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Endovascular Treatment of Infected Aortic Aneurysms

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WHAT THIS PAPER ADDS

- The purpose of this work is to contribute to discussion about whether it is possible to manage local aortic wall infection by antibiotics and endovascular treatment only, without excision and debridement of surrounding tissue, and whether or not the placement of a foreign material into the infectious terrain will further worsen the infection.

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ABSTRACT

Objective: To report on the short- and long-term outcomes of patients with primary infected aortic aneurysm (IAA) treated by stent graft (SG) in two centers.
Material and method: Over a period of 15 years, 32 patients with IAA underwent endovascular treatment. None had undergone previous aortic surgery. The causal relationship was gastrointestinal infection in 9 patients (28%), endovascular diagnostic/therapeutic procedures/resuscitation in 6 (19%), wound infection after previous surgeries in 5 (16%), urinary infection in 4 (13%), urology or gastroenterology procedures in 3 (9%), pancreatitis in 2 (6%), endocarditis in 1 (3%) and phlebitis in 1 (3%) patient. We implanted 11 bifurcated, 10 tubular thoracic, 4 aorto-uni-iliac, 4 tubular abdominal and 1 iliac SG. Two other surgeries were hybrid procedures.
Results: The etiological agent was identified in 28 (88%) patients. Twenty-six (81%) patients survived the 30-day postoperative period. Sixteen (50%) survived to 1-year follow-up and 13 (40.6%) survived to 3-year follow-up. Three patients have survived for less than 1 year and a further 3 for less than 3 years, so far. Among patients with aneurysms situated in central parts of the thoracic and infrarenal aorta there was a better death/survival ratio than among patients with a proximal or distal aneurysm location.
Conclusion: The implantation of a SG may be an alternative to open surgery in selected groups of patients with primary IAA. Aneurysms of the central part of the thoracic or abdominal aorta have a more favorable prognosis with endovascular treatment.

Introduction

Primary false aortic aneurysms are caused either by septic embolization from another source, primary arteritis which leads to damage of the wall, infection of a pre-existing aneurysm or a post-traumatic pseudoaneurysm, or by direct transfer from the surrounding infected tissue.[1–4] The most frequently identified bacteria are Salmonella and Staphylococcus but a wide range of other agents have been identified.[2,5–7]

Patients undergoing conservative treatment have little chance of survival, due to the rapid progression of pseudoaneurysms and the likelihood of spontaneous rupture and bleeding.[8] The classical surgical procedure consists either of the radical removal of the infected arterial segment and its surroundings contaminated by the infection, followed by in situ replacement by a prosthesis impregnated with silver ions or rifampicin, or biological replacement (arterial allograft or autologous femoral vein), or of sealing the

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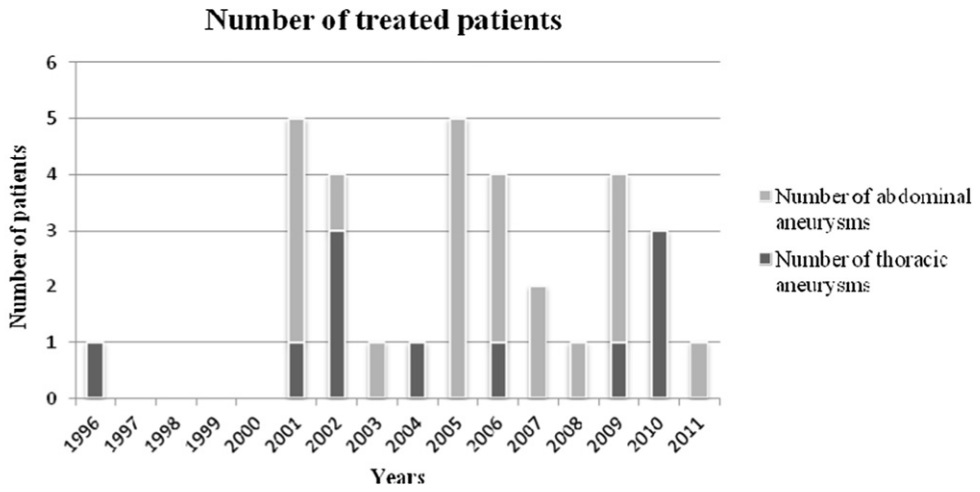

Chart 1. Total number of patients treated per year with respect to the location of the aneurysm.

Figure 1. Number of treated patients with respect to location of the aneurysm.

proximal and distal arterial stump and implementation of an extra-anatomic bypass.[9–14] In 1998, Semba et al. published a series of three patients with infectious aneurysms of the thoracic aorta treated for the first time with an endovascular stent graft (SG).[15] The placement of prosthetic material in the infected terrain may be controversial but the short-term and mid-term results are promising.[16–18] An endovascular procedure is recommended in emergency cases with a contained arterial wall rupture, in high-risk patients, and in situations with an unfavorable terrain after previous abdominal or thoracic surgeries. Some authors advocate using SG only as a temporary bridge to delayed open surgery.[19,20] Postoperative removal of infected debris from the aneurysm sac or surrounding tissue could further improve the results.[21,22] Long-term follow-up data are lacking. We question whether it is possible to manage aortic wall infection by antibiotics and endovascular treatment alone, without excision and debridement of surrounding tissue, and whether the placement of a foreign material into the infectious terrain may not worsen the infection further.

