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Patient-Tailored Approach for Diagnostics and Treatment of Mycotic Abdominal Aortic Aneurysm

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Background: The existing literature on mycotic aortic aneurysm is scarce and focuses on treatment. This study evaluates the clinical characteristics, diagnostics, treatment and outcome of patients with a mycotic abdominal aortic aneurysm treated in a tertiary referral center.
Methods: A retrospective cohort study was conducted including all patients with a proven mycotic abdominal aortic aneurysm admitted between May 2010 and July 2020. Primary outcome was mortality and secondary outcome included complications such as vascular graft/endograft infection.
Results: Twenty-four patients with a mycotic abdominal aortic aneurysm were included. Patients had a mean age of 68 ± 9 years and 20 (83%) were male. Thirteen patients (57%) had positive preoperative blood cultures. *Streptococcus pneumoniae* was most frequently isolated by blood culturing, pus, and vascular, or perivascular tissue cultures (17%). In 19 (83%) patients the mycotic abdominal aortic aneurysm was located infrarenally, in three (13%) patients suprarenally, and in one (4%) patient juxtarenally. Median follow-up was 20 (7–42) months. In 8 patients (33%) vascular graft and or endograft infection was diagnosed after surgical repair. Ten (42%) patients died during the follow-up period. The main causes of death were vascular graft/endograft infection-related ($n = 4$) and rupture of the mycotic abdominal aortic aneurysm ($n = 3$). No patient characteristics could be identified as predictive for mortality.
Conclusions: This study shows a large variation in presentation, diagnostic approaches, and surgical and antibiotic treatment of mycotic abdominal aortic aneurysm. The detailed information about the diagnostic approaches to this rare disease and its antibiotic and/or other treatment contributes to existing knowledge of mycotic abdominal aortic aneurysm. Because of the individual variation patients should be discussed in a multidisciplinary team with a vascular surgeon, infectious disease specialist, and clinical microbiologist.

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Abbreviations: (MAA), mycotic aortic aneurysm; (SUVmax), maximum standardized uptake values; (TBR), tissue-to-background ratio; (VGS), visual grading scale.

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INTRODUCTION

Mycotic aortic aneurysm (MAA) has a poor prognosis. Because of its rapid expansion the risk of rupture is very high. The underlying mechanism is an infection of the aortic wall. The incidence of MAAs in Western countries is 0.65 to 2% of all aortic aneurysms, and at the moment of presentation most patients are younger than those with non-mycotic aneurysms[1,,2] MAAs can develop from septic emboli, by hematogenous spread, or directly spreading from infected tissue adjacent to the vascular wall. The most common causative micro-organisms are Staphylococcus and Salmonella species.[3] Clinical presentation can be diverse and range from systemic symptoms of infection to more localized symptoms.[4] It is therefore important that MAAs be recognized early and prompt treatment be initiated.

Currently diagnosis is based on clinical characteristics (abdominal and back pain, pulsating mass, fever, and sepsis), medical history (prior infections, immunocompromised status due to disease or medication), laboratory markers (elevated C-reactive protein (CRP) or elevated leukocyte count, positive blood- or aortic tissue culture), radiological findings with duplex ultrasound, computed tomography (angiography) (CT(A)), and/or magnetic resonance imaging (MRI) (e.g., saccular/multilobular aneurysm, periaortic soft tissue mass or gas formation).[5] There are indications that ^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography (^{18}F-FDG PET/CT) can play an additional role in the diagnosis of MAAs. The conventional treatment regime includes antibiotics combined with surgery (endovascular or open).[6,7]

Although several studies have been published, there are no clear guidelines for diagnosis, management, or treatment. The larger abdominal MAA studies are register-based, resulting in less detailed information; they are mainly focused on treatment and do not include conservatively treated patients.[8,9]

This retrospective study was conducted to evaluate clinical characteristics, diagnostic approaches, treatment, and outcome of patients with MAA admitted to our tertiary referral center.

MATERIAL AND METHODS

Study Design and Population

In a retrospective cohort study, data of all patients with an MAA admitted to our tertiary referral center between May 2010 and July 2020 were collected. Following the European Society for Vascular Surgery (ESVS) guidelines, the diagnosis was based on a combination of symptoms and clinical presentation (abdominal/back pain, fever, sepsis, and/or shock), laboratory markers (CRP and white blood cell count and/or a positive blood or aortic tissue culture), and radiological findings on CT.[10] Seven patients with a thoracic MAA were excluded, given the differences in presentation, imaging, and treatment with abdominal MAA.

The Medical Ethical Institutional Review Board granted dispensation for the study from the Medical Research Involving Human Subjects Act (WMO) obligation (registration no. METC 2020/0282). As a consequence, informed consent was not obtained. Patient data were processed and electronically stored in agreement with the declaration of Helsinki – Ethical principles for medical research involving human subjects.[11] Data were stored and analyzed anonymously.

Data Extraction

Data were extracted from the electronic patients file (EPIC). The list was completed by identifying patients through searches on intervention codes and codes of the International Statistical Classification of Diseases and Related Health Problems (ICD-10). Missing data was added by contacting general practitioners and referring hospitals.

