Infected aortic aneurysms: Aggressive presentation, complicated early outcome, but durable results

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Objective: **Infected aortic aneurysms are rare, difficult to treat, and associated with significant morbidity. The purpose of this study was to review the management and results of patients with infected aortic aneurysms and identify clinical variables associated with poor outcome.**

Methods: **The clinical data and early and late outcomes of 43 patients treated for infected aortic aneurysms during a 25-year period (1976-2000) were reviewed. Variables were correlated with risk of aneurysm-related death and vascular complications, defined as organ or limb ischemia, graft infection or occlusion, and anastomotic or recurrent aneurysm.**

Results: **Infected aneurysms were infrarenal in only 40% of cases. Seventy percent of patients were immunocompromised hosts. Ninety-three percent had symptoms, and 53% had ruptured aneurysms. Surgical treatment was in situ aortic grafting (35) and extra-anatomic bypass (6). Operative mortality was 21% (9/42). Early vascular complications included ischemic colitis (3), anastomotic disruption (1), peripheral embolism (1), paraplegia (1), and monoparesis (1). Late vascular complications included graft infection (2), recurrent aneurysm (2), limb ischemia (1), and limb occlusion (1). Mean follow-up was 4.3 years. Cumulative survival rates at 1 year and 5 years were 82% and 50%, respectively, significantly lower than survival rates for the general population (96% and 81%) and for the noninfected aortic aneurysm cohort (91% and 69%) at same intervals. Rate of survival free of late graft-related complications was 90% at 1 year and 5 years, similar to that reported for patients who had repair of noninfected abdominal aortic aneurysms (97% and 92%). Variables associated with increased risk of aneurysm-related death included extensive periaortic infection, female sex, *Staphylococcus aureus* infection, aneurysm rupture, and suprarenal aneurysm location ($P < .05$). For risk of vascular complications, extensive periaortic infection, female sex, leukocytosis, and hemodynamic instability were positively associated ($P < .05$).**

Conclusion: **Infected aortic aneurysms have an aggressive presentation and a complicated early outcome. However, late outcome is surprisingly favorable, with no aneurysm-related deaths and a low graft-related complication rate, similar to standard aneurysm repair. In situ aortic grafting is a safe and durable option in most patients. (J Vasc Surg 2001;34:900-8.)**

Management of infected aortic aneurysms remains one of the most challenging clinical problems for the vascular surgeon. Infected aortic aneurysms are rare and difficult to treat. They are frequently associated with complicating factors, such as rupture, sepsis, and paravisceral location, that result in increased morbidity and mortality.[1-2] The classic teaching for treatment of infrarenal infected aneurysms has been aneurysm resection, soft-tissue debridement, remote arterial reconstruction out of the field of infection, and antibiotics. However, aneurysms located in the thoracoabdominal and paravisceral aortas are not amenable to conventional extra-anatomic reconstruction. Often, in situ aortic replacement is necessary, potentially exposing the patient to an increased risk of graft-related complications.

Previous reports have documented satisfactory results with in situ reconstruction in the setting of aortic sepsis.[3-9] However, most series contain a small number of patients with limited follow-up. The purposes of this study were to provide contemporary data on the surgical outcome of patients treated for infected aortic aneurysms and to identify clinical variables associated with increased risk for aneurysm-related death and vascular and graft-related complications.

PATIENTS AND METHODS

We identified 6137 patients who underwent aortic reconstruction for aneurysms of the thoracoabdominal or abdominal aorta at the Mayo Clinic between January 1, 1976, and January 1, 2000. Forty-three patients from this group were treated for an infected aortic aneurysm distal to the subclavian artery, a relative incidence of 1 in 142 patients (0.7%). Primary aortic infection was defined by (1) operative findings (inflammation and purulence), (2)

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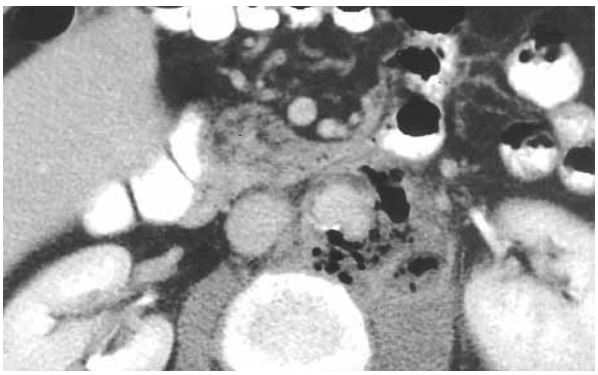

Fig 1. Enhanced computed tomographic scan reveals a large paravisceral aortic aneurysm with gas bubbles and periaortic fat stranding suggestive of infected aortic aneurysm.

