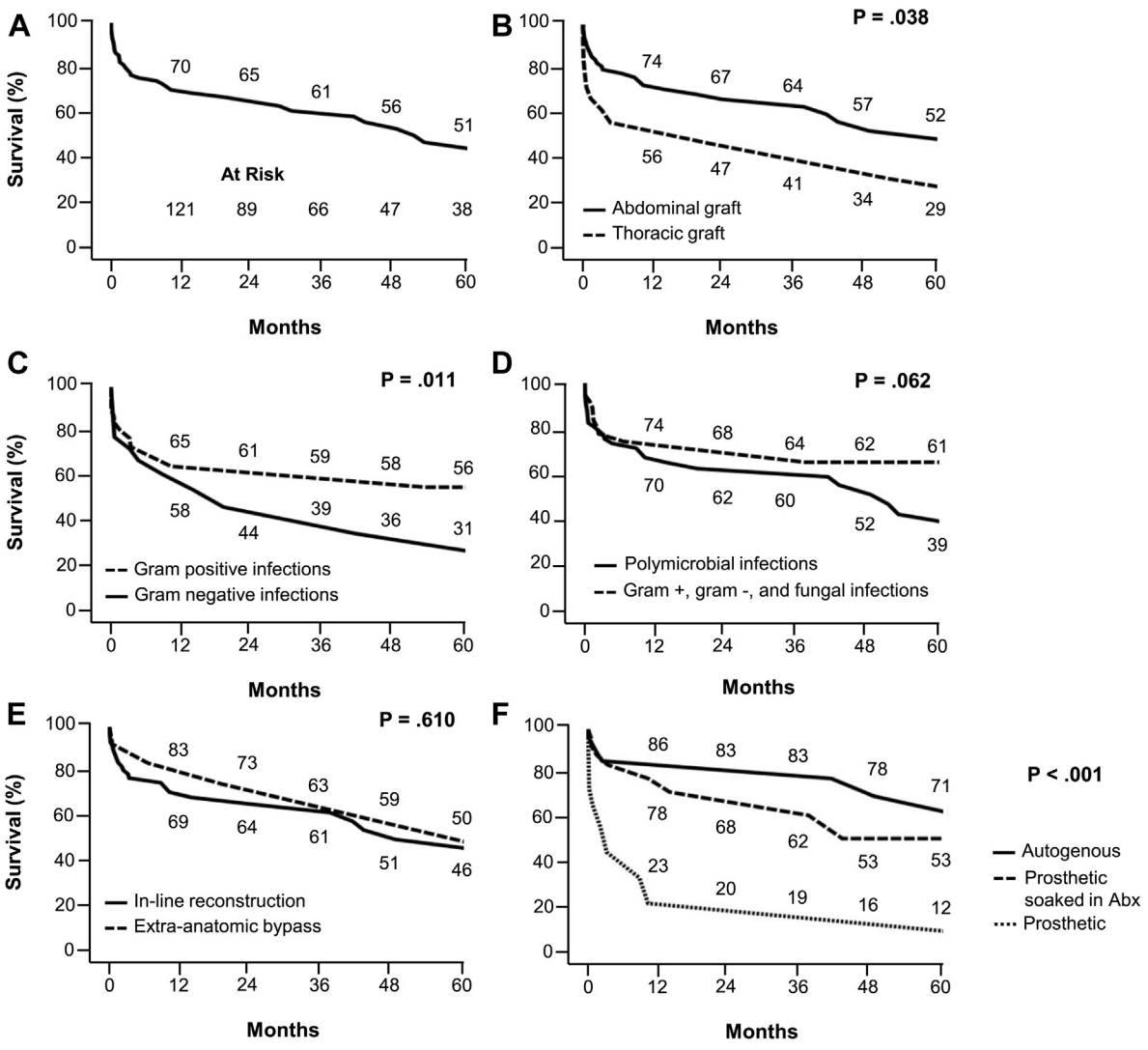

Fig 3. Patient survival **(A)** overall, **(B)** infected endovascular aortic repair (EVAR) vs thoracic endovascular aortic repair (TEVAR), **(C)** gram-positive infections vs gram-negative infections, **(D)** polymicrobial infections vs gram-positive, gram-negative, and fungal infections, **(E)** in-line reconstruction vs extra-anatomic bypass, and **(F)** autogenous reconstruction vs prosthetic grafts soaked in antibiotics (*Abx*, in-line and bypass) vs prosthetic grafts not soaked in antibiotics (in-line and bypass).

was congruence in data collection, and it allowed centers to contribute varying numbers of patients to create a robust database from which stronger conclusions can be gleaned.

