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Long-term experience with endovascular therapy of the descending thoracic aorta

Research Article

Jan Raupach*[1], Jan Vojacek[2], Miroslav Lojik[1], Jan Harrer[2], Vendelin Chovanec[1], Alexander Ferko[3], Petr Hoffmann[1], Pavel Ryška[1], Ondrej Renc[1], Antonin Krajina[1]

1 Department of Radiology, Faculty Hospital and Faculty of Medicine, Charles University, Hradec Kralové, Czech Republic

2 Department of Cardiosurgery, Faculty Hospital and Faculty of Medicine, Charles University, Hradec Kralové, Czech Republic

3 Department of Surgery, Faculty Hospital and Faculty of Medicine, Charles University, Hradec Kralové, Czech Republic

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Abstract: Background: To review single centre experience of endovascular treatment of descending thoracic aorta. Methods: Between May 1999 and September 2012, 72 patients were treated overall (53 men, 19 women, mean age 60.1 years) for degenerative aneurysms (n = 5), ruptured aneurysms (n = 4), aortic ulcers (n = 8), infected aneurysms (n = 4), type B aortic dissections (n = 23), and traumatic aortic injuries (n = 28). Results: The technical success rate was 98.6%, 30-day mortality was 8.3%, 1-year mortality was 13.8%, and overall mortality was 22.2%. Mortality caused by the treatment of aortic diseases was 6.9%. Permanent stroke occurred in 1 patient, and paraplegia developed in 1 patient. In a group of 23 patients whose left subclavian artery (LSA) was covered, claudication of the left upper extremity developed in 2 cases. Conclusions: Endovascular therapy offers a very effective and less invasive alternative to the surgical approach for a wide range of the thoracic aortic disease. The main advantage of using TEVAR seems to be in acute conditions when a stent graft stabilizes the aorta and prevents further bleeding and organ ischemia. Regular follow-up is mandatory for early recognition of specific TEVAR complications.

Keywords: *Thoracic aorta • Aneurysm • Dissection • Aortic trauma • Stent graft • Complications*

1. Introduction

Prognostically, thoracic aortic diseases rank among the most serious and complicated cardiovascular diseases. Clinical manifestations of these acute conditions are similar; therefore, these diseases are classified under the unifying term acute aortic syndrome, which includes symptomatic aortic aneurysms, dissections of the aorta, penetrating aortic ulcers, and intramural hematomas. The incidence of these diseases is on the rise, probably because of the increasing incidence of risk factors such as smoking, hypertension and obesity.

The estimated annual incidence of thoracic aortic aneurysms is 6 cases per 100 000 people, and acute dissection affects up to 20 individuals per million [1,2]. In addition to acute aortic syndrome, the descending thoracic aorta can be affected by a traumatic injury [3]. Traditional surgical treatment of the aorta ranks among the most challenging surgeries, and, despite new techniques, it is still associated with significant morbidity and mortality. Surgery of the descending thoracic aorta in acute conditions produces a high risk of paraplegia (8%–17%), and the risk of mortality is up to 60% [4].

In the past ten years, thoracic endovascular aneurysm repair (TEVAR) has become an accepted alternative to the classical surgical approach, particularly in high-risk patients. This method is minimally invasive without thoracotomy/sternotomy and manipulation of the thoracic aorta. In addition, an extracorporeal circuit is not required, and blood losses are markedly lower.

* *E-mail: janraupach@seznam.cz*

The stent graft is usually introduced via the femoral artery into the affected site of the aorta. The pathologically altered section of the thoracic aorta is thus excluded from blood circulation, allowing healing to take place. TEVAR enables earlier rehabilitation and a shorter period of hospitalization. Focal diseases of the straight section of the descending thoracic aorta are particularly morphologically suitable for this treatment, as they provide good conditions for the fixation and tightness of stent grafts [5-10]. Gradual technical developments have improved the flexibility of thoracic stent grafts that can also be employed in the area of the aortic arch. The main problem is ensuring sufficient length of the proximal anchoring zone. To address this problem, either a technique that covers the branching of the left subclavian artery (LSA) is used or the endovascular approach is combined with surgical resewing of the branches of the supra-aortic arteries (hybrid aortic repair) [11,12].