Fig 2. Aortogram shows a saccular aneurysm with lobulated contour in the paravisceral aorta consistent with infected aneurysm.

clinical evidence of infection (fever, pain, leukocytosis), and (3) positive aneurysm wall culture. Patients with culture-negative aneurysms were analyzed individually and had to have convincing operative findings, fever of unknown origin, and at least 1 week of preoperative antibiotic treatment. Other supporting findings included positive blood culture, positive imaging study, and pathologic findings such as acute, chronic, or granulomatous inflammatory changes with bacteria, mycobacteria, or fungus on special stains. Patients with aneurysms of the ascending aorta, aortic arch, or aortic branches or prosthetic graft infections, and patients with positive aneurysm wall culture but no evidence of active infection, were excluded from the study.

Demographics, clinical characteristics, and operative data were collected from the patients' records. Aneurysm location was classified[10] as descending thoracic, thoracoabdominal, paravisceral, pararenal, juxtarenal, and infrarenal. The choice of vascular reconstruction was based on aneurysm location, extent of infection, and surgeon's preference. In general, extra-anatomic bypass was used to treat infrarenal aneurysms with extensive aortic and periaortic purulence. In situ bypass was used to treat suprarenal aneurysms or infrarenal aneurysms with minimal purulence. Early and late medical and surgical morbidity and mortality were recorded. Early perioperative period was defined as occurring during the hospital stay without regard to the number of days after the operation. Chronic renal failure was defined as a serum creatinine level of 1.5 mg/dL or greater and postoperative renal failure as an increase of 50% or greater in the baseline serum creatinine. Late follow-up data were obtained from medical records, office visits, correspondence with referring physicians, and telephone interviews. Clinical variables were correlated with early and late aneurysm-related deaths and vascular complications, defined as organ or limb ischemia, graft infection or occlusion, and anastomotic or recurrent aneurysms. We attempted to ascertain whether the complication was graft-related and whether the problem was a direct cause of death.

Clinical characteristics. Of the 43 patients treated for an infected aortic aneurysm, 32 were men (74%) and 11 were women. Mean age was 71 years (range, 46 to 94 years). Thirty patients (70%) had at least one comorbid condition associated with some degree of immunosuppression; comorbid conditions included diabetes (33%), chronic renal failure (30%), chronic steroid use (16%), and chronic disease (16%), such as rheumatoid arthritis (2), non-Hodgkin lymphoma (1), multiple myeloma (1), neutropenia (1), and monoclonal gammopathy (1) (Table E I, online only). Twenty patients (46%) had a recent infection; infections included pneumonia (6), cholecystitis (4), urinary tract infection (4), endocarditis (3), diverticulitis (2), soft-tissue infection (2), and osteomyelitis (1). One patient with endocarditis had a history of infected ascending aortic aneurysm. Five patients had previous gastrointestinal operations in the vicinity of the aneurysm and four had recent invasive procedures.

Forty patients (93%) were symptomatic (Table I). Duration of symptoms before surgery was, on average, 38 days (range, 1-220 days). Twenty-three patients (53%) had ruptured aneurysms. Of these, 9 were diagnosed preoperatively (6 contained and 3 free ruptures) and 14 had contained ruptures found during the operation. Laboratory findings included mean white blood cell count of 12.8/mm^3 (1.9-33) and sedimentation rate of 78 mm/hour (2-135).

Forty-two patients underwent preoperative imaging studies and 34 (81%) had at least one imaging modality consistent with the diagnosis of infected aortic aneurysm.

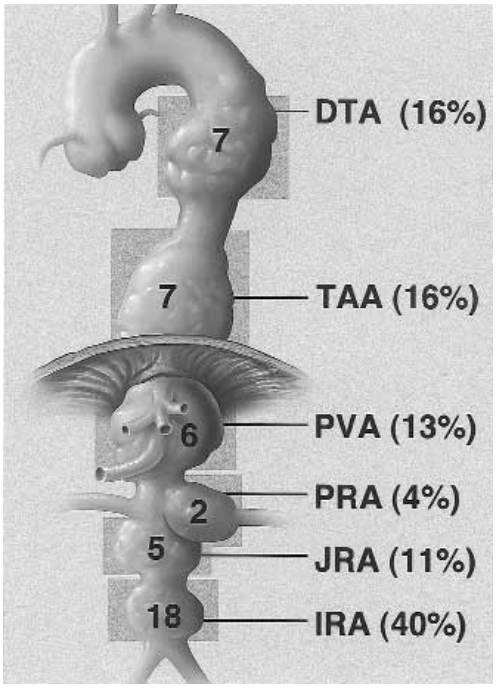

Fig 3. Infected aortic aneurysms were distributed in the descending-thoracic, thoracoabdominal, paravisceral, pararenal, juxtarenal, and infrarenal aortas.