Material and Methods

Our study describes the results from two vascular surgery centers in Prague, Czech Republic: Department of Vascular Surgery in Na Homolce Hospital and Department of Cardiovascular Surgery in General University Hospital. We registered patients with primary infected aortic aneurysms treated by endovascular approach and followed them up prospectively.

Our protocol was to perform endovascular stent-grafting in all patients with primary infected aortic aneurysms, when no previous artificial prosthetic material was present. During the same period, we performed 12 open procedures for primary infectious aortic inflammation, where the anatomical situation was not convenient for the endovascular method, and 84 open procedures for prosthetic infection in the aorto-iliac position (32 in situ allogenic, 41 in situ prosthetic replacements and 23 extra-anatomic reconstructions). We preferred open surgery in all cases of prosthesis infection, where the infected artificial material had to be completely removed. For new replacements, we preferred to use fresh arterial allograft whenever it was available. None of our endovascular procedures were intended as a bridge for later open surgery. During the same period, we implanted over 1424 SGs in thoracic or infrarenal aortic conditions.

Cohort

From 1996 to 2010, 32 patients (25 men, 7 women) with a mean age of 67 years (42–83, median 69) underwent endovascular treatment in our institutions, due to primary infected aortic aneurysms. There were 11 thoracic aorta aneurysms (6 in men and 5 in women; 8 primary infections and 3 infections of pre-existing aneurysms) and 21 abdominal aneurysms (19 in men and 2 in women; 14 primary infections and 7 infections of pre-existing aneurysms). None of the patients had a multiple infectious lesion at the time of first presentation. The patients were registered chronologically according to the time of hospital admission. The incidence of infected aortic aneurysms varied over the years (Fig. 1).

Diagnostic criteria

The highly suspected causative etiology was primary bacterial gastrointestinal infection (colitis) in 9 (28%) patients, coronary surgery, or cardiac or peripheral vascular catheter procedures in anamnesis and cardiopulmonary resuscitation in 6 (19%) patients, wound infection after previous general or orthopedic surgery procedures in 5 (16%) patients, urinary infection in 4 (13%) patients, urology or gastroenterology treatments in 3 (9%) patients and infectious pancreatitis in 2 (6%) patients. Endocarditis was the cause in 1 (3%) and infectious phlebitis with sepsis in 1 (3%) patient. None of the patients had undergone previous aortic surgery, no

Table 1
Associated diseases and other important factors (present during the last 12 months before the outbreak of infectious aortitis).

Comorbidities	Number	%
Smoking	16	50
Myocardial infarction in medical history	13	40.6
Diabetes compensated by oral antidiabetics or diet	8	25
Chronic renal failure	6	19
Chronic heart failure	4	12.5
Diabetes mellitus compensated by insulin	2	6.3
Myeloma	2	6.3
Dialysis	2	6.3
Immunosuppressive treatment	1	3.1
Corticosteroid therapy	1	3.1

Table 2
Clinical manifestation.

Clinical manifestation	Number	%
C-reactive protein (>5 mg/L)	32	100
Positive blood culture examination acquired before or during the endovascular procedure	25	78
Morphology typical of infectious aneurysms	25	78
Excentric saccular and irregular shape typical for false aneurysm	24	75
Infection of pre-existing abdominal aneurysm	6	18.8
Infection of pre-existing thoracic aneurysm	2	6.3
Fever	24	75
Pain	24	75
Leukocytosis (>10.0 G/L)	22	69
Infection infiltration into the surrounding tissue	7	22
Intervertebral spaces	4	
Psoatic abscess	2	
Ischemic colitis	1	
Aneurysm rupture, bleeding	3	9.4
Contained rupture (intramural hematoma)	2	6.3
Infection caused aorto-caval fistula	1	3.1

artificial prosthetic material was present and none of them had an aorto-enteric fistula. Some of the causes occurred in combination. We found no clear relationship in only 2 (6%) patients. Other important factors and conditions are listed in Table 1.

All patients were symptomatic at diagnosis. The main symptoms were pain and fever, and the laboratory signs were elevated leukocytes and C-reactive protein. Numerous blood, body fluid and tissue cultures were performed in all patients. In patients where the microbiological agent was not specified before operation, blood cultures were also taken by blood and debris catheter aspiration directly from the aneurysm during the endovascular procedure. These intraoperative cultures were positive in 3 patients out of 6. The total number of positive hemocultures taken pre- or peri-operatively was 25. Four positive microbial cultures were acquired from abscess or perianeurysmal infiltrate punctures done during open hybrid or secondary surgical procedures. Clinical manifestations are listed in Table 2.

