

➤ **Original Article** ◀

Surgical Management of Mycotic Aortic Aneurysms

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Purpose: A mycotic aneurysm is an uncommon disease associated with a high mortality rate when managed surgically. This study reviewed our experiences in the surgical management of mycotic aortic aneurysms.

Methods: In total, 26 patients who underwent surgery for a mycotic aneurysm were retrospectively reviewed. The mycotic aneurysms involved the thoracic aorta in 9 patients, the thoracoabdominal aorta in 4 patients, and the abdominal aorta in 13 patients. An overt aortic rupture in the mediastinum or retroperitoneal space was detected in 4 patients. Patients were classified into one of two groups, febrile or afebrile, and background characteristics, surgical intervention, and early and late mortalities were all compared.

Results: There were 19 patients who underwent open surgery, and 7 patients underwent endovascular repair. No significant differences in the clinical characteristics were found between the two groups; however, the incidence of postoperative complications was significantly higher in the febrile group than in the afebrile group ($P=0.024$). Overall mortality was 15.4% (4/26), and 30-day mortality was 7.7% (2/26).

Conclusion: Although febrile patients had a higher incidence of postoperative complications, surgical mortality from a mycotic aneurysm was within an acceptable range. Each patient should be thoroughly evaluated and treated on a case-by-case basis, using conventional open repair, endovascular repair, or a combination of both approaches.

Keywords: mycotic aortic aneurysm, surgical management, endovascular treatment

Introduction

Mycotic aortic aneurysm is an uncommon disease that

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makes up 0.65% to 2% of all aortic aneurysms.¹⁾ The gold standard for its treatment is resection, debridement of infected tissues, and graft replacement. Many adjunctive procedures and techniques have been proposed to avoid recurrent infection, including the use of 1) an omental flap or pedicled muscle flap to isolate the graft and fill dead space; 2) an open dressing and delayed closure²⁾; 3) biological materials, such as a homograft or spliced vein graft; and 4) a silver-coated graft or antibiotic-soaked graft.^{3,4)} Because the surrounding tissue may be infected with bacteria, extensive resection is frequently necessary. Despite meticulous surgical planning, the mortality rate after open surgical repair can be as high as 40%.^{3,5,6)} This high surgical mortality may be related to the severe medical comorbidities of the patients (e.g., diabetes or steroid use), the extensive surgical procedures performed, and unstable preoperative conditions due to aneurysm rupture or sepsis.⁷⁾ Recent studies suggested that endovascular therapy is a minimally invasive option for the treatment of such moribund patients.^{8–13)} The purpose of this study was to compare the perioperative complications, surgical methods, and mortality in patients with mycotic aneurysms who are in either an active or inactive infective phase.

Methods

Patients

Here, 26 consecutive patients who underwent surgery for an infected aortic aneurysm from January 2002 to May 2015 were retrospectively analyzed. Written, informed consent was obtained from all patients prior to surgery. The following patient characteristics were analyzed: age, sex, medical history, tobacco use, comorbidities, symptoms, fever, results of microbiological cultures, aneurysm location, treatment modality, early and late complications, survival, and need for reintervention.

The patients were classified into two groups by temperature: the febrile group, with a temperature greater than or equal to 38°C within 24 hours before surgery, and the afebrile group, with a temperature less than 38°C. A diagnosis of an infected aneurysm was made according to clinical features, including signs, symptoms, and labora-



tory tests [e.g., fever, pain, leukocytosis, and elevated C-reactive protein (CRP) levels], positive blood cultures, or characteristic radiologic features (e.g., lobulated vascular mass, indistinct and irregular aortic wall, perianeurysmal edema, perianeurysmal soft-tissue mass, and perianeurysmal gas).^{14,15} Intravenous antibiotics were given once the diagnosis of infected aortic aneurysm was confirmed. The choice of antibiotic regimen was based on blood culture results and microorganism sensitivity testing. In cases of negative bacterial cultures, an empiric antibiotic regimen was used. Patients who had a lobulated pseudoaneurysm without any history, signs, or symptoms of infection were excluded from this study.