Table I. Clinical presentation and laboratory findings in patients with infected aortic aneurysms

Variable	*n (N = 43)*	*%*
Symptomatic	40	93
Elevated sedimentation rate	18*	86
Fever	33	77
Pain (abdominal or back)	28	65
Leukocytosis > 12.000	23	54
Chills	22	51
Sweats	12	28
Enlarging aneurysm	12	28
Gastrointestinal symptoms†	10	25
Rupture‡	9	21
Pulsatile mass	7	16
Hemodynamic instability	3	7

*N = 21.
†Gastrointestinal symptoms included nausea/vomiting (6) and diarrhea (5).
‡Nine patients were diagnosed preoperatively, and 14 patients with contained ruptures were diagnosed during the operation.

Diagnostic imaging included computed tomographic scan of the chest and/or abdomen in 39 patients (positive in 67%, Fig 1), Indium-111-labeled white blood cell scan in 12 (positive in 83%) (Fig E 1, online only), angiogram in 10 (positive in all cases, Fig 2), and magnetic resonance angiography in four.

Bacteriology. Cultures were obtained from aneurysm wall (42), blood (32), or bronchial washing (1). Seventy-seven percent of patients (33/43) had at least one positive culture (Table II). Aneurysm-wall culture was positive in 27 cases (64%) and intraoperative Gram stain in 22 cases (52%). The culture agreement (blood and aneurysm wall) was as follows: 16 had both positive for the same organism, 6 had both negative, 6 had positive blood culture and negative aneurysm-wall culture, and 2 had negative blood culture and positive aneurysm-wall culture. One patient had blood culture positive for *Escherichia coli* and aneurysm-wall culture positive for *Bacteroides fragilis*. Overall, 30 patients (70%) were receiving antibiotics preoperatively for a mean period of 20 days (range, 0-250 days). All patients with culture-negative aneurysms were taking antibiotics.

Intraoperative findings. Aneurysms were located at or above the renal arteries in 26 patients (60%) (Fig 3). The mean aneurysm size was 5.9 cm (range, 3-12 cm). Aneurysms were saccular in 29 patients (67%) and fusiform in 14 patients (33%), without differences in clinical characteristics, bacteriology, or associated comorbidities. Other findings included aneurysmal extension to iliac arteries (9), multiple aneurysms (2), primary aortoduodenal fistula (2), and aortocaval fistula (1). The majority of patients (63%) had periaortic infection with extension of inflammation and purulence to adjacent organs, most commonly the duodenum (11), inferior vena cava (9), left renal vein (5), left kidney (4), left pleural cavity (3), pancreas (2), spleen (2), sigmoid colon (2), and stomach (1). One patient with an infected thoracoabdominal aorta had *Staphylococcus aureus* peritonitis.

Operative treatment. Of the 43 patients, 42 were taken to the operating room and 41 underwent definitive vascular reconstruction. The operation was classified as emergent (12), urgent (9, within 48 hours of vascular consultation), or elective (21). One patient with a ruptured clostridial descending-thoracic aneurysm died in the emergency department. One patient with multiple aneurysms (pararenal and infrarenal) died of exsanguinating hemorrhage during attempt at aortic clamping. Surgical treatment was in situ aortic prosthetic polyester graft reconstruction in 35 patients (85%) and axillobifemoral bypass in 6 patients (15%). In the in situ group, 28 patients had straight grafts and 7 had bifurcated grafts to the iliac (4) or femoral (3) vessels. The aortic clamp was placed at the descending-thoracic (12), supraceliac (8), suprarenal (4), or infrarenal aorta (17). The mean clamping time was 39.5 minutes (range, 20-87 minutes). In seven patients, a rifampin-soaked graft was prepared by soaking a gelatin-impregnated Dacron graft at room temperature in a 60 mg/mL solution (1200 mg rifampin powder in 20 mL sterile saline) for between 30 minutes and 1 hour. In the extra-anatomic bypass group, aneurysms were located in the infrarenal (5) and juxtarenal (1) aortas. All patients underwent extensive aortic and periaortic debridement with excision and culture of the aneurysm wall. Additional vascular procedures included aortorenal artery bypasses

Table II. Bacteriology of infected aortic aneurysms

Organism	*Culture obtained from blood (n = 32) (74%)*	*Culture obtained from aneurysm wall (n = 42) (98%)*	*Total (N = 43) (%)*
Culture-positive	25 (78)	27 (64)	33 (77)
Staphylococcus*	7	10	11 (26)
Escherichia coli	6	3	6 (14)
Streptococcus	4	3	5 (12)
Salmonella species	4	4	4 (9)
Listeria monocytogenes	0	1	1 (2)
Bacteroides fragilis	0	1	1 (2)
Candida	0	1	1 (2)
MAC	0	1	1 (2)
Haemophilus influenza	1	1	1 (2)
Clostridium species	1	1	1 (2)
Coccidioides immitis	1	1	1 (2)

*Staphylococcus included 6 cases of *Staphylococcus aureus* and 5 cases of staphylococcus coagulase-negative infection.
MAC, Mycobacterium avium complex.