The aim of the present paper is to evaluate retrospectively the long-term (12-year) results of endovascular treatment of the descending thoracic aorta in high-risk patients. The most frequently treated diseases of the aorta in the present cohort were traumatic injury of the aorta and type B aortic dissection.

2. Materials and methods

2.1 Cohort of patients

From May 1999 to September 2012, our team at the Faculty Hospital Hradec Kralove, Czech Republic, treated endovascularly 72 patients for thoracic aorta diseases. The cohort included 53 men and 19 women aged 17 to 86 years, with a mean age of 59.8 years. Table 1 shows the individual types of thoracic aorta diseases and the mean age of the treated groups.

Table 1. Treated diseases of the descending thoracic aorta.

Disease	Cases	Mean age in years (range)
Degenerative aneurysm	5	60.0 (43–72)
Ruptured degenerative aneurysm	4	65.4 (59–73)
Penetrating aortic ulcer	8	72.1 (53–83)
Infected aneurysm	4	57.8 (20–70)
Aortic dissections of type B	23	59.2 (46–87)
Traumatic injury of the aorta - acute	23	36.1 (17–56)
Traumatic injury of the aorta - chronic	5	68.2 (59–77)
Total number	72	59.8 (17–87)

2.2 Planning and endovascular surgery

Preoperative imaging was performed by means of CT angiography (Somatom Plus 4, Emotion 6, Definition AS+; Siemens, Forchheim, Germany). The axial CT layers ≤ 3 mm in width were evaluated. Therapy was provided only to patients with suitable morphology where sufficient length (15 mm) of the proximal and distal anchoring zone was assumed or created. Another necessary precondition was good passability of the pelvic arteries (ø ≥ 7 mm).

Endovascular treatment was carried out under sterile conditions in a standard angiographic room under fluoroscopic control. From the prepared femoral artery, a preloaded stent graft in cartridge was introduced after arteriotomy into the thoracic aorta where it was released under controlled hypotension (mean pressure 80 mmHg) (Figure 1).

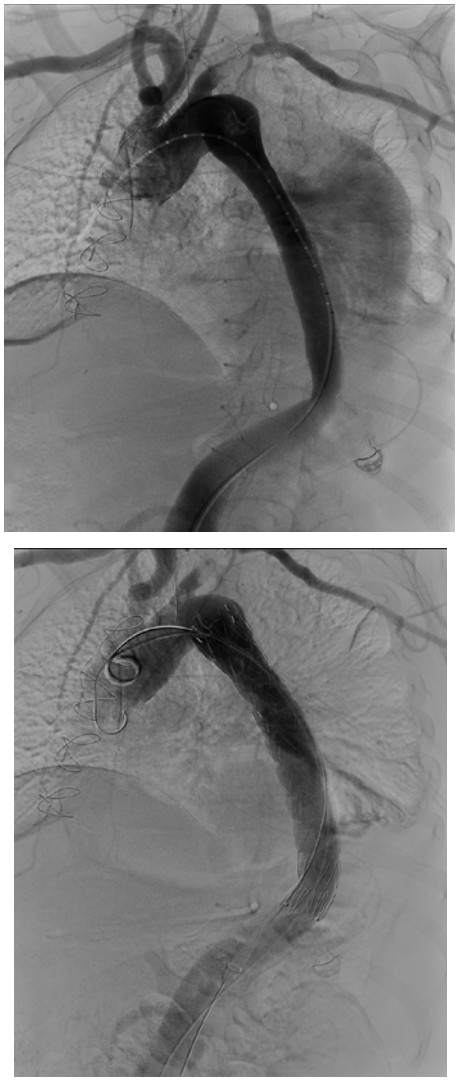
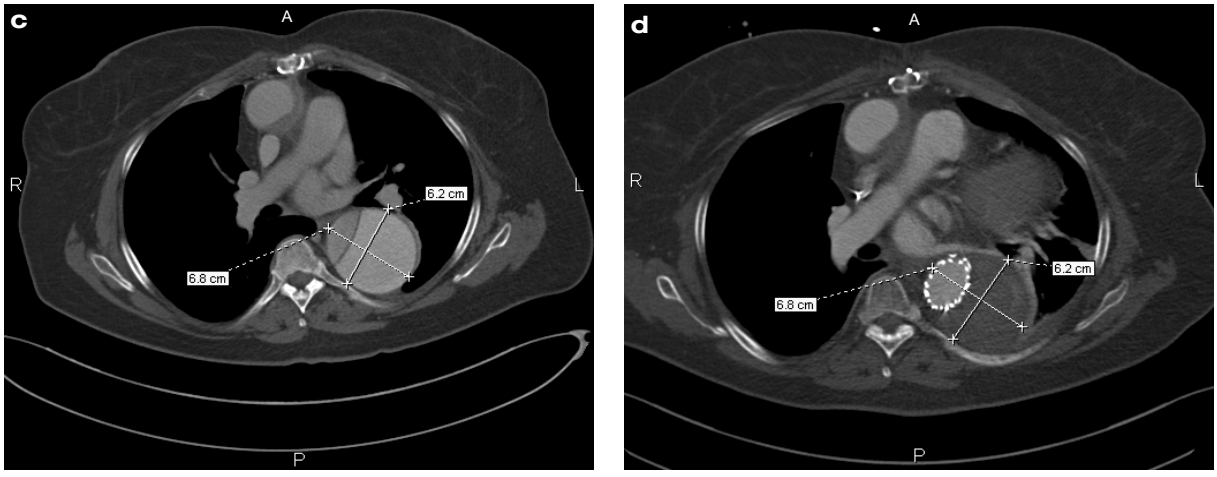