Surgical intervention

Surgical intervention was considered after completion of the antibiotic treatment (i.e., 4 to 6 weeks) for patients with a good response to the antibiotic regimen. Early surgery was indicated for uncontrolled infection or evidence of overt/contained aortic rupture. Fistula formation to the respiratory or gastrointestinal tract with massive bleeding was managed by emergency surgery, which was defined as a surgical procedure performed within 24 hours of patient admission to the hospital. Urgent surgery was defined as a surgical procedure performed after 24 hours but within 48 hours of admission. Surgical management included extensive debridement of infected tissues, copious irrigation of the surgical field with saline, and in situ or extra-anatomical reconstruction with omental wrap/omentopexy. Extra-anatomical bypass was used in cases of severe, purulent infection of the aneurysmal sac or incomplete debridement due to severe adhesions. Endovascular treatment was used for hemodynamically unstable patients or for elderly, medically fragile patients. Endovascular techniques with homemade stent grafts became available in 2005, and commercial stent grafts were introduced in 2008 at our institution.

Postoperative antibiotics were administered intravenously in the hospital for at least 4 weeks after surgery and until the clinical and laboratory parameters [e.g., temperature, white blood cell (WBC) count, and CRP levels] had normalized. In patients undergoing endovascular repair, antibiotics were continued orally for at least 6 months or longer at the surgeon's discretion.

Follow up and data analysis

Early mortality was defined as death within 30 days after the surgical procedure. Follow up consisted of a clinical examination, hematologic tests, and computed tomography (CT) imaging performed one week, six months, and 12 months after the procedure, and then annually thereafter. Telephone interviews of patients, patients' family members, or their primary care physicians were performed

for patients who did not visit our hospital during follow up.

Statistical analysis was conducted using SPSS statistical software (release 11.5.0; SPSS, Inc., Chicago, IL, USA). A P value less than 0.05 was considered significant.

Results

Patient profile and laboratory examination

Among the 26 patients who underwent surgical intervention during the 10-year study period, 11 were in the febrile group and 15 in the afebrile group. **Table 1** illustrates the patient characteristics. No significant differences in clinical characteristics were found between the febrile and afebrile groups.

The number of patients exhibiting preoperative evidence of infection, including leukocytosis and elevated CRP levels was 18 (73.1%). Although the febrile group had a higher WBC count and a higher CRP levels than the afebrile group, the differences were not significant. Many aneurysms were symptomatic; 15 patients (57.8%) had clinical symptoms, including back pain in 3 patients, abdominal pain in 10 patients, and chest pain in 2 patients, which were dependent on the location of the aneurysm; 18 patients had fevers within 3 months of surgery.

There were 9 patients (34.6%) with positive blood cultures. The most common organism was *Staphylococcus* species (**Table 2**).

Surgery and outcomes

The anatomical distribution of infected aneurysms was to the thoracic aorta (including the transverse aortic arch and the descending aorta) in 9 patients, the thoracoabdominal aorta in 4 patients, and the abdominal aorta in 13 patients. An overt aortic rupture into the mediastinum or retroperitoneal space was seen in 4 patients (2 in the transverse aortic arch, 1 in the descending aorta, and 1 in the abdominal aorta). These patients all underwent emergency surgery during the febrile phase of infection. Overall, 12 patients underwent emergency surgery, 2 underwent urgent surgery, and 12 underwent elective surgery.

In total, 19 (73.1%) patients underwent open surgery, and 7 patients (26.9%) underwent endovascular procedures, including 1 endovascular aneurysm repair (EVAR) and 6 thoracic endovascular aneurysm repairs (TEVARs). Among the 19 patients who underwent open surgery, in situ reconstruction combined with omentopexy was performed in 16 patients (3 in the thoracic aorta, 3 in the thoracoabdominal aorta, and 10 in the abdominal aorta), and extra-anatomical procedures were performed in 3 patients.