(3), aorto-celiac-superior mesenteric artery bypass (1), femoral artery embolectomy (1), femoral artery interposition graft (1), and lumbar sympathectomy (1). The graft was covered with omental flap (41%), bovine pericardium (2%), or simple retroperitoneal closure (27%). Patients with descending-thoracic aneurysms or with extra-anatomic bypass had no graft coverage (30%). Nine patients had concomitant abdominal procedures, including cholecystectomy (5), splenectomy (4), nephrectomy (3), repair of duodenal defect (2), excision of gastric leiomyoma (1), Hartmann procedure (1), and adrenalectomy (1). Closed-suction drainage was used in 23 patients. Antibiotic treatment was continued for life in 40% of patients (13/33) and for 1 to 6 months in all other patients. Antibiotic duration was based on surgeon's preference.

Statistical analysis. Survival curves were calculated by using the Kaplan-Meier method. Differences in survival were determined by using the log-rank test. For analysis of categorical variables, the χ^2 and Fisher exact tests were used. Differences between means were tested with the Mann-Whitney test. Univariate analysis to assess the independent effects of clinical variables on surgical outcome was done with the Cox proportional hazards model. Expected survival rate was calculated from life tables for the white population of the State of Minnesota[11] and for patients who underwent repair of noninfected (ruptured and nonruptured) aortic aneurysms at the Mayo Clinic.[12] The incidence of late graft-related complications was compared with that observed for patients who underwent standard abdominal aortic aneurysm (AAA) repair.[13] A *P* value of less than .05 was used to determine statistical significance.

RESULTS

Early outcome. The operative mortality was 21% (9/42) and was not significantly different in patients who underwent in situ (7/35) versus extra-anatomic bypass (1/6). Two patients (5%) died of exsanguinating hemorrhage in the operating room. Each patient had a ruptured *Staphylococcus aureus* aneurysm, one in the descending-thoracic aorta and the other in the pararenal aorta. One patient (2%) with a ruptured staphylococcus coagulase-negative paravisceral aneurysm developed an anastomotic rupture in the proximal anastomosis of the aortic graft-renal artery bypass. Despite graft excision and a left nephrectomy, she died in the operating room. Although it was suspected, there was no evidence of early graft infection in this patient. Myocardial infarction was the cause of death in 3 patients (7%), 1 day, 5 days, and 18 days after the operation. Two patients (5%) died of multisystemic organ failure, one in the immediate postoperative period (*Staphylococcus aureus* thoracoabdominal aneurysm), and the other 7 days after in situ repair of a *Salmonella* species paravisceral aneurysm complicated by necrotizing pancreatitis. One patient who presented with a nonruptured thoracoabdominal aneurysm died at home of unknown cause on the twenty-fifth day after surgery.

The mean length of stay was 25 days (range, 6-119 days). Twenty-five patients (60%) had significant postoperative complications, including transient renal failure in 7 patients (17%) and permanent renal failure in 5 (12%), respiratory failure requiring prolonged ventilation in 5 patients (12%), myocardial infarction in 4 patients (10%), pneumonia in 3 patients (7%), acute pancreatitis in 2 patients (5%), and cerebrovascular accident in 1 patient (2%). Surgical complications occurred in 9 patients (21%), including wound complications (3), major bleeding (1), ischemic colitis (3), peripheral arterial embolism (1), paraplegia (1), and permanent monoparesis (1) (Table E II, online only).

Late outcome. The mean clinical follow-up was 4.3 years (range, 40 days to 22 years). Late follow-up was available in all but 3 patients. Cumulative survival rates at 1 year and 5 years was 82% and 50%, respectively, significantly lower than those observed for the general population[11] (96% and 81%) and noninfected aortic aneurysm[12] cohort (91% and 69%) (Fig 4). Late deaths (18/43) were not attributed to the initial aneurysm, but were the result

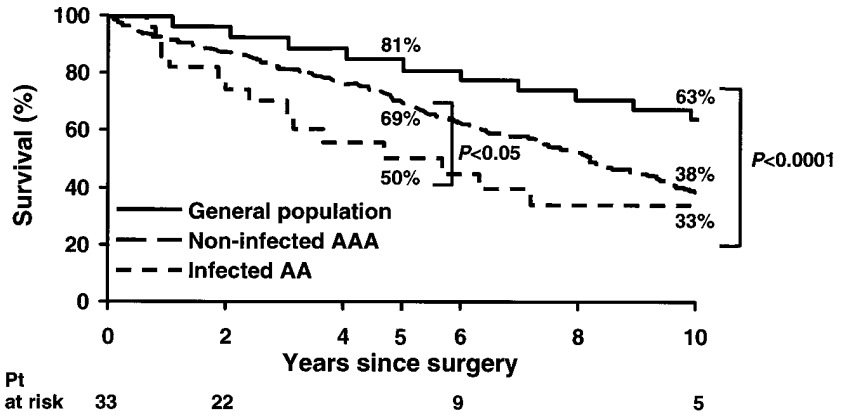

Fig 4. Kaplan-Meier survival curve for patients with infected aortic aneurysms as compared with the general population[11] and noninfected aortic aneurysm cohort.[12] Survival for patients with infected aneurysms is lower than that observed for the general population at 1 year, 5 years, and 10 years ($P = .0001$) and for noninfected aortic aneurysms at 1 year and 5 years ($P = .05$). The survival difference between infected and noninfected aneurysms is lost at 9 years' follow-up.