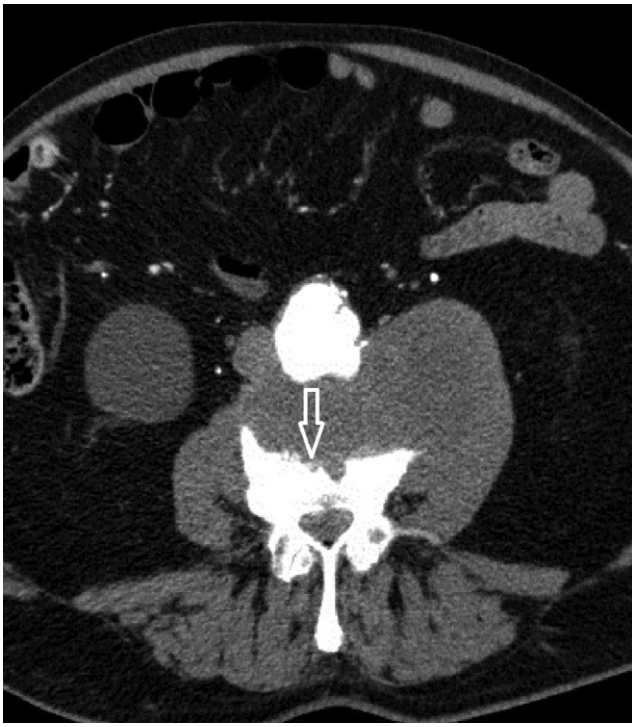

Figure 3. Vertebral destruction caused by spreading infection (arrow). Note large periaortic infiltration. CT scan at admission. From medical history, this patient had cholecystectomy followed by surgical wound fistula, lasting months, infected by Salmonella, and he suffered Salmonella sepsis and Salmonella subfrenic abscess several months before admission. Secondary infection of abdominal aortic aneurysm known of for years.

Figure 2. Contrast-enhanced hyperemic inflammatory rim (arrows) of the aneurysm. CT scan at admission 63 days after an episode of septic fever and diarrhea. Infectious agent never identified.

Figure 4. Abscess in the left psoatic muscle with gas bubbles (arrow). CT scan at admission. Staphylococcus aureus identified from hemocultures and from abscess. Duration of case history 35 days. In medical history recent repeated PTA and arterial stent implantation.

Computerized tomography angiography (CT AG) was our first-choice diagnostic examination. We distinguished asymmetric irregular aneurysm shape, periaortic infiltration and contrast saturation of the hyperemic inflammatory rim of the aneurysm (Fig. 2). The spread of the infection in the surrounding tissue lead in some patients to vertebral destruction (Fig. 3) or formation of a psoatic abscess (Fig. 4). Air bubbles were rarely present (Fig. 4). FDG/PET CT (Fig. 5a,b) was performed before surgery in 22 patients. However, in 10 patients the CT finding of arterial wall inflammation was considered sufficient proof of infectious etiology. FDG/PET CT was used also during follow-up in selected patients (Fig. 5c,d).

Antibiotic regime before and after the procedure

After the diagnosis, 100% of patients received antibiotic treatment lasting from 2 to 31 days (16 days on average) before the endovascular procedure. In 22 patients, the treatment was targeted according to the sensitivity identified from preoperative blood cultures, and in 6 patients according to microbial cultures from other body sources. In 4 patients, the antibiotics were purposely changed depending on the type of infectious agents from the perioperative cultivation. In 4 patients, broad-spectrum antibiotics were administered for unknown infections. After the procedure, antibiotic treatment was continued for up to 4–8 weeks depending