Patient Characteristics

The following patient characteristics were collected: age (at time of presentation), sex, height, weight, body mass index (BMI), and medical history (e.g., tobacco use, hypertension, hyperlipidemia, diabetes mellitus, malignancy). Cardiac, pulmonary and renal status were evaluated. Tobacco use, hypertension, hyperlipidemia, diabetes mellitus, and cardiac, pulmonary, and renal status were classified by the Society for Vascular Surgery (SVS) system (class 0–3) according to the Ad Hoc Committee on Reporting Standard. Tobacco use was scored positive if there was current use or less than one year of abstinence (class 2 and 3 of the SVS system). Other variables collected using the SVS criteria were positive if the status was scored ≥ 1.[12]

Diagnostics

Clinical symptoms that were dichotomized (yes/no) included pain, fever (>38.5°C), unintentional weight loss, loss of energy, loss of appetite, nausea or vomiting, and changes in bowel habits. The inflammatory markers (laboratory findings) CRP

level (mg/L) and white blood cell count (10^9/L) were collected. Timing of serum collection was at the initial presentation in the hospital.

Preoperative CTA and ^{18}F-FDG PET/CT-scans were evaluated.[13,14] The location of the abdominal aortic aneurysm was classified into suprarenal, juxtarenal, and infrarenal. Morphology was either fusiform or saccular. The following dichotomous CTA characteristics were collected: appearance of the wall (multilobulated, yes/no), thickening of the aortic wall, interruption of aortic wall calcification, adjacent soft-tissue stranding, adjacent collection of gas, periaortic lymph nodes, rupture (contained in the retroperitoneal space or full-blown), cortex interruption of the vertebrae close to the aneurysm, and luminal ulceration (disruption of the plaque surface with adherent organizing thrombus).[15] The maximum anteroposterior aneurysmal diameter and the side-to-side diameter were measured in the transversal plane (mm). CTA data were collected by 1 author (DL) and checked by a second author (NP).

The following ^{18}F-FDG PET/CT characteristics were collected: maximum standardized uptake values (SUVmax) at the level of the MAA (region of interest), tissue-to-background ratio , (calculated as: SUVmax of MAA divided by SUVmax of a liver region), patterns of uptake (homogenous or heterogenous), and a visual grading scale . The visual grading scale included the following categories: grade 1 = FDG uptake comparable to the background, grade 2 = low FDG uptake (comparable with that by inactive muscles or fat), grade 3 = moderate FDG uptake (clearly visible, but less than physiological FDG activity in the bladder), grade 4 = high FDG uptake (comparable with physiological FDG uptake in the bladder).[15] All measurements were taken by one author (DL) and checked by a second author (RS). The measurements were taken on EANM Research Lab (EARL) reconstructions.

Microbiological diagnostic approaches were evaluated. Results of cultures derived from blood (preoperative), preoperative para-aortic puncture material, and intraoperative pus/tissue were collected.

Treatment

Treatment modality was gathered, including open surgery (synthetic graft, biological xenograft or autologous graft), endovascular aneurysm repair (EVAR), or treatment with antibiotics only. Omental wrapping of the aorta was performed in open surgery with high risk of infection (for example MAA repair or replacement surgery in infected vascular endografts), except if too little (suitable) omental tissue was present. If open treatment had been selected, autologous venous reconstruction was preferred due to the lower (re)infection risk in comparison with synthetic grafts. If there was no suitable vein or in case of emergency surgery (and endovascular repair was not possible), a bovine pericardial xenograft was preferred.[17] Detailed information about antibiotic treatment (including dose and duration) were also collected. Complications of treatment were noted, such as graft infection and/or endoleak.

Follow-Up

Date and reason of death were collected. If the patient survived the follow-up period, the last day of follow-up (i.e. outpatient clinic visit) was noted.

Statistical Analysis

Categorical variables were described with frequencies (percentages). Distribution of continuous data were checked visually and supplemented by the Shapiro-Wilk test. Normally distributed data were presented as mean ± standard deviation (SD). Skewed distributed data were presented as median and interquartile range (IQR). Survival was estimated with the Kaplan-Meier curve. Univariate cox regression analyses were performed to determine whether one or more baseline characteristics were associated with mortality. The amount of effect on mortality was described with hazard ratios. No multivariate cox regression analysis was done because of the low number of patients and events.

Statistical significance was set at $alpha < .05$. Statistical analyses were performed using SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp).

RESULTS

Basic Characteristics and Comorbidities

Twenty-four patients with an MAA were included in the analysis following the listed criteria. Patients had a mean age of 68 ± 9 years and 20 (83%) were male; 15 patients (63%) were known with tobacco use (including current smokers or those with less than one year of abstinence) and 14 patients (58%) with hypertension. Hyperlipidemia, diabetes mellitus, and malignancy were present in 11 (46%), 5 (21%), and 6 (25%) patients, respectively (Table I).