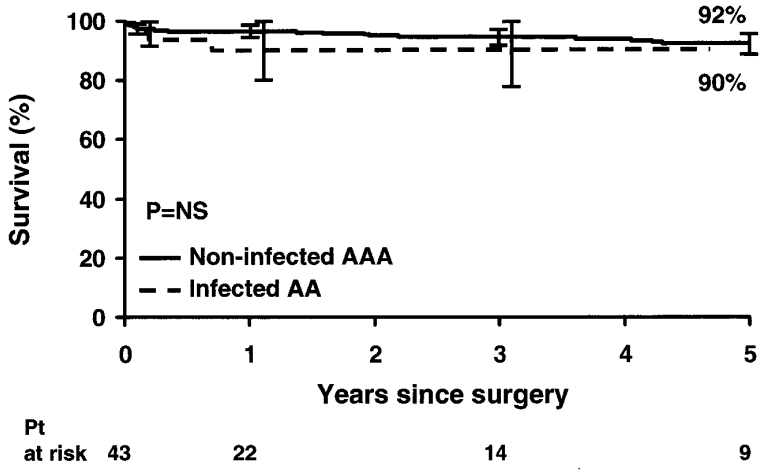

Fig 5. Kaplan-Meier curve for late graft-related complications in patients who underwent repair of infected aortic aneurysms versus noninfected abdominal aortic aneurysms.[13] The incidence of complication is not significantly different in either group ($P > .05$).

of cardiovascular causes (28%), cancer (22%), stroke (11%), respiratory failure (11%), renal failure (6%), and unknown etiology (22%). Rates of survival free of late vascular complications were 87%, 77%, and 64% at 1 year, 5 years, and 10 years, respectively. Rate of survival free of late graft-related complications was 90% at 1 year and 5 years, not significantly different from that observed for patients who underwent repair of a noninfected AAA (97% and 92%, Fig 5).[13]

Late vascular complications occurred in six patients and included three graft-related complications. Two patients developed graft infection. The first patient had monoclonal gammopathy and a culture-negative infrarenal aneurysm confirmed histologically to be the result of gram-positive cocci suggestive of streptococci. His initial operation included an axillobifemoral bypass and resection of an incidental gastric leiomyoma. Two months later he presented with persistent fluid collection in the right side of the groin, which required complete graft excision and a left axillofemoral with femorofemoral crossover graft, despite conservative treatment with intravenous antibiotics and closed-suction irrigation. Subsequently, he developed a proximal anastomotic disruption on the twenty-second day after surgery and required a patch angioplasty. He died 33 months later, without evidence of graft infection at autopsy. The second patient presented

Table III. Univariate analysis of clinical and operative variables as risk factors for aneurysm-related death

	Frequency of aneurysm-related death (%)				
Variable	*Without*	*With*	*RR*	*95% CI*	P *value*
Positive association or trend					
Extensive periaortic infection	0 (0)	10 (36)			.008
Female sex	5 (16)	5 (45)	3.8	1.1-13.2	.03
Staphylococcus aureus	7 (19)	3 (50)	3.6	0.9-14	.06
Rupture	6 (18)	4 (44)	3.1	0.9-11	.08
Negative association or trend					
Infrarenal location	8 (40)	2 (9)	0.2	0.04-0.9	.03

RR, Relative risk ratio; *CI*, confidence interval.

Table IV. Univariate analysis of clinical and operative variables as risk factors for early and/or late vascular complications

	Frequency of vascular complication (%)				
Variable	*Without*	*With*	*RR*	*95% CI*	P *value*
Positive association or trend					
Extensive periaortic infection	2 (13)	16 (57)	7.4	1.7-33	.008
Female sex	10 (31)	8 (73)	3.6	1.4-9.5	.008
Leukocytosis > 16.0	13 (36)	5 (71)	3.3	1.1-9.6	.03
Hemodynamic instability	15 (38)	3 (100)	3.7	1.1-13.2	.04
Rupture	12 (35)	6 (67)	2.4	0.9-6.4	.08
Negative association or trend					
Infrarenal location	12 (60)	6 (26)	0.3	0.1-0.8	.01
Infection restricted to the aorta	16 (57)	1 (8)	0.08	0.01-0.6	.01
Infrarenal clamp	12 (50)	4 (24)	0.3	0.1-1.06	.06