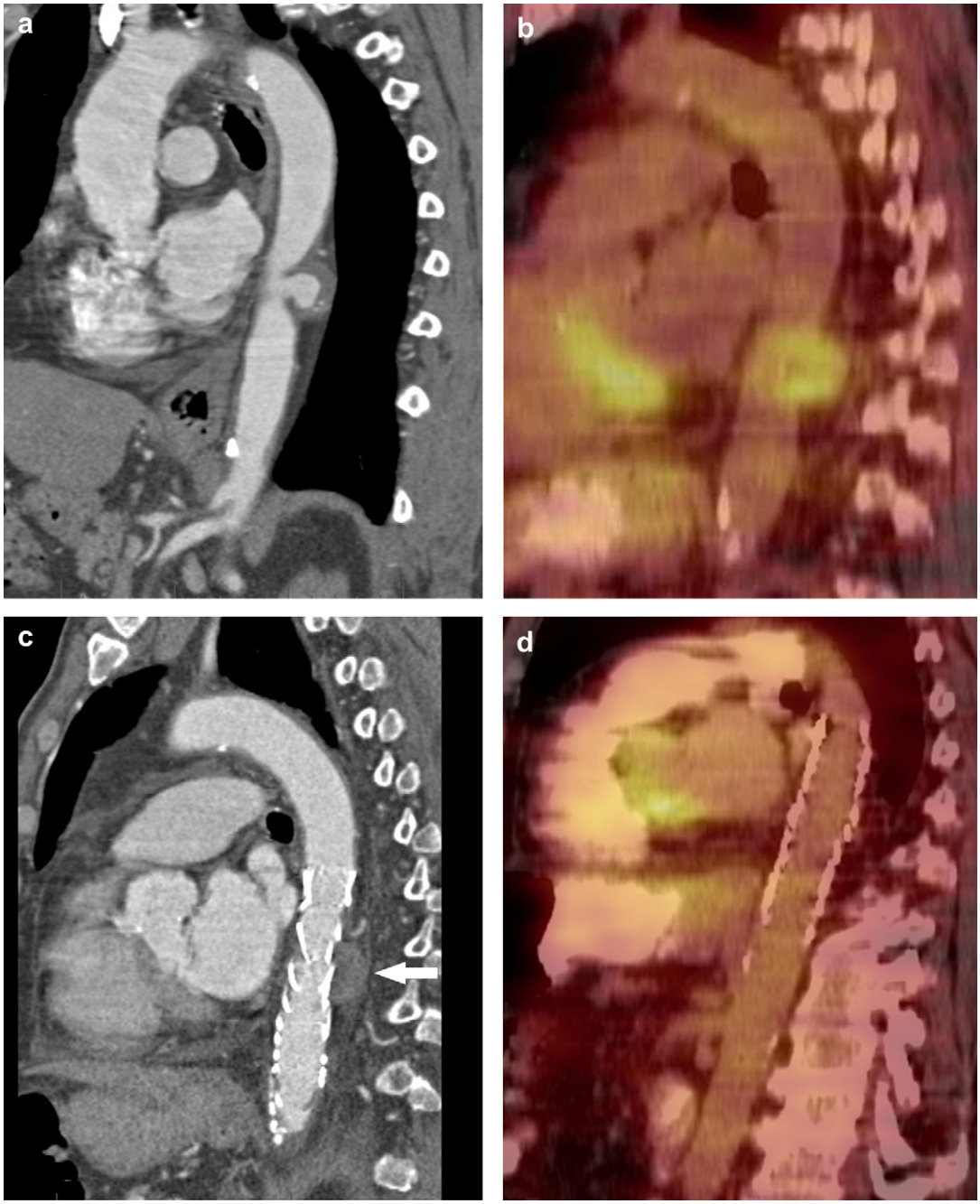

Figure 5. a. Saccular aneurysm of descending aorta with inflammatory infiltration lining on CT. Salmonella was captured in hemocultures, infection originated from urinary tract, anamnesis duration 56 days. CT scan. b. Significant metabolic activity typical of infected aneurysm on FDG/PET CT. c. CT scan, the same view 1 week after tubular SG implantation. Arrow points at the thrombosed aneurysms. d. FDG/PET CT after 1 year: metabolic activity disappeared, no signs of aneurysm or residual inflammation.

upon the decrease of inflammatory markers, but at least 4 weeks after normalization of leukocytes, CRP, procalcitonine and body temperature. In patients with Salmonella infection, antibiotic treatment was changed from intravenous to oral form at the time of hospital discharge and continued indefinitely. However, in some Salmonella patients this long-term therapy was discontinued after several months or years due to adverse reactions, decisions of other physicians or patient non-compliance, with no signs of recurrent infection.

Endovascular and surgical procedures

All endovascular procedures were performed in an operating theatre equipped with a mobile C-Arm OEC 9800 (General Electric Company, Fairfield, CT, USA) or in a hybrid operating room with a fixed biplanar device (Axiom Artis, Siemens, Erlangen, Germany) under total (22 patients) or local (10 patients) anesthesia. In all cases, the femoral arteries were surgically exposed. The procedure types are shown in Table 3. In the infrarenal abdominal position, we used four tubular SGs in cases where the aneurysm was excentric saccular with a very narrow neck, and when we expected safe coverage of the aneurysm inflow. The reasons for aorto-uni-iliac type of SG were obliteration or severe stenosis of iliac artery in 3 patients and anatomical reasons in 1 patient. In total, four different SG products were used: Gore (W.L. Gore, Newark, DE, USA), Endofit (LeMaitre Vascular, Inc., Burlington, MA, USA), Medtronic (Medtronic, Minneapolis, MN, USA) and ELLA (ELLA CS, Hradec Kralove, Czech Republic).

We registered the incidence of infectious agents and the success rate of the therapeutic procedure in both short-term (up to 30 postoperative days) and long-term follow-ups. We considered those patients cured whose laboratory markers decreased to normal values, who did not have a high temperature, signs of sepsis or extravasation during the monitoring period, and whose inflammatory picture on CT and FDG/PET CT had diminished. Diagnosis was by CT AG, which we performed after 1, 3 and 6 months and then yearly. FDG/PET CT was performed at least 3 months after SG implantation, depending on the duration of antibiotic treatment.

Results

The average time from the onset of symptoms to the date of hospitalization was 34.6 (7–150) days. The mean time from the first symptoms to diagnosis was 28 (3–136) days. The mean time from diagnosis to surgery was 11 days. The duration of hospitalization at our institution was 22.9 (2–190) days. The etiological agents of infectious disease are summarized in Table 4.

Morbidity and mortality

During the 30-day postoperative period, 6 (18.8%) patients died. Three (9.4%) died due to progressing sepsis and multiorgan or renal failure. Three (9.4%) patients died from other causes: one of secondary mycotic infection in post-antibiotic pseudomembranous colitis, one of acute myocardial infarction (AMI) with a pulmonary edema, and one of late pulmonary and hepatic failure on the 19th day after distal leak treatment by an additional extension. Early mortality is presented in Table 5.