Figure 1a,b. 72 year old woman with chronic aortic dissection type B and progressive dilatation of the descending aorta at 68 mm. Angiography in the left oblique projection shows filling dilated false lumen through the primary entry (a). A control angiography after stentgraft introduction revealed full exclusion of the false dissection lumen (b). Pre-operative (c) and 7th day CT follow-up (d) compared outcome of endovascular treatment with complete thrombosis of the false lumen.



CONTINUED **Figure 1c,d.**

In 2 patients, percutaneous introduction of a stent graft by means of the Prostar XL (Abbott Laboratories, Redwood City, California, USA) system was used with subsequent closure of the site of puncture. In 1 patient, the stent graft was introduced from the surgically prepared common iliac artery because of the gracile pelvic bed. The endovascular procedure was carried out under general intubation anesthesia after the administration of 5000 IU of heparin. The dose of heparin was reduced or excluded in traumatic aortic injury and if bleeding occurred. Antibiotics (ATB) were given during endovascular treatment and subsequently continued for a period of 7 days, with the exception of infected aneurysms—in which case, the antibiotic protocol was completely different. In 23 patients having a short proximal landing zone, we intentionally covered orifice of the left subclavian artery (LSA); in 4 patients, the trunk of the LSA was simultaneously closed to prevent a collateral endoleak. Embolization by means of spirals was employed once, and a vascular occluder AVP II (AGA Medical Golden Valley, Minnesota, USA) was used 3 times. Before the planned covering of the LSA, cerebral circulation was examined, particularly at the vertebrobasilar region. The contraindication to covering the LSA was if the hypoplastic right vertebral artery did not communicate with the basilar artery. In 3 patients, the short proximal anchoring zone was extended by a previous surgery: 1) transposition of the brachiocephalic trunk and the left common carotid artery (ACC) to the ascending aorta using a vascular prosthesis; 2) carotid-carotid crossover bypass; 3) replacement of the ascending aorta and the aortic arch + prosthetic carotid bypass with the left ACC (Figure 2).

Altogether, 91 thoracic stent grafts were introduced in 72 patients, for an average of 1.3 stents per patient. Different types of stent grafts were employed, with gradual modification according to their development and commercial availability. The types of stent grafts used are listed in Table 2. Stent grafts with diameters of 22–38 mm and lengths of 80–200 mm were implanted. The diameter of the stent grafts was oversized by 15% above the diameter of the anchoring zones; in dissections, it was oversized by 10%. The design of the stent graft was selected according to the length and shape of the proximal anchoring zone.

Table 2. Types and number of stent grafts used.