RR, Relative risk ratio; *CI*, confidence interval.

with a *Candida* sp juxtarenal aneurysm associated with a primary aortoduodenal fistula. Treatment included aortic and periaortic debridement, primary closure of the duodenal defect, in situ aortobifemoral bypass, and 4 months of antifungal therapy. Nine months after surgery, he presented with graft infection and required a right axillobifemoral bypass followed by in situ graft removal. The patient died 4 months later from a cerebrovascular accident. Finally, one patient developed a para-anastomotic aneurysm after an in situ thoracoabdominal aneurysm repair and died 4 years later of myocardial infarction.

Three late vascular complications were not considered to be graft-related, including a recurrent atherosclerotic descending-thoracic aneurysm 3 months after in situ aortic grafting for infrarenal aneurysm, a remote graft occlusion in a patient who had a right femoral interposition graft used to treat a femoral pseudoaneurysm years before his infected aortic aneurysm, and a patient who presented with worsening peripheral vascular disease requiring femoropopliteal bypass after in situ straight aortic grafting. Tables III and IV summarize univariate analyses of clinical variables associated with complicated outcome. There was no association for type of vascular reconstruction, immunosuppression, aneurysm morphology (saccular versus fusiform), *Salmonella* sp infection, use of rifampin-soaked graft, use of omental coverage, and duration of antibiotic treatment.

DISCUSSION

This study shows that infected aortic aneurysms comprise only a minority of all aneurysms (0.7%) but continue to be challenging in several aspects. First, the diagnosis is difficult and frequently made in late stages with fulminant sepsis and aneurysm rupture. Second, patients are often immunocompromised hosts, which may in part explain the increased perioperative morbidity and mortality. Third, infected aneurysms are more frequently located in the paravisceral and thoracoabdominal aortas, often requiring extensive periaortic debridement and reconstruction of visceral branches. And fourth, the ideal treatment remains controversial, and there is special concern over whether the type of reconstruction might contribute to an increased incidence of graft-related complications.[3-9]

Contemporary series continue to report a high incidence of aneurysm rupture (50%-85%) in patients with infected aneurysms.[4,6,9,14] This confirms the general belief that the natural history of infected aneurysms is one of an insidious febrile illness leading to early rupture and death

without prompt surgical intervention. Despite the fact that most patients are symptomatic, symptoms are usually nonspecific (eg, fever, pain), and patients typically undergo an extensive investigation before they are taken to the operating room. The classic triad of fever, back pain, and pulsatile mass, described in 40% of the patients in previous reports,[7] was found in only 16% of our patients. The fact that these patients are often immunosuppressed may contribute to more aggressive infections and early aneurysm rupture.[1,4,9] In fact, 70% of our patients had at least one chronic comorbid condition—most commonly diabetes, renal failure, or steroid use—that predisposes a patient to invasive or necrotizing infections. Similarly, since the introduction of antibiotics and effective treatment for valvular disease, the predominant organisms *Streptococcus pyogenes*, pneumococcus and *Enterococcus* sp have become less common, and virulent organisms more common.[15,16] *Staphylococcus aureus* and *Salmonella* sp are the dominant infecting organisms in most recent series.[4,9] Several studies on staphylococcus-associated endocarditis have documented the aggressive and virulent nature of this organism and *Salmonella* sp is thought by many to exhibit a more virulent course because of its ability to invade the normal intima and cause early aneurysm rupture.[16]

The complicated early outcome in patients with infected aortic aneurysms probably reflects the combination of an aggressive presentation, high rupture rate, and complex aneurysm location in immunocompromised hosts. With the limitations imposed by a retrospective review and a small number of patients, we attempted to identify variables associated with poor outcome. Extensive periaortic infection was the one variable most significantly associated with risk of aneurysm-related death and vascular complication. Aneurysm rupture was associated with a positive trend, and the lack of statistical significance likely represents a type II error caused by the small number of patients and confounding factors. Patients with hemodynamic instability had increased risk of vascular complications, as previously reported by Moneta and associates.[6]

The positive association between female sex and increased risk of aneurysm-related death and vascular complications was somewhat unexpected. The association of female sex and increased mortality was previously reported in patients with noninfected ruptured and nonruptured AAAs.[17,18] Noel and associates[18] recently reviewed the Mayo Clinic experience with 413 ruptured AAAs and found a 68% mortality rate for women and a 40% rate for men ($P < .001$). Women are known to have higher mortality rates for coronary artery disease, cerebrovascular disease, and other types of cardiovascular surgery, notably coronary artery bypass and heart transplantation.[17,18] The reasons for gender differences in mortality rates are unknown, and further investigation will be required.