Explantation of endovascular stent grafts for any etiology is associated with a high morbidity and mortality and often requires a more proximal aortic clamp than the index procedure would have required. Patients who require explantation because of infection have worse outcomes than those with endoleak or stent failure because of underlying sepsis, comorbidities, and the extent of resection required.[12]

Diagnosis of infection occurred in the most of these patients <22 months from the index operation, indicating that infection of the graft may occur relatively soon after implantation. In fact, nearly 34% of the patients in our series had an infectious complication in the perioperative period of their original operation, and the index procedure in 14% was contaminated. These observations are supported by studies that show decreased resistance to infection within the first week after implantation of covered stents in a canine model.[15]

The mean of 156 days between diagnosis and treatment in our study could be explained by an attempt by surgeons to avoid a second large abdominal operation and to treat the patient medically, and most patients were started on antibiotic therapy and medically optimized during this period. There was also occasionally a delay in the patient's

Table VII. Multivariate predictors associated with morbidity and mortality in patients managed surgically

Graft-related mortality	P *value*
Prosthetic graft (in-line and extra-anatomic)	<.01
Estimated blood loss >6000 mL	<.01
Chronic infection	<.01
Procedure duration >420 minutes	.018
Rupture at presentation	.022
Preoperative creatinine >2.1 mg/dL	.029
Society for Vascular Surgery comorbidity score >6	.042
Endoleak at presentation	.043
Aortic fistula at presentation[a]	.084
Prosthetic graft not soaked in antibiotic[a]	.153
Groin infection complication[a]	.276
Age >70 years[a]	.441
Infection between index procedure and endograft infection diagnosis[a]	.687
Persistent sepsis	
Prosthetic graft (in-line and extra-anatomic)	.011
Polymicrobial infection	.021
Groin infection after initial aortic procedure	.042
Extra-anatomic bypass	.045
Aortic fistula at presentation[a]	.117
Prosthetic graft not soaked in antibiotic[a]	.174
Gram-negative cultures[a]	.335
Smoking history[a]	.388

[a]Indicates the variable was significant in univariate analysis.

referral from the primary care center to the tertiary center that managed the infected aorta.

Although placement of endografts in infected fields has been reported, it may be appropriate to only use the endograft as a bridge to open revascularization, because these bridge grafts are prone to ongoing infection.[16,17] In addition to the perioperative infectious complications in our series, 38% of patients had an interval infection, 34% had an interval procedure that may have been a nidus for infection, and 25% had an endoleak after the initial graft placement that was treated with sac intervention in more than half (most commonly for type II endoleaks). The Zenith (Cook, Bloomington, Ind) EVAR device and the TAG (W. L. Gore and Assoc, Flagstaff, Ariz) TEVAR device were the most common grafts removed, but this is likely related to the prevalent use of these grafts rather than a particular device predilection for infection. Given these findings, clinicians should prescribe prophylactic antibiotic therapy in every EVAR/TEVAR patient, initially and when undergoing subsequent invasive procedures, to decrease possible contamination of the covered stents.

Our patients had a morbidity rate of ~35% and an overall mortality at 5 years of 51%. Those with TEVAR had worse outcomes than EVAR in our series as well as in others,[13] with an overall 5-year mortality of 29%. This increase in TEVAR mortality was predominantly in the perioperative period and likely related to higher rates of aortic fistulization, need for left heart bypass, and a higher cross-clamping level than in patients undergoing EVAR excision. In addition, techniques that can be used readily in the abdominal aorta, such as NAIS or extra-anatomic bypass, are fraught with technical issues in the chest, thus limiting the repair options in most cases to cryopreserved allograft or prosthetic bypass with soft tissue coverage.

The standard of care for management of both EVAR and TEVAR infection is explantation of the graft, débridement of necrotic tissue, and reconstruction of the aorta, often with autologous tissue coverage using omentum or fascia lata. Interestingly, our data show a difference in outcomes depending on the type of repair used. Patients with prosthetic repairs, particularly if not impregnated with antibiotics, had worse survival than those with autogenous repairs using cryopreserved venous or arterial bypasses or deep vein harvested from the femoral-popliteal distribution (NAIS procedure), despite these procedures taking longer. In fact, on multivariate analysis, use of a prosthetic graft was a predictor of overall graft-related mortality. Impregnating the prosthetic grafts with rifampin improved outcomes, and should be done if replacement with autogenous tissue is not possible. Owing to the positive binding mechanism between rifampin and Dacron, reinfection rates in the face of infection decrease to between 4% and 22% when soaked with this antibiotic.[18]

Previous studies of open aortic graft infections found the presence of an abscess was a contraindication to the use of an in situ prosthetic aortic replacement.[10,11] It is possible that in the setting of infected EVAR/TEVAR, the presence of an aneurysm sac behaves similarly to an abscess, making prosthetic replacement less favorable than an autologous or cryopreserved allograft. In addition, the acuity of the operation may have influenced the type of repair. It is possible that surgeons chose a prosthetic graft or prosthetic extra-anatomical bypass for emergency cases when an NAIS procedure was not appropriate or when autogenous grafts, such as cryopreserved aortoiliac grafts, were not immediately available. Therefore, the degree of emergency and conduit may have had an effect on the outcomes associated with each procedure. Although the data did not specifically support omental or soft tissue graft coverage, omental or tissue coverage is recommended based on extrapolation of data from open infected graft series.[10]