Table I. Patient characteristics, clinical and laboratory findings in patients with mycotic aortic aneurysm

Characteristic	*N* (%) or mean ± SD or median (IQR)
No. of patients	24 (100)
Age in years	68 ± 9
Sex, males	20 (83)
BMI (kg/m^2)	26 ± 3
Tobacco use	15 (63)
Hypertension	14 (58)
Hyperlipidaemia	11 (46)
Diabetes mellitus	5 (21)
Malignancy	6 (25)
Cardiac disease	8 (33)
Pulmonary disease	7 (29)
Renal disease	7 (29)
Symptoms	
Pain	22 (92)
Fever	6 (25)
Weight loss	4 (17)
Loss of energy	9 (38)
Loss of appetite	6 (25)
Nausea or vomiting	8 (33)
Change of bowel habits	8 (33)
Laboratory findings	
CRP[b] (mg/L)	134 (67-231)[a]
White blood cell count (10^9/L)	17 (14-21)[a]

[a]median and IQR. IQR is written as: (first quartile-third quartile),
[b]C-reactive protein.

Clinical Presentation

Twenty-two (92%) patients presented with pain and 6 (25%) patients with fever. Laboratory findings included a median initial CRP level of 134 (IQR: 67–231) mg/L and a median white blood cell count of 17×10^9/L (IQR: 14–21) (Table I).

Diagnostic Imaging

All patients underwent a CTA scan. In 19 (83%) patients the MAA was located infrarenally, in three (13%) suprarenally, and in one (4%) patient juxtarenally. The median anteroposterior diameter measured in the transversal plane was 51 ± 24 mm and from side-to-side 60 ± 35 mm. Twelve (52%) patients had a fusiform morphology and 11 (48%) a saccular aneurysm. The most common CTA characteristics were thickening of the aortic wall (n = 18, 78%), interruption of arterial wall calcification (n = 16, 70%), and luminal ulceration (n = 14, 61%). Six (26%) patients were demonstrated to have a contained rupture at presentation and one (4%) with a full blown rupture. Other MAA-related characteristics are shown in Table II.

Figure 1 shows the transversal (1A) and sagittal (1B) CTA views of an infrarenal ventral saccular MAA of one of the patients.

Six patients underwent ^{18}F-FDG PET/CT scanning. The median SUVmax was 5.9 (5.1–8.6) and the tissue-to-background ratio 2.5 (1.5–3.4). All scans showed a heterogenous distribution of ^{18}F-FDG uptake within the aortic wall. The median score of the visual grading scale was 3.0 (2.8–3.3) (Table II). Figure 1C shows the transversal ^{18}F-FDG PET/CT view of the same patient at the same level as the CTA in Figure 1A. There is a heterogeneous uptake of ^{18}F-FDG in the aortic wall.

Microbiological Diagnostic Approaches

In total 18 patients (75%) had positive cultures (blood, intraoperative pus/tissue and/or pus puncture). In 23 (96%) patients' blood cultures were taken, 13 (57%) of which were positive. One patient did not have preoperative blood cultures because of an acute presentation with emergency surgery. Two patients had a preoperative puncture of a pus collection around the aneurysm and both cultures were positive. Ten patients (42%) had intraoperative tissue/pus cultures, seven (70%)

Table II. Anatomical details and signs of infection as found on computerized tomography angiography and ^{18}F-FDG PET/CT-measurements

Characteristic	*N* (%) or mean ± SD or median (IQR)
Number of patients with CTA[a]	23[b] (100)
Location	
- Suprarenal	3 (13)
- Juxtarenal	1 (4)
- Infrarenal	19 (83)
Morphology	
- Fusiform	12 (52)
- Saccular	11 (48)
Wild multilobulated appearance	5 (22)
Thickening of aortic wall	18 (78)
Interruption of arterial wall calcification	16 (70)
Adjacent soft tissue stranding	8 (35)
Adjacent collection of gas	1 (4)
Periaortic lymph nodes	12 (52)
Contained rupture	6 (26)
Full-blown rupture	1 (4)
Cortex interruption (vertebrae)	2 (9)
Luminal ulceration	14 (61)
Maximum anteroposterior diameter (mm) transversal plane	51 ± 24
Maximum side-to-side diameter (mm) transversal plane	60 ± 35
No. of patients with ^{18}F-FDG PET/CT[c]	6 (100)
SUVmax[e]	5.9 (5.1-8.6)[d]
TBR[f]	2.5 (1.5-3.4)[d]
Heterogenous pattern of uptake	6 (100)
VGS[g]	3.0 (2.8-3.3)[d]

[a]Computed tomography angiography,
[b]based on 23 patients, one CTA is missing,
[c]^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography,
[d]Median and IQR. IQR is written as: (first quartile-third quartile),
[e]Maximum standardized uptake values,
[f]Tissue-to-background ratio,
[g]Visual grading scale.

of which were positive. *Streptococcus pneumoniae* was most frequently cultivated (n = 4, 22% of patients with positive cultures), followed by *Staphylococcus aureus* and *Escherichia coli* (n = 3, 17%) and *Salmonella species* (n = 2, 11%). See Table III for a detailed description of the diagnostics, antibiotic treatment, and outcome per patient.

Modes of Treatment

Invasive treatment was given to 20 patients (83%). Endovascular treatment was considered indicated whenever it seemed feasible (depending on the anatomy of the aneurysm), especially in critical ill patients or in case of emergency surgery. Thirteen patients (54%) underwent open surgery and 7 patients (29%) endovascular repair, possibly as a bridge to surgery. Finally, 2 of these patients indeed underwent open reconstruction after previous EVAR.