Ella (Ella CS)	4
Endofit (Le Maitre Vascular)	21
Talent (Medtronic, AVE)	22
Valiant (Medtronic, AVE)	30
Captivia (Medtronic, AVE)	14
Total number	91

2.3 Examination and criteria of success

The patients were checked on day 7 after operation, at 6 and 12 months, and then every year by means of CT angiography. At the same time, the clinical condition of patients was evaluated in the Cardiological Consultation Room of the Cardiovascular Center. The criteria for successful therapy were that the thoracic aneurysm was fully excluded from the blood flow and that the sac of the aneurysm was simultaneously diminished or stabilized. In dissection, the authors considered the treatment successful when there was thrombosis and subsequent regression of the false channel for the length of the introduced stent graft. For cases of aortic injury, bleeding, and penetrating aortic ulcers, successful treatment resulted in stabilization of the condition and arrest of bleeding.

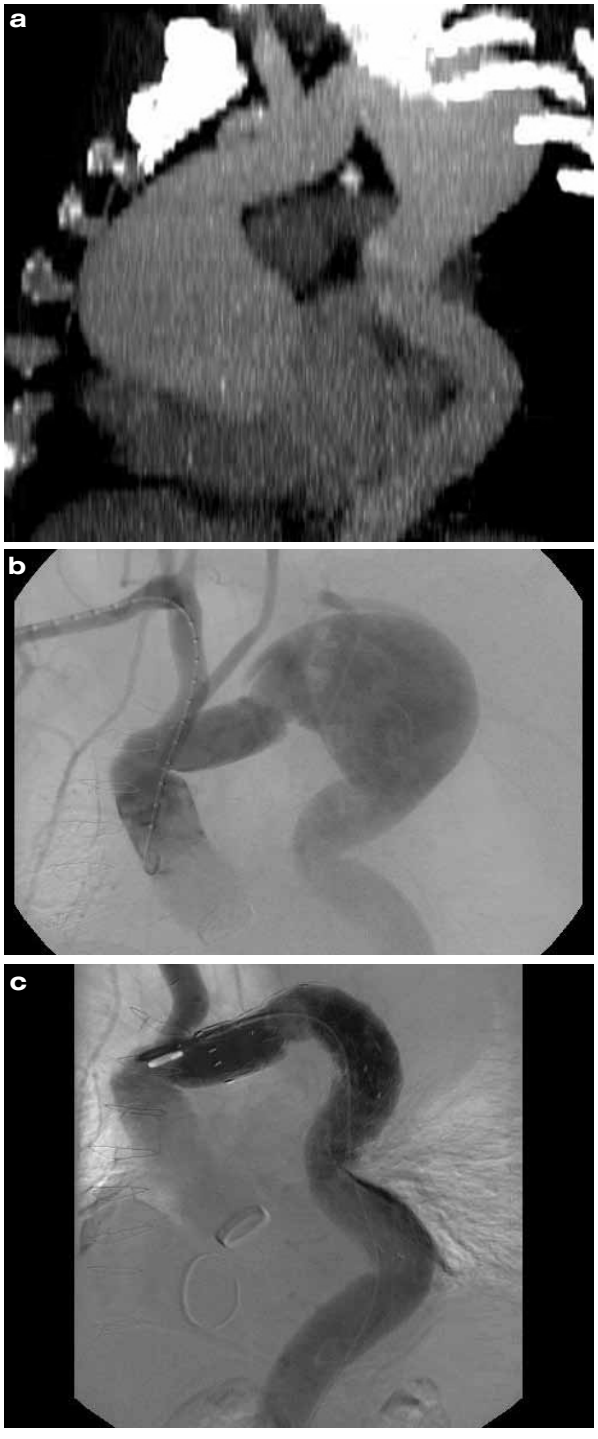


Figure 2. Preoperative multiplanar reconstruction of CT angiography in the sagittal plane demonstrates large aneurysms of the ascending and descending aorta (a). First, the ascending aorta surgery was performed, which consisted of replacement of the aortic root (Bentall operation) and aortic arch (elephant trunk), and transfer of the branch of the left ACC with a vascular prosthesis to the aortic conduit (a vascular prosthesis with an inbuilt valve) (b). The aneurysm on the descending aorta was treated by implantation of a stent graft and the branch of the LSA was closed with a vascular occluder (c).

