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Treatment of acute thoracic aortic syndromes using endovascular techniques

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PURPOSE
Acute thoracic aortic syndrome (ATAS) is a novel term to define emergency aortic conditions with common clinical features and challenges. Traditional management of ATAS includes surgical replacement of the aorta and is correlated with high perioperative mortality and morbidity. We aimed to evaluate our experience and outcomes in patients presenting with ATAS, managed by endovascular techniques.

METHODS
This cohort consisted of 31 consecutive patients (24 males; mean age, 57.5±13.81 years; range, 19–84 years) with acute thoracic aortic pathologies who underwent endovascular repair between January 2011 and January 2015. The study was designed as a retrospective analysis of prospectively maintained data.

RESULTS
Complicated acute type-B aortic dissection was the most common pathology (35.5%). All aortic stent-grafts (n=37) and dissection stents (n=9) were implanted with 100% procedural success. The overall in-hospital mortality was 9.7%. The mean follow-up duration of patients who were alive at 30 days was 25.9±11.49 months (3–53 months). So far, there have been no late deaths after 30 days.

CONCLUSION
In the high-risk setting of ATAS, endovascular procedures come forward as novel therapeutic strategies with promising results. Endovascular repair of ATAS can be considered as a first-line treatment alternative under emergency conditions with encouraging results, particularly when conventional surgical repair cannot be implemented due to prohibitive comorbidities.

Acute thoracic aortic syndrome (ATAS) is a novel term to define emergency aortic conditions with common clinical features and challenges. ATAS was first described as a pathology that embraces a diverse group of patients with similar clinical characteristics comprising penetrating aortic ulcer (PAU), intramural hematoma (IMH), and aortic dissection (AD) (1). More lately, symptomatic aortic aneurysms, aortic transection, iatrogenic or traumatic aortic intimal laceration have also been included in this syndrome as they also carry a similar risk of death (2). These hazardous emergency conditions can be grouped together; not only they all share the same pathology, but also they require early diagnosis, transfer to a relevant center, rapid establishment of medical therapy and urgent repair, and a cardiovascular intensive care unit for postprocedure care (3). The reason for grouping these conditions into one entity is so that specific algorithms can be developed in specialized aortic centers with the aim of better outcome.

Conditions contributing to ATAS are various. The most common risk factor for ATAS is hypertension (4). Pain is the most prevalent symptom of ATAS and needs instantaneous attention including diagnostic imaging methods, like multidetector-row computed tomography (MDCT), transesophageal echocardiography, or magnetic resonance imaging (4). Prognosis is directly associated with undelayed diagnosis and proper treatment.

Surgical management of ATAS includes replacement of the aorta and is associated with high perioperative morbidity and mortality (5). The potential advantages of endovascular aortic repair (EVAR) are related to its minimal invasiveness (2). This less invasive approach promotes EVAR especially for patients, who are unfit for surgery due to comorbidities or hemodynamic instability (2). Therefore, in the high-risk setting of ATAS, endovascular re-

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pair emerged as a novel therapeutic method, with promising results. The objective of this study is to evaluate our experience and outcomes in patients presenting with acute thoracic aortic syndrome managed by endovascular techniques.

Methods

The study group consisted of 31 consecutive patients with acute thoracic aortic pathology affecting the arch and/or descending aorta, who underwent endovascular treatment at a single institute between January 2011 and January 2015. A team of vascular surgeons and an interventional radiologist provide 24-hour emergency service in our center. The study was designed as a retrospective analysis of prospectively maintained patient data and image files. All patients underwent MDCT angiography. For differential diagnosis of the IMH, unenhanced CT acquisition was done. The radiologist and the surgeons interpreted the images together to determine suitability for endovascular repair. Echocardiography and duplex ultrasonography were used to exclude type-A dissection and examine the carotid and vertebral arteries.

Patient characteristics

Patient demographics and major comorbidities are shown in Table 1. There were seven female (22.6%) and 24 male (77.4%) patients with a mean age of 57.5±13.81 years (range, 19–84 years). Time interval between symptom and EVAR ranged from three hours to two days (mean, 12.5±8.56 hours). Aortic pathologies are presented in Table 2. Complicated acute type-B AD was the most common pathology (35.5%). The etiology was iatrogenic in two of type-B AD patients, hypertension in the others. The patients with type-B ADs were considered as complicated due to recurrent pain, periaortic or mediastinal hematoma, and increasing pleural effusion. Mean maximal aortic diameter in these patients was 47.2±9.3 mm. Dissection extended to abdominal aorta in 81.8% of the AD patients.