During further follow up with a median of 45 (4–110) months, another 10 (31.3%) patients died: four (12.5%) due to persistent infection or infection penetrating into the surrounding tissue (5th, 5th, 11th and 12th month) and six (18.8%) of other causes (colon tumor with metastases, pneumonia after hip surgery, stroke, meningioma, other aneurysms, pedal gangrene). Late mortality is shown in Table 6. The other 16 (50.0%) patients were alive after an average follow-up period of 42 months (4–86).

Table 7 and Table 8 show the influence of various aneurysm and procedure characteristics on short- and long-term results. Simplicity of SG implantation led to longer survival in comparison with hybrid procedures or technically compromised results necessitating secondary endovascular procedures (e.g. SG extension). Patients with ruptured infected aneurysms had a high perioperative mortality of 80%. Perioperative renal failure, multi-organ failure or AMI had a perioperative mortality of 57%, and operation during ongoing sepsis resulted in 100% 30-day mortality. Concerning location, patients with aneurysms situated in central parts of the thoracic and infrarenal aorta had better results than patients with proximal or distal aneurysms (Table 8). Implantation of a tubular SG into the subrenal aorta does not meet the requirement for extensive proximal and distal coverage and safe SG anchoring to the unaffected aorta. Two out of four tubular abdominal SGs were either distorted or had a significant leak, leading to the death of the patient. We noticed a difference in survival between the patients treated by the first generation (ELLA CS) and by the second generation (Gore, Endofit, Medtronic) SGs. The older generation was associated with higher mortality during 30-day and 1-year periods (6 patients out of 7), while the new generation showed better results (30-day and 1-year mortality, 7 patients out of 25).

In two (6.3%) patients, an endoleak was found during long-term follow-up, one proximal in the thoracic and one distal in the abdominal position of the bifurcated stent graft. The thoracic SG was extended, but the patient died following an AMI. Abdominal endoleak was successfully treated by distal extension (Table 8).

Twenty-six (81.3%) patients survived the 30-day postoperative period. Sixteen (50%) survived to 1-year follow-up and 13 (40.6%) survived to 3-year follow-up. Three surviving patients have been alive for less than 1 year and a further three patients for less than 3 years. A Kaplan–Meier curve (Fig. 6) shows the 30-day, 1-year and 3-year simulated survival in our cohort. From the 13th month after the endovascular procedure, all deaths had causes other than the primary disease/infection.

Table 3
Surgical procedure.

Type of procedure/SG	Number
Bifurcated	11
Tubular (thoracic)	10
Aorto-uni-iliac	4
Tubular (subrenal)	4
Hybrid procedure (tubular SG and visceral vessel revascularization)	2
Iliac	1

Table 4
Identified infectious agents.

Agents	Gram +/–	Number	%
Salmonella enteritidis	–	13	40.6
Staphylococcus aureus	+	4	12.5
Staphylococcus MRSA	–	1	3.1
Pseudomonas aeruginosa	–	3	9.4
Candida albicans	NS	1	3.1
Citrobacter freundii	–	1	3.1
Listeria monocytogenes	+	1	3.1
Klebsiella pneumoniae	–	1	3.1
Proteus vulgaris	–	1	3.1
Serratia marcescens	–	1	3.1
Streptococcus viridans	+	1	3.1
Not identified (1x Staphylococcus epidermidis)	NS	4	12.5

Table 5
Causes of early mortality.

No.	Sex	Age	Clinical symptoms	Infection localization	Infectious agent	Procedure type (SG type)	Complications	Reintervention	Time of death	Cause of death
1	Male	81	Pain	Subrenal aorta	Salmonella	Tubular abdominal	AMI, SG collapse	None	2nd day	AMI, pulmonary edema, retroperitoneal hemorrhage
2	Female	75	Back pain, fever	Thoracic aorta	Staph. aureus	Tubular thoracic	Continuing sepsis, proximal endoleak	None	2nd day	Multiorgan failure, continuing sepsis
3	Female	69	Fever, pain, fluidothorax	Thoracic aorta supra-diaphragmatic	Salmonella	Tubular, uncovered part across celiac trunc	Distal endoleak	Open conversion on 2ndp.o. day	4th day	Multiorgan failure, continuing sepsis destroyed aortic wall
4	Male	72	Pain, ruptured aneurysm	Above abdominal aorta bifurcation	Salmonella	Bifurcated	Candida albicans sepsis, renal failure	None	15th day	Renal failure, post-antibiotic colitis, mycotic sepsis
5	Male	62	Pain	Subrenal aorta	Salmonella	Tubular abdominal	Distal endoleak, ascites	Aorto-iliac extension + cross-over bypass	19th day	Pulmonary and hepatic failure
6	Male	66	Back pain, fever	Above abdominal aorta bifurcation	Staph. aureus	Aorto-uni-iliac SG + cross-over bypass	Continuing sepsis, enterorrhagia, post-antibiotic colitis	None	22nd day	Continuing sepsis, renal failure

Table 6
Causes of late mortality.