2.4 Statistical methods

Informed consent was obtained before each treatment according to the stipulations of the local ethics committee of our centre. Results were obtained and evaluated retrospectively. We calculate 30-day, 1-year and total mortality of our group, and separately, mortality caused by the treatment or the principal disease of the aorta.

3. Results

Technical success in our cohort was 98.6% (71/72). In 1 patient with a rupture of a degenerative aneurysm, the tightness of the stent graft in the proximal, anchoring zone could not be achieved because of a short and angulated neck. During subsequent dilatation using a Reliant latex balloon (Medtronic AVE), caudal dislocation of the stent graft into the aneurysmal sac took place. In this case, the morphological difficulty was wrongly interpreted in the preoperative CT. The patient was transported to the operating theater for open surgery, during which he died. In the other 71 patients, the stent graft was introduced and released in the planned site.

The follow-up period in our cohort ranged from 1 to 144 months, with an average of 48.4 months. The 30-day mortality of the cohort was 98.3% (6/72), the 1-year mortality was 13.8% (10/72), and the total mortality was 22.2% (16/72). Mortality caused by the treatment or the principal disease of the aorta was 6.9% (5/72); the causes included: 1 technical failure of therapy, looseness of the stent graft in ruptured aneurysm; 1 collapse of the stent graft with distal hypoperfusion after treatment of acute aortic injury; infection of the stent graft in the 4th month after treatment of mycotic aneurysms and the development of aortobronchial fistula; and 2 aortic ruptures at 10 days and 3 months after successful treatment of type B aortic dissection.

In 1 case (1.4%), permanent paraplegia developed after the treatment of acute traumatic injury of the aorta, and an ischemic stroke occurred in 1 patient (1.4%) after treatment for a ruptured type B aortic dissection. Table 3 lists all complications connected with the endovascular treatment in the cohort.

Table 3. Complications of implantation of a stent grafts in the descending thoracic aorta.

Complications	Incidence
Paraplegia + transient paresis	2.8% (2/72)
Ischemic stroke	1.4% (1/72)
Collapse of stent graft	1.4% (1/72)
Retrograde dissection or IMH of the ascending aorta	4.2% (3/72)
Proximal or distal endoleak of type Ia/b	9.7% (7/72)
Infection of the stent graft and development of aortobronchial fistula	1.4% (1/72)
Covered perforation of the esophagus in infected aneurysm	1.4% (1/72)
Claudication of LUE in covering the branching of LSA	8.7% (2/23)
Postimplantation syndrome	25% (17/68)

3.1 Postimplantation syndrome

In 17 (25%) patients treated for non-infected aneurysms of the aorta (n=68), transient occurrence of fever, leukocytosis, and increased C-reactive protein were observed after therapy. Hemocultures from these patients were negative, laboratory values normalized, and fever spontaneously disappeared within 3 to 5 days after treatment. These symptoms were ranked among the manifestations of postimplantation syndrome, i.e., a general reactive response to a foreign material introduced to the blood bed.

3.2 Reintervention

Due to the looseness of the stent graft in the proximal or distal anchoring zone, 7 extensions were introduced in the second period. From an etiological standpoint, 1 case was treated for a degenerative aneurysm, and 6 cases were treated for aortic dissection. In 3 patients, a gradual development of an abdominal aneurysm occurred after treatment of the dissected thoracic aorta that twice required open surgery. One patient with a 45-mm abdominal aortic aneurysm (AAA) was regularly monitored. Of the cohort of 23 patients who received the planned covering of the LSA, 2 (8.7%) patients developed limiting claudications of the left upper extremity. In 1 patient, spontaneous improvement occurred, and, in the other patient, a revascularization intervention (carotid-subclavian bypass) was performed 6 months after the initial treatment.