Repair of an infected aortic aneurysm raises concern about risk of late complications, and published data on late outcome are very limited in this group of patients. This study shows that patients who leave the hospital continue to be exposed to an increased mortality rate as compared with the general population and noninfected aortic aneurysm cohort. However, late mortality does not seem to be caused by the initial infected aneurysm per se, but rather by the natural history of associated comorbidities and underlying atherosclerotic disease. In respect to the risk of late graft-related complication, we found no difference in the risk when compared with standard AAA repair. At 5 years, the incidences of any graft-related complication and graft infection (10% and 6%, respectively) were comparable with those reported for standard AAA repair (8% and 1.3%, respectively).[13]

Finally, is in situ aortic grafting adequate treatment for infected aortic aneurysms? With the limitations recognized, we found that in situ reconstruction is a safe and durable option in most patients with infected aortic aneurysms. The argument in favor of extra-anatomic bypass is the theoretic advantage of reducing the risk of graft infection, because revascularization is generally performed in a location remote from the site of infection. However, recent series continue to report a high incidence of complications with extra-anatomic bypasses, including a 20% aortic stump disruption, a 20% to 29% amputation rate, and a 20% risk of reinfection.[3-7] In addition, certain anatomic sites, such as around the aortic arch, thoracoabdominal aorta, and paravisceral aorta are not amenable to conventional extra-anatomic reconstruction, and in situ grafting is unavoidable.[3,4] Furthermore, axillobifemoral bypass followed by aneurysm excision is a challenging and prolonged operation, which may account for the increased mortality rate in some series. Therefore, we should reevaluate the classic doctrine that extra-anatomic reconstruction is the treatment of choice for primary aortic sepsis. Our experience[8] with in situ aortic replacement in the setting of graft infection and graft-enteric fistula included an 8% mortality rate and a 100% 5-year limb-salvage rate, significantly better than the results reported for extra-anatomic bypasses (20% and 75%, respectively). In the matter of graft reinfection, in situ repair did not offer any advantage yet, with identical reinfection rates (22%) to that reported for axillobifemoral bypass.[8] It is now generally accepted that in situ aortic grafting is an appropriate choice for most patients with primary aortic infection. The choice of the ideal conduit is still controversial. Rifampin-soaked grafts may prevent graft infection by reducing early graft seeding.[19] We had no reinfection when using rifampin-soaked grafts. Other safe alternatives include autogenous superficial femoral vein grafts[20] and cryopreserved arterial allografts.[21] For patients with fulminant sepsis, extensive aortic infection, and aortic-enteric fistula, there is no ideal surgical option, but in situ prosthetic grafting may represent the most expeditious method of arterial reconstruction, with acceptable early and late morbidity rates.

In summary, infected aortic aneurysms have an aggressive presentation and a complicated early outcome. Late outcome is surprisingly favorable with no aneurysm-related deaths and a low graft-related complication rate, similar to

the outcomes of patients who underwent standard AAA repair. The presence of primary aortic infection should be suspected in patients with fever, pain, leukocytosis, immunosuppression, and a saccular aneurysm located in unusual aortic location. Our initial diagnostic modality is a computed tomographic scan, followed by angiogram in stable patients with pararenal or visceral involvement. Once the diagnosis is established or suspected, our management algorithm includes early operation, aneurysm excision, aneurysm wall culture, aortic and periaortic debridement, omental coverage of the aortic graft or stump whenever possible, and, most recently, the use of rifampin-soaked grafts and lifelong antibiosis. We generally reserve extra-anatomic bypass for patients with infrarenal or juxtarenal aneurysms with extensive periaortic infection caused by virulent organisms. We feel that in situ aortic grafting is a safe and durable option in most patients.

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DISCUSSION

Dr John D. Corson (Iowa City, Iowa). The Mayo group have provided us with some interesting data on a large 25-year series of infected aortic aneurysms. Because of the fact that 45% of their cases involved the aorta above the renal arteries, with 16% being thoracoabdominal aortic aneurysms and 13% aneurysms with involvement of the visceral arteries, in situ aortic replacement was the surgical option in these patients. Indeed, in this series 35 patients or 85% of the group were treated in this fashion. The data from these patients are the strength of this paper. In the manuscript they discuss seven patients who had a rifampin-soaked bypass graft used, but it was not clear what other types of bypass grafts were used. In the past few years, there have been other alternatives to conventional bypass grafts for in situ replacement, such as aortic homografts, allografts, or the superficial femoral vein as suggested by Clagett's group in Dallas. What conduit would the authors advise us to use for in situ replacements?

How long should we continue antibiotics after an in situ replacement? Is the decision for antibiotic duration predicated on the immunocompromised status of the patient or the organism cultured? Interestingly, 70% of their patient population was immunocompromised, but only 40% had long-term antibiotic usage. However, 5% of the group had reinfection.

Finally, should we culture the walls of aortic aneurysms even if clinically there is no hint of infection?