No.	Sex	Age	Clinical symptoms	Infection localization	Infectious agent	Procedure type (SG type)	Complications	Reintervention	Time of death	Cause of death
1	Female	61	Pain, fever	Descending thoracic	Proteus	Hybrid procedure tubular SG + aorto-mesenteric bypass	Mycotic sepsis, pneumonia, femoral phlebothrombosis	None	4 months	Meningioma, cavernous sinus thrombosis, hepato-renal failure, decubital sepsis
2	Female	82	Abdominal pain, fever	Descending thoracic	Pseudomonas aeruginosa	Tubular	Respiratory failure, gastritis, hematemesis	None	5 months	Pedal gangraena sepsis, refused further surgery
3	Male	67	Back pain	Descending thoracic	negative (Staph. epiderm.)	Tubular	New dissection in abdominal aorta and iliacs	None	5 months	Continuing sepsis
4	Male	69	Back pain, paraparesis	Above bifurcation	Serratia marcescens	Bifurcated	Psoatic abscess, infectious polyradiculoneuritis spondylitis L3-L4	Abscess evacuation	5 months	Persistent infection, multiorgan failure
5	Male	60	Abdominal pain	Above bifurcation	Negative	Bifurcated	Distal endoleak, SG iliac leg extension	None	6 months	New aneurysm in visceral abdominal segment, refused another procedure
6	Male	56	Pain, fever	Visceral aorta	Klebsiella pneumoniae	Hybrid procedure; branched bypass to CT, SMA and RA	Spondylodiscitis	Neurosurgical hemilaminectomy and stabilization	11 months	Recurrent sepsis, abscess in both psoatic muscles
7	Male	62	Asymptomatic	Descending thoracic	Pseudomonas aeruginosa	Tubular	Proximal endoleak, dislocation of SG	Tubular extension of previous SG after 12 months	12 months	Persistent infection, unstable angina, AMI, cardiogenic shock
8	Male	71	Pain	Infrarenal aorta	Listeria monocytogenes	Aorto-uni-iliac SG + cross-over bypass	None	None	60 months	Stroke
9	Male	67	Pain	Infrarenal aorta	Salmonella	Bifurcated	None	Cholecystectomy	83 months	Pneumonia after hip joint surgery
10	Male	68	Fever	Descending thoracic	Salmonella	Tubular	None	None	110 months	Colon cancer, hepatic metastases

The Kaplan–Meier function was simulated with Statistica 9 Software.

Discussion

Stent grafts have been successfully used for infectious pseudoaneurysms in carotid, femoral, subclavian and brachial arteries.[23–26] Based on our results, the endovascular treatment of primary infected aneurysms of the thoracic or abdominal aorta is a possible alternative to open surgery. In patients not suitable for conventional open surgery, it may be possible to manage local aortic wall infection by antibiotics and endovascular treatment. The introduction of a foreign material into the infectious terrain will not necessarily further worsen the infection.[27] Excision, debridement of surrounding tissue or drainage of abscesses may be required in patients where infection has spread to adjacent structures. On the other hand, usage of a stent graft does not preclude later open repair, and in a situation of impending rupture it could be used as a "bridge to surgery". Both previously ruptured infectious aneurysms and contained ruptures have an unfavorable prognosis - in our cohort only 20% survived the perioperative period. Patients with non-ruptured aneurysms localized in the middle part of the thoracic descending or infrarenal aorta, with sufficient proximal neck, who underwent a straightforward endovascular procedure (without the need for secondary endovascular intervention), which covered as long an adjacent arterial segment as possible, without limiting organ failure and with successfully pre-operatively controlled infection, had the greatest chance of long-term survival.

In our experience, patients treated with the first generation of stent grafts had a higher mortality during the 30-day and 1-year periods, partly because of a higher rate of endoleaks compared to the second generation devices. According to our observations, during the initial 3 years of the study, only 50% of patients survived for over 1 year after the operation.

Targeted antibiotic treatment led to a significant decrease in the high mortality rate normally associated with this diagnosis. Therefore, maximum effort should be made to identify the infectious agent. From a tactical point of view, it is very important to ascertain the causative agent before starting antibiotic therapy. Following microbiological diagnosis, the preoperative period should be used as effectively as possible for intravenous administration of antibiotics, and the stent graft should not be implanted before the blood cultures are negative.[16,17,27] The minimum time to allow for the beneficial effect of antibiotics is 3–7 days.[19,27] During the setting up/preparation of the stent graft for implantation, it can be soaked with an antibiotic solution.[28] It is appropriate to continue antibiotic treatment for 4–8 weeks after surgery; in the case of Salmonella, a treatment period of at least 6 months is advised and, according to some sources, life-long antibiotic therapy is recommended in individual cases.[16,29] Infection spreading into the intervertebral spaces, with the subsequent destruction of discs or retroperitoneal abscess formation, leads to severe complications. Additional surgical procedures such as excision of infected tissue, decompression of abscess by incision or percutaneous drainage of these secondary deposits will improve results, and may help to eradicate the infection.[29,30] Spine stabilization may be accomplished in patients with vertebral destruction. A hybrid technique to treat infected vascular reconstruction, combining stent graft, surgical revision and vacuum-assisted wound closure, was reported on recently.[31]

Table 7
Significant aneurysm characteristics and their relation to numbers of dead or surviving patients. AMI: acute myocardial infarction; RF: renal failure; MOF: multiorgan failure; EL: endoleak; SG: stent graft.