Eleven patients (35.5%) with the signs of a rupture or contained rupture were treated emergently. Ruptured AD, aneurysm, and traumatic aortic injury patients were included in this group. Four patients (12.9%) had end-organ ischemia. Three patients were hemodynamically unstable; the remaining patient was treated under stable conditions. Four patients had previous cardiac surgery (two coronary artery bypass grafting, one aortic valve replacement, and one ventricular septal defect closure). The main symptom of conscious patients at admission was abrupt pain with initially severe intensity (83.9%). The second leading symptom was dyspnea (74.2%). Prominent symptom at the time of presentation was low output syndrome in 9.7% of the patients. One patient with PAU had hemoptysis.

Patients presenting with ATAS were treated initially with analgesics and antihypertensive drugs in the cardiovascular intensive care unit (ICU). However, patients presenting with circulatory shock were taken immediately to the endovascular suite after a diagnostic MDCT scan. Patients who were conscious gave written consent.

EVAR procedure

All endovascular interventions were performed in the cath-lab by a dedicated vascular team. While twenty-eight patients were treated under general anesthesia, three patients were operated under locoregional anesthesia. In our center, pro-

Main points

- Acute thoracic aortic syndrome (ATAS) is an emergency condition, and the interval between symptom to EVAR might range from hours to days. The mean interval was 12±8.56 hrs in our series, and 90.3% of EVAR procedures were performed within 24 hours.
- Hypertension is the most common risk factor for ATAS and pain is the most common presenting symptom regardless of the underlying condition in our study.
- Since ATAS embraces a diverse group of patients with similar clinical characteristics, adjuvant or secondary procedures might be needed.
- Patients are obliged to a rigorous follow-up protocol that requires contrast-enhanced MDCT.
- Endovascular repair of ATAS can be considered as a first line approach with encouraging results (100% procedural success and 9.7% in hospital mortality in our series), particularly when conventional surgical repair cannot be performed due to comorbidities.

Table 1. Patient demographics and history

Variable	
Demographics	
Age (years), median (range)	57.5 (19–84)
Gender (male:female), n	24:7
Patient history, %	
Hypertension	74.2
Atherosclerosis	35.5
Previous myocardial infarction	16.1
Previous cardiac surgery	12.9
Chronic obstructive pulmonary disease	45.2
Chronic renal failure	9.7
Diabetes mellitus	22.6
Active smoker	51.6

Table 2. Aortic diseases

Aortic pathology	n (%)
Complicated acute type B aortic dissection	11 (35.5)
Symptomatic chronic aortic dissection	3 (9.7)
Symptomatic aortic aneurysm	2 (6.5)
Penetrating aortic ulcer	2 (6.5)
Intramural hematoma	4 (12.9)
Transection	8 (25.8)
Aortic pseudoaneurysm (acute aortic graft occlusion)	1 (3.2)

phylactic cerebrospinal fluid (CSF) drain is inserted if there is planned long-segment coverage, occlusion of the left subclavian artery (SCA) or internal iliac arteries, extensive disease (proximal to the left SCA to the coeliac axis with involvement of infrarenal aorta and/or internal iliac arteries), or previous infrarenal aortic repair. The left SCA was assessed in each patient taking into account the status and dominancy of the vertebral arteries, the length of aorta to be covered, the presence of a previous infrarenal repair or aneurysm, and the status of the internal iliac arteries.

Prophylactic antibiotics and heparin sodium (3000 IU in transection patients, 5000 IU in the rest of the patients) were administered routinely. Vascular access was achieved through common femoral artery. Next, the delivery system was introduced and advanced into the desired position under fluoroscopic guidance. After exact positioning, the aortic stent-grafts and dissection stents were deployed. An ultimate angiogram was accomplished to affirm the position of the devices, to evaluate patency of the branch vessels, and to verify the effectiveness of the stents. Thereafter, the placement system was removed and the femoral arteriotomy was closed with a previously placed purse-string 5/0 polypropylene suture.

Patients were obliged to a rigorous follow-up protocol that requires a contrast MDCT and clinical evaluation at discharge, three and 12 months after surgery, and yearly thereafter. Unenhanced CT and duplex scan were performed in patients with renal failure. Clinical follow-up consisted of physical and laboratory examinations including serum creatinine and urea at one month, three months, and annually thereafter. During this period four different stent-grafts were available in our clinic (Table 3). Thirty-seven stent-grafts were implanted in 31 patients: Zenith® TX2® (Cook Medical) in 17 patients (54.8%), GORE® TAG® (W. L. Gore and Associates) in seven patients (22.6%), Valiant® (Medtronic Vascular) in four patients (12.9%), Ankura® (Lifetech Scientific Co., LTD.) in three patients (9.7%). As an adjuvant procedure, Djumbodis® dissection system (Saint Come-Chirurgie) was placed in two patients (6.5%) and Zenith® dissection stent (Cook Medical) was placed in seven patients (22.6%); all nine deployments were technically successful. Dissection stents were deployed when AD extended to the abdominal aorta and blood flow remained reduced due to compression of true lumen.