Postoperative complications were significantly more common in the febrile group than in the afebrile group

Table 1 Demographics and clinical, laboratory, and treatment characteristics of the 26 patients

	Total (n=26)	Febrile (n=11)	Afebrile (n=15)	P value
Age (years)	68.9±10.9	70.2±9.4	68.0±12.1	0.61
Gender (male)	22 (84.6%)	9	13	0.735
Comorbidity	11 (42.3%)	6	5	0.279
Diabetes mellitus	6 (23.1%)	3	3	—
Pneumonia	1 (3.8%)	1	0	—
Interstitial pneumonia	1 (3.8%)	1	0	—
Paraplegia (post-trauma)	1 (3.8%)	1	0	—
Steroid use	1 (3.8%)	0	1	—
Liver abscess	1 (3.8%)	0	1	—
Clinical symptoms (pain)	15 (47.8%)	5	10	0.279
Laboratory finding				
WBC count (10 ³ /μL)	10100	11121	9282	0.384
CRP level (mg/L)	9.1	13.7	6.1	0.087
Positive blood culture	9 (34.6%)	5	4	0.32
Aneurysm location				
Thoracic aorta	9 (34.6%)	6	3	0.067
Thoracoabdominal aorta	4 (15.4%)	0	4	0.063
Infrarenal abdominal aorta	13 (50%)	5	8	0.691
Rupture	4 (15.4%)	4	0	0.011
Fistula	4 (15.4%)	1	3	0.446
Aortobronchial	1 (3.8%)	1	0	—
Aortoesophageal	2 (7.7%)	0	2	—
Aortoduodenal	1 (3.8%)	0	1	—
Surgery				
Emergency	12 (46.2%)	8	4	—
Urgent	2 (7.7%)	1	1	—
Elective	12 (46.2%)	2	10	—
Open	19 (73.1%)	9	10	0.39
In situ reconstruction	16 (61.5%)	7	9	—
Extra-anatomic bypass	3 (11.5%)	2	1	—
Endovascular surgery	7 (26.9%)	2	5	0.39
TEVAR	6	2	4	—
EVAR	1	0	1	—
Reintervention	4 (15.4%)	2	2	0.735
Recurrent infection	3 (11.5%)	1	2	—
Scheduled, staged surgery	1 (3.8%)	1	0	—

WBC: white blood cells; CRP: C-reactive protein; TEVAR: thoracic endovascular aneurysm repair; EVAR: endovascular aneurysm repair

Table 2 Blood culture results

Microorganism	Total (n=26)	Febrile (n=11)	Afebrile (n=15)
Culture positive	9 (34.6%)	5	4
MSSA	2 (7.7%)	2	0
MRSA	1 (3.8%)	0	1
<i>Staphylococcus capitis</i>	1 (3.8%)	0	1
<i>Streptococcus pneumoniae</i>	1 (3.8%)	1	0
<i>Listeria monocytogenes</i>	1 (3.8%)	1	0
<i>Corynebacterium</i>	1 (3.8%)	0	1
<i>Klebsiella</i>	1 (3.8%)	0	1
<i>Salmonella</i>	1 (3.8%)	1	0

MSSA: Methicillin-sensitive *Staphylococcus aureus*; MRSA: Methicillin-resistant *Staphylococcus aureus*

(Table 3; $P=0.024$). Overall hospital mortality was 15.4% (4/26). While mortality in the febrile group was lower than that in the afebrile group (3/11 vs. 1/15), it was not statistically significant ($P=0.15$). Early mortality within 30 days of surgery was 7.7% (2/26); causes of death included mediastinitis after TEVAR for an aorto-esophageal fistula in one patient and reperfusion rhabdomyolysis in another patient who underwent resection and debridement with an axillo-bifemoral bypass for a juxtarenal infected aortic aneurysm. In-hospital death, other than early death, occurred in 2 patients (7.7%, 2/26) who underwent emergency total arch replacement for ruptured aortic arch aneurysms. In these 2 patients, a diagnosis of infected aneurysm was made after a culture or pathological examination of the surgical specimens. Debridement was incomplete, and an omental flap was not used in these cases. There was no significant difference in mortality rates between the febrile and afebrile groups. Early and late outcomes are summarized in Table 4.