Significant aneurysm characteristic		*n*	Periop. death <30 days	30 days–1 year		1–3 years		Surviving 3 and more years
				Dead	Surviving	Dead	Surviving	
Infectious agent	Salmonella	13	4			0	2	7
	Staphylococcus	5	2	0	2			1
	Pseudomonas	3		2	0			1
	Candida, Citrobacter, Listeria	3						3
	Klebsiella, Proteus, Serratia	3		3	0			
	Streptococcus	1		0	1			
	Not identified	4		2	1			1
Technical feasibility	Easy SG	24	2	3	4	0	2	13
	Hybrid procedure	2		2	0			
	Problematic result of implantation (EL type I, SG distortion)	6	4	2	0			
	Secondary endovascular procedure done	2	1	1	0			
	Secondary open procedure for abscess, spondylodiscitis	6	1	2	1	0	1	1
Other medical conditions	Perioperative AMI, RF, MOF	7	4	2	0			1
	Operation during ongoing sepsis	3	3					
Aneurysm characteristic	Non ruptured	27	2	7	3	0	2	13
	Ruptured	5	4					1
Extension of infection	Limited to aortic wall and <10 mm	7	1	0	1			5
	Inflammatory infiltration around aneurysm >10 mm and <20 mm	6		2	1			3
	Inflammatory infiltration around aneurysm >20 mm	13	5	1	1	0	1	5
	Abscess, spondylodiscitis	6		4	1	0	1	
Aneurysm location	Thoracic proximal	1		1	0			
	Thoracic central	5	1	0	1	0	1	2
	Thoracic distal	5	1	3	1			
	Infrarenal proximal	1		1	0			
	Infrarenal central	8		0	1	0	1	6
	Infrarenal distal	12	4	2	1			5

Table 8
Significant procedure characteristics, technical success and their relation to numbers of dead/surviving patients. Abbreviations: EL: endoleak; AMI: acute myocardial infarction; XO: cross-over bypass.

Aneurysm localization	Procedure/SG type	Perioperative course/influence on aneurysm/cause of death	Periop. death <30 days	30 days–1 year		1–3 years		Surviving 3 years and more
				Dead	Surviving	Dead	Surviving	
Thoracic proximal	Tubular	Proximal EL, tubular extension after 12 months, persistent infection, unstable angina, AMI		1				
Thoracic central	Tubular	Disappeared in 3 months						1
	Tubular	Disappeared in 2 months						1
	Tubular	Successful, no EL					1	
	Tubular	Decreased significantly in 12 months						1
	Tubular	Continuing sepsis, multiorgan failure	1					
Thoracic distal	Tubular	Decreased after 6 months					1	
	Tubular	New dissection in abdominal aorta and iliacs		1				
	Tubular	Distal EL, open conversion on 2nd day, sepsis, multiorgan failure	1					
	Hybrid:single bypass to SMA and tubular SG from thoracic to visceral aorta, above renals	Chronic myeloma. Meningioma and cavernous sinus thrombosis, hepatorenal failure and decubital sepsis		1				
	Tubular	Respiratory failure, pedal gangrene, sepsis, refused intervention		1				
Infrarenal proximal	Hybrid: branched bypass to left RA, CT and SMA, tubular SG from thoracic to abdominal aorta	Spondylodiscitis and recurrent sepsis after 11 months, hemilaminectomy and spine stabilization, evacuation of abscesses in both psoatic muscles		1				
Infrarenal central	Bifurcated	Disappeared in 24 months						1
	Aorto-uni-iliac + XO	Disappeared in 22 months						1
	Aorto-uni-iliac + XO	Disappeared in 24 months						1
	Tubular	Spine stabilization, aneurysm decreased						1
	Bifurcated	Significantly decreased to in 36 months						1
	Tubular	Significantly decreased in 48 months						1
	Bifurcated	Significantly decreased and infiltration disappeared						1
Infrarenal distal and iliac	Tubular	Distal EL type I, conversion to aorto-uni-iliac SG + XO bypass, hepatic and pulmonary failure	1					
	Tubular	SG distortion, continuing hemorrhage, AMI, pulmonary edema	1					
	Bifurcated	Disappeared in 3 months						1
	Bifurcated	Decreased in 36 months						1
	Bifurcated	Severe thrombocytopenia,						1
	Aorto-uni-iliac + XO	Sepsis, enterorrhagia, post antibiotic colitis, renal failure	1					
	Iliac tubular	Disappeared in 3 months						1
	Bifurcated	Disappeared in 6 months						1
	Bifurcated	Distal EL and iliac extension after 4 months. New aneurysm in visceral segment after 6 months, refused another procedure		1				
	Bifurcated	Psoatic abscess drainage, spine stabilization, persistent infection, multiorgan failure		1				
	Bifurcated	Pulmonary fibrosis on daily oxygenotherapy, pulmonary and renal failure after procedure, mycotic sepsis	1					
	Bifurcated	Psoatic abscess drainage						1
	Aorto-uni-iliac + XO	Psoatic abscess drainage					1	

Gram-negative infections are considered more difficult to manage and a relative contraindication to surgical replacement in situ.[32] In our cohort, a gram-negative infection was detected in 20 (62.5%) patients. In the early mortality group, the G-infection was detected in 4 out of 6 patients (66.7%), and in the group with late mortality, in 5 out of 8 patients (62.5%).