Open surgery was subdivided into conventional open surgery (replacement with a Dacron prosthesis) (n = 8, 61%), open surgery with an autologous vein (common femoral vein) (n = 4, 31%), and open surgery with a biological xenograft (bovine pericardial graft, named No-React Non-valved Conduit (Biointegral Surgical Inc, Mississauga, ON, Canada). ((n = 1, 8%) (Table IV). Figure 2 shows a photograph taken during open surgical repair of a juxtarenal MAA, with clamping of the right renal artery, and the proximal and distal abdominal aorta. Four patients (17%) were not treated surgically. In 3 cases due to comorbidities and the fourth patient died because of a ruptured aneurysm after presentation, before treatment.

Table III. Overview of microbiological cultures, antibiotic therapy, surgical therapy, and outcome per patient

	Blood cultures	Perioperative tissue and/or pus cultures	Puncture	Antibiotic treatment	Antibiotic course duration, preoperatively or postoperatively	Surgical treatment	Outcome
1	Negative	NP[a]	NP	Ceftriaxon 2g IV[b] BID[c]	2 days postop until failure	No	Mortality caused by MAA-rupture
2	Negative	NP	*Mycobacterium bovis*[a]	Ceftriaxon 2g IV BID, Rifampicin/Isoniazid 300/150 mg oral BID, Moxifloxacin 400 mg oral OD[d]	8 days Ceftriaxon preop, Rifampicin/Isoniazid postop lifelong, 2 months Moxifloxacin postop	Endovascular repair	Adverse events: no
3	Negative	NP	NP	Piperacillin/Tazobactam 4g/0.5g IV OD, Vancomycin 1100 mg IV OD, Caspofungin 70 mg IV OD	6 weeks postop	Endovascular repair	Adverse events: no
4	*Streptococcus agalactiae*	NP	NP	Benzylpenicillin 4000000 IE IV OD, Amoxicillin 1000 mg oral OD	6 weeks Benzylpenicillin postop followed by Amoxicillin until failure	Endovascular repair	Adverse events: no
5	Salmonella species	Salmonella species	NP	Ceftriaxon 2g IV BID, Ciprofloxacin 500 mg oral BID	2 weeks Ceftriaxon postop followed by 4 weeks Ciprofloxacin	Open reconstruction (autologous vein)	Cardiac-related mortality
6	NP	*Coxiella burnetii*	NP	Doxycycline 100 mg oral BID, Hydroxychloroquine 200 mg TID[e]	8 weeks Doxycycline, 6 weeks Hydroxychloroquine postop	Open reconstruction (Dacron)	Occlusion of L a. femoralis communis requiring thrombectomy and vascular graft/endograft infection and infection-related mortality
7	*Staphylococcus aureus*	NP	NP	Flucloxacillin 12 g IV OD, Rifampicin 450 mg oral BID	2 weeks Flucloxacillin postop followed by 7 months Rifampicin	Open reconstruction (Dacron)	no
8	Negative	NP	NP	Augmentin 625mg oral TID, Cotrimoxazole 960 mg oral BID	Postop until failure	Endovascular repair	Vascular graft/endograft infection for which treated with replacement surgery (xenograft, bovine pericardium)
9	Negative	NP	NP	Augmentin 500 mg/125 mg oral TID	10 days postop	Open reconstruction (autologous vein)	Adverse events: no

(*continued on next page*)

Table III (*continued*)

	Blood cultures	Perioperative tissue and/or pus cultures	Puncture	Antibiotic treatment	Antibiotic course duration, preoperatively or postoperatively	Surgical treatment	Outcome
10	Negative	*P. mirabilis*	NP	Cefotaxime 1g IV QID, Cotrimoxazole 800–160 mg BID	2 weeks Cefotaxime postop followed by 4 weeks Cotrimoxazole	Open reconstruction (Dacron)	Adverse events: no
11	Negative	*E. coli*, *E. faecalis*, Candida species	NP	Ciprofloxacin 250 mg oral BID, Fluconazole 200 mg oral OD	Postop until failure	Open reconstruction (Dacron)	Vascular graft/endograft infection and pulmonary-related mortality
12	*Streptococcus pneumoniae*	*E. faecalis*	*E. faecalis*	Vancomycin 300mg IV BID, Ciprofloxacin 500 mg oral BID	2 months postop	Open reconstruction (Dacron)	Vascular graft/endograft infection
13	Salmonella	Salmonella	NP	Meropenem 1000mg IV TID, Vancomycin 2400 mg IV OD	6 months postop	Endovascular repair	Vascular graft/endograft infection, endoleak type I and infection-related mortality
14	*Staphylococcus aureus*	NP	NP	Flucloxacillin 12 g IV OD, Clindamycin 600 mg oral TID	6 weeks Flucloxacillin postop followed by Clindamycin until failure	Endovascular repair	Endoleak type I, vascular graft/endograft infection, for which treated with replacement surgery (xenograft, bovine pericardium) and infection-related mortality
15	Negative	Negative	NP	Ciprofloxacin 500 mg oral BID, Clindamycin 300 mg oral BID	Postop until failure	Open reconstruction (autologous vein)	Vascular graft/endograft infection and infection-related mortality
16	Negative	*E. coli*	NP	Amoxicillin 500 mg oral TID	2 months postop	Open reconstruction (Dacron)	Vascular graft/endograft infection
17	*Streptococcus equi*	NP	NP	Benzylpenicillin 12g IV OD	Starting 1 day preop continuing until 6 weeks postop	Open reconstruction (autologous vein)	Adverse events: no
18	*Streptococcus pneumoniae*	Negative	NP	Benzylpenicillin 18000000 IU IV OD	6 weeks postop	Open reconstruction (autologous vein)	Adverse events: no