Revision surgery for recurrent infection was required in 3 patients during the remote period (Table 5, patients 1–3).

Of the 3 patients, 2 who underwent TEVAR required open repair within 6 and 15 months, due to a graft infection and a type I endoleak, respectively. The first patient was a 73-year-old woman who had an infected aortic arch aneurysm complicated by an aortobronchial fistula and massive hemoptysis. An emergency TEVAR was performed as a bridge therapy, and uneventful recovery with shrinkage of the aneurysm was obtained. However, the infection recurred, and the aneurysm redeveloped after the discontinuation of oral antibiotics at 6 months after TEVAR. Debridement of the infected tissue by a left upper lung lobectomy and distal arch replacement with omentopexy was performed successfully. The second patient was a 72-year-old man who underwent emergency TEVAR for a mycotic descending aneurysm and aorto-esophageal fistula. While the postoperative course was uneventful, a late type I endoleak caused the aorto-esophageal fistula to reopen. Removal of the graft and descending aortic replacement with an omental wrap was performed 6 months after the first procedure.

A scheduled, staged revision was performed in one pa-

Table 3 Complications and mortality rates after surgery for mycotic aortic aneurysm

	Total (n=26)	Febrile (n=11)	Afebrile (n=15)	P value
Complications	9 (34.6%)	6	3	0.024
Mediastinitis	2 (7.7%)	2	0	—
Pneumonia	2 (7.7%)	2	0	—
Rhabdomyolysis	1 (3.8%)	1	0	—
Multiorgan failure	1 (3.8%)	0	1	—
Incomplete paraplegia	1 (3.8%)	0	1	—
Graft infection	1 (3.8%)	0	1	—
Iliopsoas abscess	1 (3.8%)	1	0	—
Revision surgery	3 (11.5%)	1	2	0.738
Graft infection	1 (3.8%)	0	1	—
Recurrent infection	2 (7.7%)	1	1	—
Scheduled bridge surgery after EVAR	1 (3.8%)	1	0	—
Mortality	4 (15.4%)	3	1	0.15
30-day mortality	2 (7.7%)	1	1	—
In-hospital mortality	2 (7.7%)	2	0	—

EVAR: endovascular aneurysm repair

Table 4 Early and late deaths

Patient	Age (years)/Sex	Group	Aneurysm location	Complication	Surgical procedure	Postoperative complication	Outcome
1	81/F	Afebrile	Descending aorta	DM Aorto-esophageal fistula	TEVAR	Mediastinitis	Dead on POD 17
2	64/M	Febrile	Juxtarenal	DM	EAB	Rhabdomyolysis	Dead on POD 1
3	59/M	Febrile	Aortic arch	DM	TAR	Mediastinitis	Dead on POD 33
4	79/M	Febrile	Aortic arch	Pneumonia	TAR	Mediastinitis	Dead on POD 95

DM: diabetes mellitus; TEVAR: thoracic endovascular aneurysm repair; EAB: extra-anatomic bypass; TAR: total arch replacement; POD: postoperative day

Table 5 Revision surgery and scheduled, staged surgery

Patient	Age (years)/Sex	Group	Aneurysm location	Complication	First procedure	Second procedure	Time between first and second procedure	Reason for revision
1	73/F	Febrile	Aortic arch	AEF	TEVAR	DAR+OF	7 months	Recurrent infection
2	72/M	Afebrile	Descending aorta	Nonperforating AEF	TEVAR	DTR+OF	6 months	Type I endoleak
3	62/M	Afebrile	Infrarenal AAA		Y-graft	Ax-biFB+OF	1 week	Recurrent infection
4	66/M	Febrile	Infrarenal AAA	Rupture	EVAR	Y-graft (autograft)	13 days	Scheduled