Forty-five percent of our cohort consisted of people with impaired immunity such as diabetics, patients dependent on corticosteroids or immunosuppressive treatment, and patients in the dialysis program. It is important to emphasize the number of patients who underwent invasive cardiovascular examinations or procedures with or without stenting and arterial angiography, or

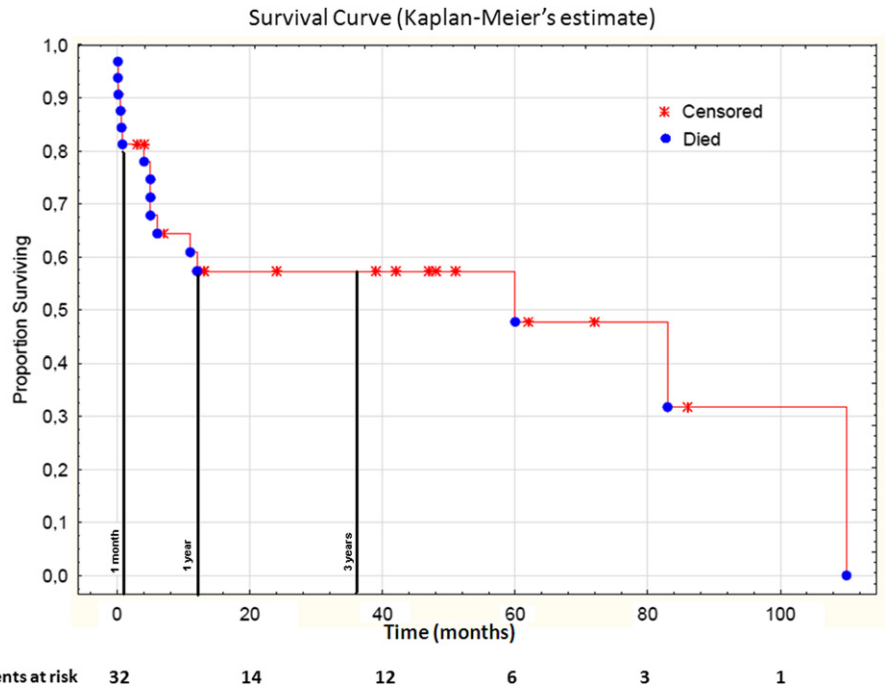

Figure 6. Cumulative survival rate (a Kaplan–Meier curve). Survival after 30 days, 1 year and 3 years is 81.3%, 50% and 40.6%, respectively.

urinary tract mini-invasive procedures, such as extraction of stones or stent implantation, or who were resuscitated during this period. This group totaled 9 patients (28.2%), and the infection occurred within 12 months post intervention. In our opinion, in all of these procedures the patients should be prophylactically medicated by broad-spectrum antibiotics before the procedure, particularly if they belong to the immunodeficient group. Another risk group is drug addicts[33]; however none were included in our cohort.

Modern hybrid diagnostic procedures, particularly PET/CT, combining the possibility of contrast-enhanced structural (CT) and metabolic (FDG-PET) imaging within one investigation, allowed a much more accurate differential diagnosis of infectious aneurysms of the aorta.[34] The metabolic activity of the process in the arterial wall is a suitable marker for monitoring the disease activity or the therapeutic success rate as a part of long-term patient monitoring.[35]

Higher metabolic activity is also shown by so-called inflammatory aneurysms of the abdominal aorta, which, however, have a different morphological image.

Infected aortic aneurysm is a disease compromising the patient not only due to difficulties caused by the anatomical localization, but also by severe systemic impairment resulting from sepsis. The already demanding surgical procedure is made more problematic by the patient's overall exhaustion. The selection of either the surgical or the endovascular procedure, and especially its timing, calls for a highly experienced team. It is also beneficial to optimize the nutritional parameters and support the functions of the affected organs before intervention. We never intentionally used stent graft as a "bridge to surgery". However, in a situation of imminent rupture it could be considered as a possibility to gain time. Care for these patients is interdisciplinary.

The organization of a randomized study to compare the results of endovascular and open procedures, and provide adequate responses, may be difficult due to the relative rareness of the condition. However, the results of treatment in large sets may help determine the appropriate tactics. Swedish authors propose the establishment of an international registry that would record all atypical pathologies including mycotic pathologies, with various treatment procedures, including conservative treatment.[33] The results could help define treatment guidelines.

Conclusion

The implantation of a stent graft may be a possible alternative to open surgery in selected group of patients with primary infected aortic aneurysm. Better results were reached in patients whose aneurysms were located in the central parts of the thoracic or abdominal aorta. High periprocedural mortality was recorded in patients with ongoing sepsis, ruptured infected aneurysms, and with perioperative renal or multi-organ failure.

Conflict of Interest

None.

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"Contribution of 18-FDG PET/CT for diagnosis of vascular prosthesis infection."

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