(*continued on next page*)

Table III (*continued*)

	Blood cultures	Perioperative tissue and/or pus cultures	Puncture	Antibiotic treatment	Antibiotic course duration, preoperatively or postoperatively	Surgical treatment	Outcome
19	*Streptococcus pneumoniae*	Negative	NP	Benzylpenicillin 12000000 IU IV OD	1 week	Open reconstruction (bio-prosthesis)	Adverse events: no
20	*Klebsiella pneumoniae*	NP	NP	missing	missing	No	Mortality caused by MAA rupture
21	Negative	NP	NP	Piperacillin/Tazobactam 4000 mg/500 mg IV OD, Augmentin 625 mg oral TID	3 months Piperacillin/Tazobactam postop followed by Augmentin until failure	Endovascular repair	Adverse events: no
22	*Staphylococcus aureus*	NP	NP	Flucloxacillin 12 g IV OD, Clindamycin 300 mg oral BID	6 weeks Flucloxacillin postop followed by Clindamycin lifelong until failure	No	Adverse events: no
23	*Streptococcus pneumoniae*	NP	NP	Piperacillin/Tazobactam 4000mg/500mg IV OD	Postop until failure	Open reconstruction (Dacron)	Malignancy-related mortality
24	*E. coli*	NP	NP	Augmentin 62 mg oral TID	2 weeks	No	Mortality caused by MAA rupture

[a]Not performed,
[b]Intravenous,
[c]Twice a day,
[d]Once daily,
[e]Three times a day.