AAA: abdominal aneurysm; AEF: aorto-esophageal fistula; TEVAR: thoracic endovascular repair; Y-graft: Y graft replacement; EVAR: endovascular aneurysm repair; DAR: distal arch replacement; DTR: descending thoracic aortic replacement; Ax-biFB: axillo-bifemoral bypass; OF: omental flap

tient with a ruptured infected abdominal aortic aneurysm (Table 5, patient 3). Emergency EVAR for shock was performed as a bridge to open repair. After delayed debridement of the infected retroperitoneal tissues, the patient underwent explantation of a stent graft and reconstruction of the abdominal aorta with a superficial femoral vein graft at 13 days after EVAR.

After a mean follow-up period of 76.1 months (range, 1–160 months), 22 (86.4%) patients remained alive.

Discussion

The present study demonstrates that febrile patients have poor outcomes; early and long-term outcomes of endovascular repair for infected aortic aneurysms are not satisfactory and should be reserved for frail patients with multiple complications; and exhaustive debridement of infected tissues, combined with the use of an omental flap, is necessary for open procedures.

If infection involves the suprarenal and/or thoracoabdominal aorta, treatment is complicated due to the necessity for visceral revascularization. Hsu et al. analyzed 46 patients with infected aortic aneurysms; on multivariate analysis, the independent predictors of aneurysm-related death were advanced age, non-*Salmonella* infection, and lack of surgery.¹⁶ Oderich et al. analyzed 43 patients with mycotic aortic aneurysms and concluded that the primary determinants of aneurysm-related death were extensive periaortic infection, female sex, a *Staphylococcus aureus* infection, an aneurysm rupture, and a suprarenal aneurysm location.¹⁷ The 4 patients who died in the present study were all males with an average age of 71 years, and 3 had *Staphylococcus* infections. The identified infections were in the active phase in three of the 4 patients.

The goals of mycotic aneurysm management are the eradication of infection and the safe establishment of arterial flow.¹⁸ Our surgical procedure varied, depending on the severity of the infection, the anatomic location of the aneurysm, and the surgical procedures available. If a severe, purulent infection or adhesions were present,

extra-anatomical bypass was considered.¹⁹ Ewart et al. reported a high incidence of complications after this procedure, including stump disruption in 20% of patients, amputation in 20% to 29% of patients, and recurrent infection in 20% of patients.²⁰ In addition, the long-term patency of an axillo-bifemoral bypass is inferior to that of a direct aortic reconstruction.¹⁹ Among four cases who underwent extra-anatomic bypass in the present study, the survival rate was 75% at 5 years. Therefore, we have recently adopted this procedure as an alternative to in situ reconstruction for patients with multiple comorbidities or severe frailty. In situ reconstruction involves the complete resection of all infected tissues, anastomoses to healthy tissues, and the use of a pedicled omental flap. A viable pedicle flap of the omentum has a rich vascular supply, an extensive lymphatic network, and is capable of occupying the dead space once the infection has cleared.²¹

Several studies have described strategies to reduce the risk of graft infection. Options include the use of an antibiotic-soaked Dacron graft, cryopreserved aortic allografts,^{22,23} and a bovine pericardial roll.²⁴ The reported incidence of recurrent infection and associated mortality and morbidity rates are much lower in rifampicin-treated grafts than in untreated grafts.^{25,26} The use of a superficial femoral/popliteal vein segment is another alternative to in situ reconstruction.²⁰ Reconstruction using a vein graft is also functional and durable over time.^{27,28} The disadvantage of using the superficial femoral vein is its limited length and the size discrepancy with the native aorta. We successfully used bilateral autologous superficial femoral veins for mycotic abdominal aortic aneurysm (AAA) repair as a bifurcated graft in one patient.