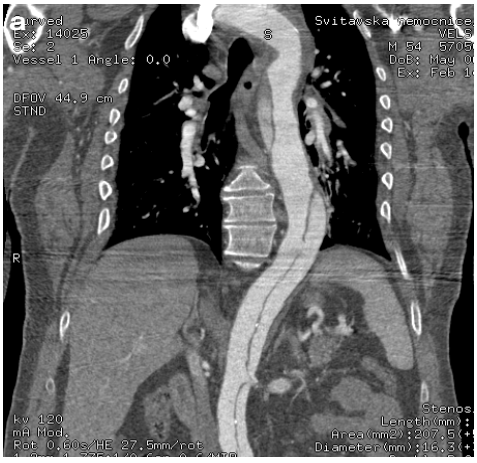
4. Discussion

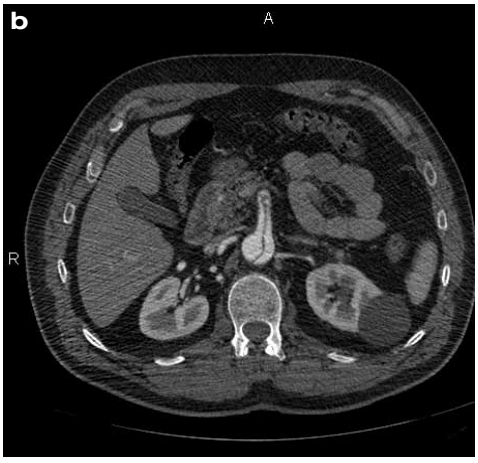
The present authors' experiences and results confirm the development and contemporary trends for the use of TEVAR, particularly in acute conditions of the descending thoracic aorta [13,14]. The recently published meta-analyses comparing the results of TEVAR and operative therapy of traumatic aortic injury have confirmed the superiority of the endovascular approach. Mortality in patients treated with stent grafts was 7.6%, whereas it was 15.2% in patients undergoing surgery [15]. The advantage is found mainly in patients with serious associated injuries in other organs (CNS, thorax, visceral organs) where the less invasive endovascular approach does not burden the patient with thoracotomy and extracorporeal circuit. To cover the injured spot on the aorta, a short stent graft is usually employed with a minimal risk of spinal ischemia. Meta-analyses have demonstrated that the incidence of paraplegia in TEVAR is below 1%, in contrast with 7% in surgical treatment [16,17]. In our cohort of 23 patients treated for acute thoracic aortic injury, 2 patients died within 30 days (8.7%). In 1 case, death was due to a complication of the endovascular therapy; specifically, a collapse of the stent graft. The other patient died on day 2, due to associated injuries of the abdominal organs and CNS (Table 4).

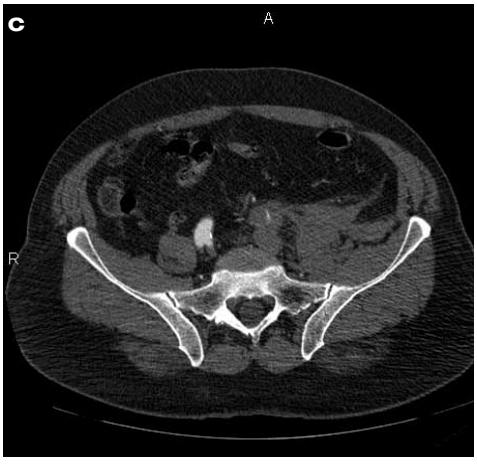
Table 4. Results after treatment of aortic injury.

Number	23
Interval between diagnosis and treatment	0–24 months
Age	Mean 59.1 years (range 46–87 years)
Endoleak Ia-proximal extension	2
Endoleak Ib-distal extension	4
development of abdominal aneurysm	3 (2 solved by operation)
30-day mortality	4.3% (1/23)
1-year mortality	8.7% (2/23)

Similar optimistic results have been achieved by TEVAR in the treatment of complicated type B aortic dissection, which is defined as an unstable aortic dissection with the presence of 1 or more of the following symptoms: leakage and/or rupture of the aorta; visceral and/or extremity ischemia; rapid increase of the false lumen,, imminent perforation; or difficult pharmacological control of hypertension with recurrent pain [18-20]. The principle behind using TEVAR in type B aortic dissection is to cover the site of the primary entry with a stent graft to induce thrombosis of the false channel and to remodel the aorta. Simultaneously, the true lumen is extended, improving perfusion of the visceral organs and lower extremities (Figure 3). The technique of endovascular fenestration [21], i.e., extension of communication between the true and false lumen in malperfusion of the branching arteries, is not as effective as the "physiological" closure of the primary entry with a stent graft. The length of the stent graft used and the risk of spinal ischemia are topics under frequently discussion. Our team usually introduces a 150-mm long stent graft first, and, if needed, distal or proximal extension is performed in the second period. Results from treating complicated type B aortic dissection document the success of TEVAR with only 10.6% mortality, as compared with 19.5% mortality for surgical treatment [22]. When TEVAR is used in complicated dissections, there is a documented decrease in the incidence of spinal ischemia to 2% versus 8% when surgery is used [18,23]. In our cohort of dissections, spinal ischemia did not occur (Table 5). The effect of TEVAR has not been safely demonstrated in stable (uncomplicated) type B aortic dissection. The INSTEAD study, which compared endovascular and conservative treatments in stable dissections, did not show a benefit of stent graft treatment in 2 years of monitoring [24]. In stable type B aortic dissection, antihypertensive conservative therapy remains the method of choice.