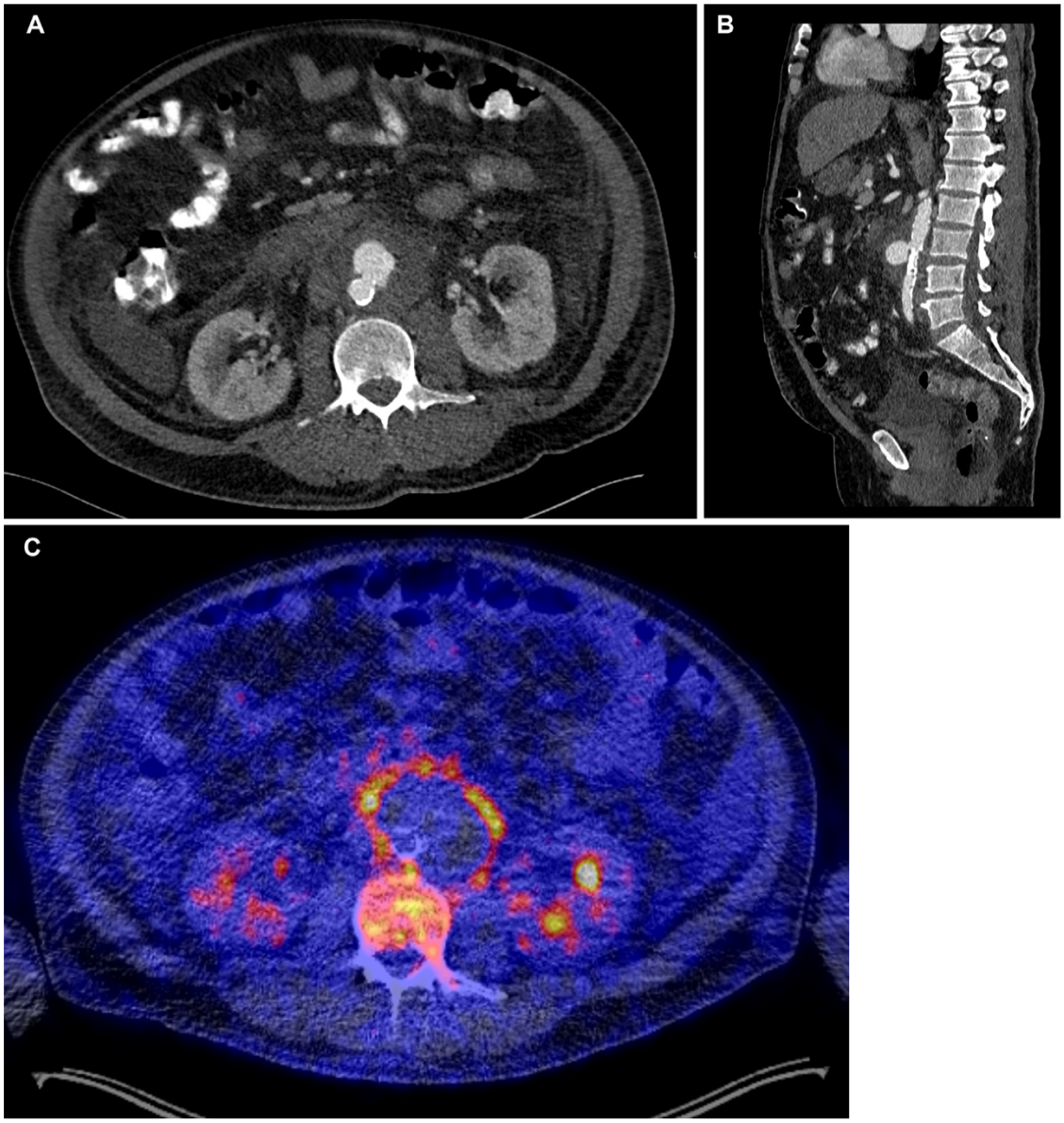


Fig. 1. Transversal (**A**) and sagittal (**B**) CT-angiography views of a thin stemmed infrarenal ventral saccular mycotic aortic aneurysm, with thickening of the aortic wall, soft tissue stranding, and mural thrombus formation. (**C**) Transversal ^{18}F-FDG PET/CT view of the same patient at the level as Figure 1A that shows a heterogeneous uptake of ^{18}F-FDG in the aortic wall.

All patients were treated with antibiotics with varying durations in accordance with decisions from a multidisciplinary expert team with a vascular surgeon, clinical microbiologist, and infectious disease specialist (Table III).

Mortality and Adverse Events

Median follow-up was 20 (IQR: 7–42) months. Ten patients (42%) died during follow-up. Patient survival from first presentation until mortality or latest follow-up is shown in Figure 3. Kaplan-Meier analysis demonstrated a cumulative survival of 83% (standard error: 5) at 1 year, 69% (standard error: 12) at 3 years and 25% (standard error: 14) at 5 years. Main causes of death were (central) vascular graft/endograft infection-related (n = 4, 40%) and MAA rupture (n = 3, 30%, all conservatively managed patients). Cardiac-, pulmonary- and malignancy-related mortality accounted each for n = 1 (10%).

The 30-day mortality rate was 0% in the group that underwent (open or endovascular) surgical repair and 50% (n = 2, both MAA rupture) in

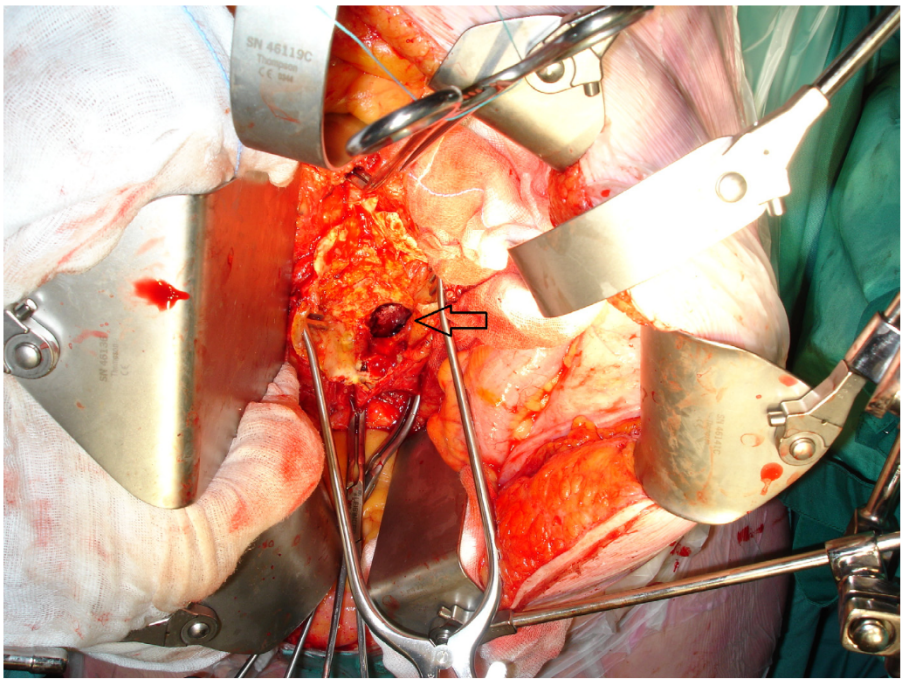


Fig. 2. Photograph of infrarenal mycotic aortic aneurysm taken during open surgical repair, the infrarenal aorta (proximal) and the right and left common iliac artery are clamped. The arrow points a dorsally ruptured mycotic penetrating aortic ulcer.