I would finally stress that early diagnosis is important. Infected aortic aneurysms are prone to rupture despite not always being of a size where conventionally we would anticipate rupture of an atherosclerotic aortic aneurysm.

Dr Gustavo S. Oderich. Dr Corson, I would like to thank you for your thoughtful comments.

Your first question addressed the available graft alternatives for in situ aortic replacement. The choice of the ideal conduit is

still controversial. As you pointed out, Dr Clagett reported his experience with superficial femoral vein grafts in the setting of aortic sepsis. We have had a limited experience with this technique and found that the prolonged operative time is one of the limiting factors in critically ill patients. Another attractive option is the use of cryopreserved arterial allografts. Some authors have advocated the use of arterial allografts with the potential advantage of reducing infection rates. We have used arterial allografts recently in cases of aortic graft infection with favorable results. The major limitations are availability, price, and lack of long-term follow-up data in these patients. Finally, we favor rifampin-soaked grafts as the conduit of choice because of its availability and potential advantage of preventing graft infection by reducing early graft seeding.

The second question addressed the duration of antibiotic treatment. There are no studies comparing short versus prolonged antibiotic treatment in this setting. This series spanned 25 years' experience, and there were no definitive criteria to select duration of treatment. However, two of the three patients with graft infection had limited antibiotics treatment. Therefore, we have recently added to our treatment strategy the recommendation of lifelong antibiosis in the setting of primary aortic infection. Patients with virulent organisms, such as staphylococcus, salmonella, and clostridium may represent a higher risk population and should definitely be considered for lifelong treatment.

Dr Corson also asked about the early diagnosis of infected aneurysms. Early diagnosis is of paramount importance as half of these patients have either contained or free aneurysm rupture. An infected aneurysm should be suspected in patients with symptomatic aortic aneurysms, fever, leukocytosis, and elevated erythrocyte sedimentation rate. Patients presenting with frank rupture should be taken emergently to the operating room. For stable patients, we currently recommend a computerized tomography (CT) scan as the initial imaging modality. In this series, 80% of the CT scans had findings suggestive of an infected aortic aneurysm, including unusual aneurysm location, saccular morphology, fat stranding, and gas bubbles. Patients with paravisceral involvement and no evidence of rupture should probably have an arteriogram to plan visceral reconstruction.

Dr Panneton, would you like to add any comments?

Dr Jean M. Panneton. One comment I would like to address is aneurysm wall culture in patients without any evidence of infection, either clinically or intraoperatively. I think that it is probably the kind of thing that you would like not to do. If you start culturing aneurysm walls routinely in all your patients, you are going to find a lot of organisms that have no clinical relevance. All the patients included in this study had obvious clinical evidence of a primary aortic infection as defined by imaging studies, clinical presentation with fever, pain and leukocytosis, or intraoperative findings such as edematous changes, purulence, periaortic involvement, or adjacent organs destruction. I would certainly not recommend routine aneurysm wall culture. I think in this setting ignorance is bliss.

Regarding the duration of antibiotic treatment, an obvious limitation of this study is that it is a retrospective review over a 25-year period. I think that the recommendation for prolonged or lifelong antibiosis 20 years ago was probably not as strong as we currently advocate. The risk of graft infection is significant in these patients, and I think pretty much all of us would recommend lifelong antibiosis in the setting of aortic infection. Patients with more virulent organisms, such as *Staphylococcus aureus*, should definitely receive lifelong antibiosis. I think Bactrim is a reasonable option for antibiotic suppression in most patients. Thank you.

Dr Harry Schanzer (New York, NY). I enjoyed very much your paper. My question is, do the bacteriological findings preop or in any way influence what you do, and is the result of your technique in any way related to the bacteriology?

Dr Oderich. We think that the fact that most patients were taking antibiotics for a mean period of 25 days before the operation might have contributed to a relatively high rate of culture-negative aneurysms. Once the diagnosis of primary aortic infection is suspected or confirmed, we advocate some general principles, including early operation, broad-spectrum antibiotics, aortic and periaortic debridement, and use of rifampin-soaked graft. We recommend in situ reconstruction for most patients and generally reserve extra-anatomic bypass for patients with infrarenal or juxtarenal aneurysms with extensive periaortic purulence. Patients with virulent organisms should probably undergo extraanatomic bypass.

Dr Panneton. Let me just add a comment on this. The only case of in situ aortic grafting that eventually developed graft infection was a patient who had Candida infection and aortoduodenal fistula. I think that if you have evidence of fungal infection, you should perform an extra-anatomic bypass whenever possible. Also, patients with salmonella infections may be best managed with extra-anatomic reconstruction because of its known virulent nature, although we had some patients with *Salmonella aortitis* who successfully underwent in situ aortic replacement. Patients with Candida infection should be treated with extra-anatomic reconstruction.