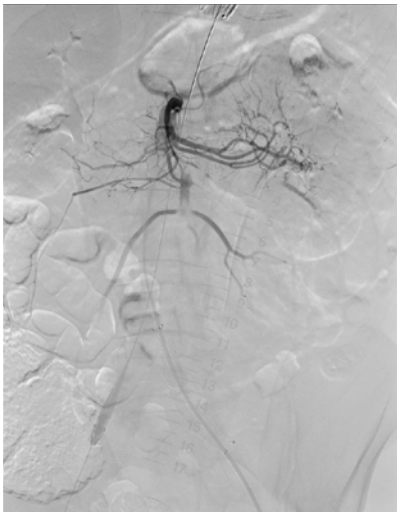


Figure 3a,f. 55 year old man with acute complicated aortic dissection type B. Pre-operative CT shows the extent of dissection from LSA to the pelvic arteries (a). Dissection also affected the trunk of the superior mesenteric artery (SMA) and left common iliac artery (CIA) and caused their static occlusion (b,c). Endovascular therapy consists of the thoracic stent graft insertion and AMS (d,e) and left CIA stenting (f,g). Follow-up CT confirms good patency of stented arteries and exclusion of the false lumen at the level of stent graft (h).

g

h

CONTINUED **Figure 3g,h.**

Table 5. Results after treatment of aortic injury.

	acute	chronic
Time from injury (delay to treatment)	Mean 20.2 hours (range 4–168 hours)	Mean 16.4 years (range 3–30 years)
Number	23	5
Age	Average 36.9 years (17–56 years)	Average 68.2 years (59–77 years)
Collapse of the stent	1	0
Paraplegia	1	0
Endoleak	0	0
30-day mortality	8.7% (2/23)	0%
1-year mortality	8.7% (2/23)	0%

An important part of this approach is periodic radiological monitoring of these patients, which is aimed at early recognition of complications with complications with subsequent use of invasive treatment.

The endovascular approach, which utilizes stent grafts, has become a recognized method of therapy in acute conditions in the descending thoracic aorta. However, there are specific complications that affect this treatment, which are discussed below. Early diagnosis of these complications and knowledge of how to treat them are the principal factors affecting successful therapy.

Vascular cerebral event (VCE): A VCE develops due to embolization of the atherosclerotic material that is released from the aortic arch during manipulation of the stent graft. Another cause of VCE in the vertebrobasilar region can be occlusion of dominant LSA. In our cohort, 1 patient developed ischemic stroke in anterior circulation. He was an 82 year old man with an aortic rupture and hemothorax due to acute dissection of type B; the branching of the LSA was covered during TEVAR. The patient gradually rehabilitated to a Rankin score of 3 and died of myocardial infarction (MI) in the 4th month after treatment. The published frequency of this complication in large cohorts of patients ranges from 0–10% [16,18,21,22].

Paraplegia: Arterial supply to the spinal cord is usually carried out via intercostal arteries, which branch at the level of the Th9-Th12 vertebrae. When this aortic segment is covered with a stent graft, transient or permanent ischemia can take place. The frequency of paraplegia also increases with the length of the stent graft. A permanent disorder affecting the motility of the lower extremities was recorded in 1 patient (1.4%), a 50 year old woman treated for traumatic aortic injury during a car crash. Cardiopulmonary resuscitation was performed, and she was intubated at the site of the accident; her neurological condition was not known. Therefore, it cannot be determined whether the ischemia affecting her spinal cord resulted from the trauma (mediastinal hematoma) before treatment or was caused by the introduction of the thoracic stent graft.