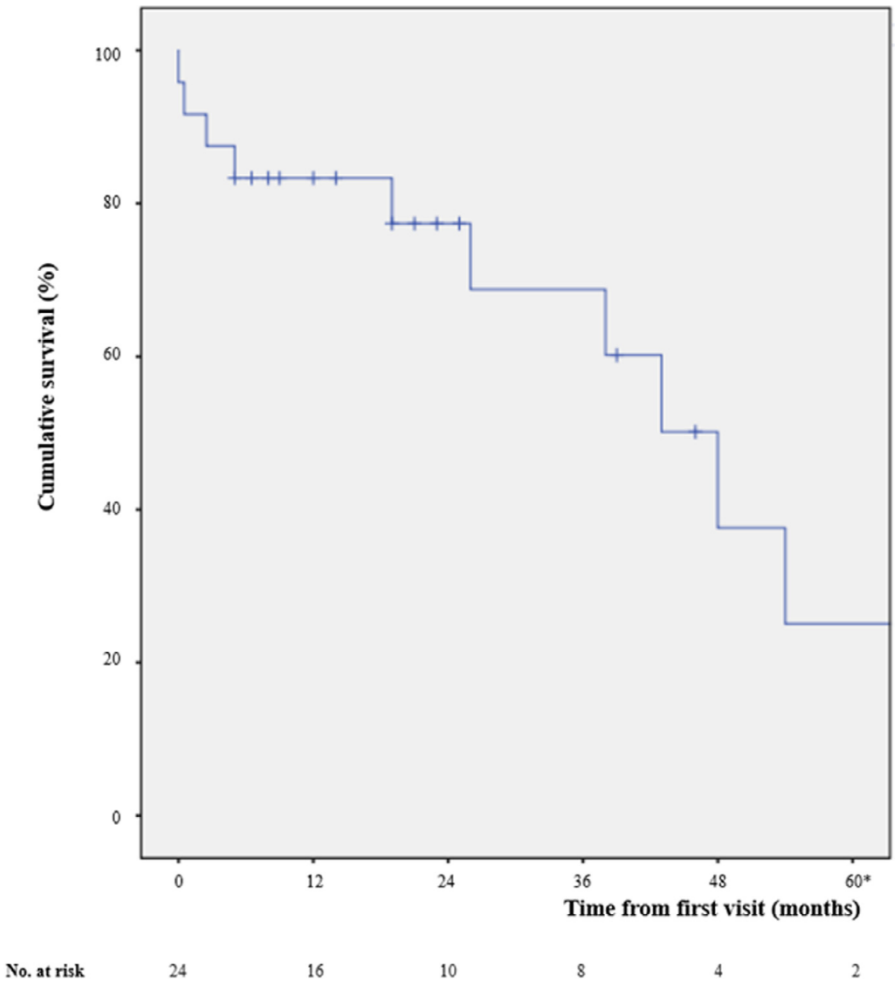
Table IV. Modes of treatment in patients with mycotic aortic aneurysm

Variable	*N* (%)
Open repair	13 (54)
- Conventional (Dacron)	8 (61)
- Autologous	4 (31)
- Bio-prosthesis	1 (8)
Endovascular repair	7 (29)
Conservative (no surgery)	4 (17)

the conservatively treated patients. The in-hospital mortality rate in the surgically treated group was 10% ($n = 2$) and the overall mortality rate in the surgically treated group was 35% ($n = 7$) with a median follow-up of 24 months (IQR: 13–45).

Postoperatively, 8 patients (33%) were diagnosed with an infected prosthesis (vascular graft/endograft infection) based on clinical, radiology and/or laboratory characteristics. Time of diagnosis ranged from 26 days till almost 3 years postoperative, with a median of 376 (IQR: 97–819) days. Five of them were initially treated with open surgery and replacement with a Dacron prosthesis and 3 with an endograft. In 2 patients the antibiotics were stopped at the time of diagnosis (after durations of 2 and 6 months, respectively). In 2 patients the same microorganism as from the preoperative cultures was found. Two patients did not have preoperative positive cultures, and in 4 patient's different microorganisms were cultured pre- and postoperatively. A total of 5 patients with a vascular graft and/or endograft infection died. All patients with a diagnosed infected graft were treated with antibiotics. Duration of antibiotic therapy was at least 6 weeks with possible extension based on symptoms, inflammatory markers (laboratory) and/or imaging. In addition to the antibiotic therapy, 3 patients were treated surgically. Two of these patients had an endograft infection. Hereafter, they underwent open surgery where the infected endograft was replaced by bovine pericardial xenograft, 3 and 13 months, respectively, after the initial procedure. The first patient had a good outcome and had no signs of (re-)infection. The second patient developed graft infection and died 6 months after the replacement surgery as the result of infection related complications. One of the patients who had undergone an open MAA repair, had an infected Dacron prosthesis. The infected prosthesis of this patient was surgically replaced with autologous deep femoral vein. The surgery was complicated 2 months postoperative by an aorto-duodenal fistula, which was treated endovascularly first and later with a rifampicin soaked Dacron graft.

Other noted adverse events included endoleak type I after endovascular repair in 2 patients



**Truncated at 60 months (No. at risk < 10%)*

Fig. 3. Survival function of patients with mycotic aortic aneurysm.

and postoperative occlusion of a femoral artery requiring thrombectomy in 1 patient initially treated with open reconstruction with a Dacron prosthesis (Table III). No patient characteristics could be identified that were predictive for mortality (Table V).

Table V. Univariate Cox regression analysis

Characteristic	HR[a] (95% CI[b])	*P*-value
Age	1.06 (0.96–1.17)	0.27
Sex	0.36 (0.046–2.90)	0.40
BMI	1.10 (0.83–1.45)	0.50
Tobacco use	0.83 (0.17–4.03)	0.82
Hypertension	0.34 (0.72–1.62)	0.18
Hyperlipidaemia	1.40 (0.34–5.75)	0.65
Diabetes mellitus	0.40 (0.096–1.71)	0.22
Cardiac disease	0.78 (0.21–2.94)	0.71
Pulmonary disease	1.46 (0.40–5.27)	0.56
Renal disease	0.52 (0.12–2.35)	0.40

[a]hazard ratio,
[b]confidence interval.