Since Semba et al. first described the use of EVAR for the management of mycotic infrarenal aneurysms²⁹; many case reviews have been published on such endovascular treatments.^{8,10–13} The use of endovascular stents to treat mycotic aneurysms has the obvious potential to reduce mortality and morbidity by avoiding open repair, full anticoagulation, single-lung ventilation, prolonged distal ischemia, and use of cardiopulmonary bypass.³⁰ A ran-

domized study of infected aneurysms is impossible due to the urgent need for surgery and the critical condition of the patients. Endovascular treatment of mycotic aortic aneurysms in the descending aorta is appropriate if infection is controlled by the administration of antibiotics. We performed TEVAR in 3 patients with descending thoracic aneurysms, and the surgical mortality rate was 33% (1/3). One patient with an aorto-esophageal fistula underwent TEVAR for a mycotic descending aneurysm; this patient died due to recurrent infection (Table 4, patient 1). During the follow-up period after discharge, 2 patients underwent revision surgery. For mycotic aortic aneurysms in the abdominal region, we prefer open repair to stent grafting, because open repair is more durable with an acceptable mortality rate. In the present study, 92% (12/13) of patients with mycotic AAAs were treated with open surgery, and the mortality rate was 8.3%. A systematic review of the literature for EVAR on mycotic abdominal aneurysm found a 30-day survival rate of 89.5% and a 2-year survival rate of 82.8%.⁹⁾ In the present study, 1 of 3 AAA patients with an aortoenteric fistula died after surgery. When the febrile and afebrile groups were compared, the rate of postoperative complications was significantly higher in the febrile group. We suggest that TEVAR or EVAR is feasible when antibiotic therapy has achieved negative blood cultures prior to surgery. Because the mortality of ruptured mycotic aneurysms can be as high as 40%,²⁷⁾ endovascular treatments can serve use as a temporary measure to achieve hemodynamic stability and as a bridging measure to allow further definitive surgical treatment.

Prolonged postoperative antibiotic therapy has been advocated as a key component of success, but there is no consensus on its optimal duration. Most commonly, parenteral antibiotics are given for 2 to 8 weeks after surgery, but whether lifelong oral antibiotics are necessary remains controversial. If patients are treated with endovascular repair, specific antibiotics based on cultures should be continued for life. During the follow-up period, regular CT imaging and evaluation of infection parameters (e.g., CRP) are necessary, because recurrent or persistent aortic or graft infection might occur.³⁾

Our current approach for patients with mycotic aortic aneurysms is to perform open aortic resection, debride infected tissues, and perform either in situ reconstruction with an omental flap or an extra-anatomic bypass. If patients are not considered suitable for open repair (e.g., due to age, hemodynamic instability, or multiple comorbidities), we will evaluate them for endovascular repair as either a definitive repair or as a bridge to open repair. If fistulization to the digestive tract or a ruptured mycotic aneurysm is noted, endovascular treatment should only serve as a bridge to a definitive treatment after hemodynamic stabilization.

Limitations

There are several limitations of this study. The study design was retrospective, the sample size was small, and the study was performed within a single institute.

Conclusion

Surgery performed during the febrile phase of a mycotic aneurysm results in significantly worse outcomes than surgery performed during the afebrile phase. However, mortality is acceptable, considering the severity of the patient's condition. Each patient with a mycotic aortic aneurysm is unique, and there is no universal surgical treatment that applies to every patient. Each patient should be thoroughly evaluated and treated on a case-by-case basis using conventional open repair, endovascular repair, or a combination of both, considering the patient's preoperative condition and the activity of the infection.

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Disclosure Statement

The authors have no conflicts of interest.

Author Contributions

Study conception: CA, WF

Data collection: CA, WF

Analysis: WF

Investigation: CA, WF

Writing: WF

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Critical review and revision: all authors

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