The better option for repair in our series was use of cryopreserved allograft or the femoral-popliteal vein (NAIS) for aortic reconstruction. The NAIS procedure has been established as an option in the management of infected aortic grafts, with a low amputation rate, high long-term patency, and acceptable perioperative and long-term mortality.[19] Its use in the management of infected stent grafts, however, has not been well described. The main disadvantage of the technique is the length of the operation, which often requires two surgical teams, and venous morbidity, which occurs as chronic venous insufficiency in up to 15% of patients, as well as a need for fasciotomies after aortic reconstruction in up to 12% of patients.[20] This was not demonstrated in our data; nonetheless, because operative time was a predictor for graft-related mortality, the use of NAIS should be reserved for patients who are able to tolerate long operative times.

Use of cryopreserved allograft is another option for aortic reconstruction in infected fields, with a 30-day

mortality of 9% to 28%, excellent graft patency, and low reinfection rates at 5 years.[21,22] Although the mean operative time for using cryopreserved allograft was 502 minutes, the median was 418 minutes, and this time often included performing additional procedures and, in some cases, thawing time or extending the graft to the distal common or superficial femoral artery using cryopreserved femoral artery. Complications attributed to this procedure in the literature include aneurysmal degeneration of the graft and bypass limb thrombosis, neither of which was demonstrated in our data.

Other predictors of all-cause and graft-related mortality are similar to other large series of open abdominal operations and include the presence of chronic infection, long duration of procedure, significant blood loss, and renal insufficiency. Polymicrobial infections predicted all-cause mortality and persistent sepsis, so patients with polymicrobial cultures should be treated with long-term antibiotic therapy in addition to complete explantation and débridement.

Nearly all of the patients in this series were initially started on broad-spectrum antibiotics before the definitive operation, but only a small subset of our patients underwent medical management alone. The follow-up period in these patients was short, and the mortality rate was high: nearly 80% of the medically managed TEVAR patients and 50% of the EVAR patients died during follow-up. Although this study does not have the power to compare medically managed patients with surgically managed patients, it adds to the literature in supporting surgical over medical management of infected stent grafts.

Limitations to this study arise mostly from the retrospective nature of the design, which is inevitable in a low-frequency disease. In addition, the initial operations in most of these patients were done at different institutions other than at the treating centers, which made it difficult to determine the incidence of endograft infection. A comparison with a noninfected EVAR/TEVAR group was not made, so that risk factors for development of infection could only be inferred. Finally, the rarity of this endograft complication resulted in only small numbers of patients being treated by each contributing center, each with a different experience and skill set. Thus, patients were not standardized, even if receiving the same definitive operation.

CONCLUSIONS

The diagnosis of infected endograft should be pursued in symptomatic EVAR or TEVAR patients presenting with history of chronic infection, interval procedures, infection complicating the initial aortic repair, or a contaminated index case. Management should be surgical, with autogenous reconstruction, and if this is not an option, prosthetic graft impregnated with antibiotics should be used.

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DISCUSSION

Dr Jon Matsumura (*Madison, Wisc*). A great presentation, Dr Duncan, on a really difficult problem. My question is in regards to the patients who had an interval procedure prior to their diagnosis of infection. What is the time between the interval procedure and the infection? How many were translumbar embolizations? I am concerned that if we are aggressive with treatment of type II endoleaks, we might be subjecting those patients to an increased risk of graft infection.

Dr Audra A. Duncan. Only 14% of the original endografts had interval procedures for endoleak. I actually thought it was a relatively low number. Not all the endoleaks were treated, slightly more than half. We did not ask specifically about translumbar approach in the data collection. I was suspecting the rate of endograft interventions would be higher.

Dr William Jordan (*Birmingham, Ala*). Thank you, Dr Duncan, for that presentation. It is very helpful information. A question similar to Jon's earlier one is, I would be interested to know how many of these infections might have occurred relative to a nonvascular procedure. I feel that we have seen cases of potentially lumbar spine operation or maybe even a urologic intervention that then potentially seeds the graft. And I also wonder if you can give us a recommendation on prophylactic antibiotics for nonvascular procedures on patients who have had endografts.

Dr Duncan. As you will see in the paper, we have a list of "other procedures" that they underwent between endovascular aortic repair and infection. The main ones we looked at were groin infections and urinary tract infection (UTI), but there is a laundry list of other procedures that they had.

At our institution we have patients take an antibiotic for any invasive procedure, dental procedures, etc. It is not consistent across institutions. I am not sure that we have data to support making that recommendation, but it is certainly something that we do as a practice.

Dr Anil Hingorani (*Brooklyn, NY*). Excellent set of data. I had a question about the cryopreserved procedures. Why do they take so long? I thought usually the neoaortoiliac system (NAIS) would take longer.

Dr Duncan. I don't know. There is some preparation time required with thawing the graft, etc, and preparing it. Sometimes it leaks from the lumbar sites. That was an unexpected number, I'll admit.