DISCUSSION

Our study shows a mortality rate of 42% in patients with an MAA after a median follow-up of 20 months. The total survival rate of 83% at 1 year is comparable with the literature. The 5-year survival rate of 25% is lower than that found by Sörelius et al., at 59%.[9] This lower survival rate in our cohort could be attributed to the inclusion of patients who did not undergo surgery. These patients may not have been physically able to withstand surgery. As shown in Table III, 3 out of 4 patients who were not operated, died. Hsu et al. also included patients who were treated conservatively and found

an overall 1-year survival rate of 25%.[16] In the group of patients that had undergone surgical treatment, the overall mortality rate was 35% ($n = 7$). However, the value of the 5-year survival rate in our cohort is limited because of the low number of patients at risk at 60 months ($n = 2$, Fig. 3).

Fifty-seven percent of the patients with preoperative blood cultures (96%) had at least 1 positive blood sample. This is comparable with the 56% found in the nationwide study on thoracic MAAs of Sörelius et al., but higher than the nationwide study of treatment of MAAs in the Netherlands of Dang et al.[8,9] Seventy percent of the intraoperative cultures (tissue and/or pus) were positive. From our viewpoint, if open surgery is performed, vascular tissue or pus should be cultured, to maximize the chances of finding the causative micro-organism in order to start targeted antibiotic therapy. In case of endovascular repair intraoperative cultures cannot be taken. This can lead to undertreatment, which will increase the risk of reinfection. Tagiwaga et al. described a case of CT-guided biopsy of periaortic wall after EVAR. This increases the chances of finding a causative agent, and thus finding the suitable therapy with the right antibiotic.[17] As shown in Table III, the second patient had negative blood cultures and underwent diagnostic puncture (and drainage) of an abdominal abscess close to the native aortic wall. Cultures showed *Mycobacterium bovis* and targeted antibiotic therapy was started. Later this patient underwent endovascular repair.

CT(A) is the preferred imaging method for diagnosing MAAs. The meta-analysis of Wang et al. showed a pooled sensitivity and specificity of CT of 82% and 93%, respectively.[18]. ^{18}F-FDG PET/CT is potentially useful for diagnosing MAA in a non-acute setting.[19–21] Our study evaluated 6 patients with a preoperative ^{18}F-FDG PET/CT-scan. They all had a heterogeneous distribution of the ^{18}F-FDG uptake with a median SUVmax 5.9 and a median visual grade of 3.0. No cut-off points are described in the literature, but the SUVmax (5.9) is comparable with the 4.5–6.5 found in the systematic literature review of Hannsberger et al. – SUV cut-off points for infection remain debatable.[22–24] The cohort study of Husmann et al. compared the diagnostic accuracy of PET/CT and contrast-enhanced CT in the detection of MAA and found a diagnostic accuracy of PET/CT higher than contrast-enhanced CT. They found a high sensitivity (probably because of the measurable SUVmax), and specificity was lower because of false-positive findings in inflammatory aortic aneurysms.[25] Next to the diagnostic value, serial ^{18}F-FDG PET/CT can potentially contribute in the follow-up to determine the duration of antibiotic therapy.[22,26] Furthermore, ^{18}F-FDG PET/CT can show infection in other parts of the body that could be the source of the MAA. Larger prospective studies are needed to estimate the diagnostic value of ^{18}F-FDG PET/CT for abdominal MAAs more accurately.

The treatment strategies found in our study were very heterogenous. Fifty-four percent of the patients had undergone open repair (Dacron prosthesis, venous reconstruction, or bovine pericardial xenograft), 29% had undergone endovascular repair, and 17% did not undergo surgical repair. Following the ESVS guidelines, open repair is the gold standard, but the use of EVAR has risen in the last decade. EVAR is minimally invasive and can be used as a bridge to surgery in acute situations and/or in critically ill patients who would otherwise be given palliative treatment. Sörelius et al. shows a significant short-term survival benefit for EVAR without late disadvantages.[9] Following Heinola et al. open repair with biological grafts gives higher midterm survival compared to other methods, probably because of the lower risk of reinfection.[17] All patients got antibiotic treatment, with variances in duration. In the literature there are no clear recommendations and durations vary from 4–6 weeks to lifelong.[8–10,27] The antibiotic treatment is influenced by the cultured micro-organism, type of surgical repair, and clinical, and biochemical status of the patient.[10] Hence treatment of MAA patients should be based individually and discussed in a multidisciplinary team with a vascular surgeon, infectious disease specialist and clinical microbiologist. This patient-tailored multi-disciplinary approach is also the recommended strategy according to the recently published study by Berard et al.[28]

This study has some limitations. The first limitation is the retrospective design, which causes a heterogenous group of patients with different diagnostic approaches and differences in treatment strategies. Another limitation is the relatively low number of patients and the lack of a comparative control group (i.e., noninfectious AAA). This reduces the strength of the results. However, MAA is a rare disease, so the results of this study are still useful for guiding future studies.

CONCLUSION

In the present study heterogeneity in presentation, diagnostic approaches, and surgical and antibiotic treatment was observed in MAA. This relatively large single-center cohort study contributes to the current knowledge on MAA by providing detailed information about diagnosis and treatment, and highlights the importance of a multidisciplinary approach.

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