In 1 patient, a transient paresis of the lower extremities developed that resolved after insertion of cerebrospinal fluid drainage. Published results report the frequency of paraplegia after TEVAR as 1%–6% [16,18]. To prevent this complication, the introduction of cerebrospinal fluid (CSF) drainage is recommended for cases involving covering of a long segment of the descending aorta.

Collapse of the stent graft: When the stent graft is markedly oversized, its radial strength can be weakened and poorly positioned in the curved part of the aortic arch. The stent graft does not fit tightly, and the blood flow leaking outside its lumen causes its collapse

and subsequently occludes the aorta. This complication occurred in our cohort during the initial period (August 1999) in 1 patient (1.4%) when only the rigid type of stent graft was available. The patient was a polytraumatized 48-year-old man with an injury that occurred in a car crash. On day 3 after treatment, the stent graft collapsed, and hypoperfusion syndrome developed in the distal direction. In spite of an urgently performed axillofemoral bypass, the patient died on day 15 after implantation. The occurrence of this complication was analyzed in 60 published cases [26]. A markedly oversized diameter of the stent graft >25% and a large curving of the aortic arch are risk factors. The recommended solution for this complication is the endovascular introduction of a proximal extension or a balloon-expandable stent to the collapsed, proximal part of the stent graft.

Retrograde dissection of the ascending aorta: An injury of the ascending aorta, which can be secondarily caused by the introduction of a stent graft to the thoracic aorta, may result in the development of a type A dissection or an intramural hematoma. In our cohort, this complication occurred in 3 patients (4.2%). In 2 cases, the complication was solved using a conservative approach, and in 1, the patient was successfully operated. Published data report a 1.3% risk for this complication, with a 26% lethality [27]. Solutions to this complication vary according to the clinical condition of the patient and range from a conservative approach to replacement of the ascending aorta.

Infection of the stent graft: Aneurysms originating from bacterial infections (infected or mycotic) rank among the most risky acquired aortic diseases, and their treatments are difficult. When a stent graft is used in an infected area, even with intensive ATB therapy, the inflammation spreads to the anchoring zones with fatal results. At the time of treatment of 4 of our patients, clinical signs of inflammation were present in 3, and a blood culture was positive in 2 of them. One patient presented Salmonella enteritidis and one presented Staphylococcus aureus. During the follow-up period, there was a progression of infection in 1 case and subsequent rupture of the aorta 4 months after implantation of the stent graft. In 1 patient, 2 months after implantation, a covered esophageal perforation occurred that was successfully treated by the replacement of the esophagus with tubularized stomach. Other patients in this group were without complications. A recent study reported that the 30-day mortality TEVAR of infected aneurysms was 5.6%, and there was a 20% risk of developing late complications; the following measures led to improved results from therapy [28]: Immediately after diagnosis, intravenous administration of antibiotics should start. Results show a significantly lower mortality in patients when antibiotics are administered at least 1 week before the implantation of the stent graft. The intravenous administration of antibiotics should continue for a period of six weeks after treatment and subsequently change to an oral form. Some authors recommend a lifelong ATB prophylaxis. In any case, antibiotics should be given at least for as long as there are clinical symptoms of infection. In our center, antibiotics are administered for a period of 12 months, and we subsequently decide on their continued use according to the clinical and CT findings: In endovascular therapy, covering the long proximal and distal anchoring zone is recommended to achieve greater stability.

5. Conclusion

In the past 12 years, endovascular treatment of diseases of the descending thoracic aorta has become the method of choice in our center. The simplicity and quickness of this method are beneficial primarily in acute conditions. The principal precondition for successful treatment is a morphologically suitable aortic pathology with anchoring zones of sufficient length. Planned covering of the branching of LSA for the improvement of proximal stabilization has an acceptable risk of ischemia of the left upper extremity and vascular cerebral events. The results have also confirmed the necessity of monitoring the patients in cardiovascular centers with periodic CT examinations, particularly in cases of complicated aortic dissection. Early recognition of specific complications enables their successful treatment and involves cooperation with all units of a complex cardiovascular center.

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