Table 3. Endovascular stent graft and dissection stent types

Device type	Device (n)	Patients (n)
Stent grafts	37	31
Zenith® TX2®	21	17
GORE® TAG®	9	7
Valiant® thoracic stent graft system	4	4
Ankura® stent graft	3	3
Dissection stents	9	9
Djumbodis® dissection system	2	2
Zenith® dissection stent	7	7

Statistical analysis

All data were prospectively gathered in our institutional database. Primary end points were technical success (complete sealing of the primary entry tear, graft patency, obliteration of the false lumen in the thoracic region, no evidence of high flow endoleak, complete coverage of the injured segment in case of PAU or IMH), 30-day morbidity (paraplegia, access complications) and mortality. Follow-up was mainly focused on mortality, branch vessel patency, renal failure, and secondary interventions. Because of the small number of patients enrolled in this study, no control groups were selected. Thus, data are presented in a descriptive analytic method.

Statistical analysis was performed using SPSS Statistics version 20.0 (IBM Corp.). Categorical variables are expressed as frequencies and percentages, and continuous variables as mean, standard deviation, and range.

Results

Endovascular repair was performed within 24 hours of presentation to our center in 90.3% of patients (28/31). Stent deployment was technically successful in all cases. The proximal landing zone was Ishimaru zone 2 in six patients, zone 3 in 23 patients, and zone 4 in two patients. The aim of the procedure was not only to cover the primary entry tear, but also to reinforce the dissected segments. One or two grafts per patient were necessary to cover the lesions (mean, 1.19±0.43 stents/patient). All patients with PAU and IMH were treated with one stent-graft. Stent diameters ranged from 26 to 46 mm and length varied from 50 to 216 mm. Prophylactic CSF drain was inserted in twelve patients.

Adjuvant procedures were as follows: Five patients had left SCA-to-carotid artery bypass to provide a sufficient proximal landing zone. Timing of the prophylactic surgical revascularization of left SCA was just prior to the endovascular procedure in the same session. In the sixth patient, due to hemodynamic instability, the surgery was done in another session after the endovascular repair. One patient required renal artery stenting. In three patients, bifurcated stent-graft was placed for abdominal aortic aneurysm. We performed thoracic EVAR (TEVAR) and EVAR procedures simultaneously. Main pathology was AD or aneurysm in these patients. They all got prophylactic CSF drains and none developed paraplegia. Dissection stents were implanted in nine patients. In a patient who survived a motor vehicle accident, pelvic arterial embolization was performed to control pelvic bleeding. In 13 patients, hemothorax was managed with percutaneous chest drainage. Procedures related to complications were performed in three patients. One patient required patch repair of the common femoral artery for damage caused by the introducer sheath. Another patient required distal arterial embolectomy. In one patient, after closure of the SCA, left SCA-to-carotid artery bypass had to be performed, because of upper extremity claudication.

The mean procedure duration was 48±26.84 min (range, 18–105 min) and mean blood loss was 145±83.20 mL (range, 75–400 mL). The mean intraarterial contrast media volume used during stent placement was approximately 152±78.36 mL (range, 60–310 mL). Mean ICU stay was 2.19±5.54 days (range, 1–32 days) and mean overall postoperative hospital stay was 5.7±6.18 days (range, 1–32 days). None of the patients required secondary procedures during follow-up.

The overall in-hospital mortality was 9.7% (3/31). Deaths were classified as acute complicated type-B AD, traumatic transection, and aortic coarctation, according to pathology. The patient who had aortic coarctation repair and pseudoaneurysm originating from the suture line, was diagnosed with an aortic occlusion secondary to acute aortic patch graft occlusion, severe malperfusion of the viscera and lower extremities, malign hypertension, and pulmonary edema. The procedure was uncomplicated, but he died of multiorgan failure on postoperative day 1. The second patient was an 82-year-old woman with acute complicated type-B AD and died following a stroke on postoperative day 12. The third patient was a 145 kg man who had an aortic transection and polytrauma with liver, spleen, and bladder injury following a motor vehicle accident and died on postoperative day 2. The mean time interval between endovascular intervention and 30-day mortality was 5±6.08 days (range, 1–12 days).

Overall five patients suffered neurologic complications. Two patients (6.5%) had a stroke (one died) and three patients developed paraplegia (9.7%); in two of them, the procedures had been performed under loco-regional anesthesia and therefore the symptoms of spinal cord ischemia were detected early in their onset. Insertion of a CSF drain fully reversed the deficit in these patients. In the latter case, the patient was operated under general anesthesia following cardiopulmonary resuscitation in the emergency unit and therefore symptoms were detected later. He was discharged with paraparesis to a rehabilitation center. When we retrospectively assessed these three patients who developed paraplegia to identify risk factors, we found that one of the patients had atherosclerosis and previous coronary artery bypass grafting, one patient was a smoker with chronic obstructive pulmonary disease and one was a diabetic smoker with end-stage renal disease. Underlying pathology was different in every patient. The patient number was too small to investigate patient or procedural factors that predict paraplegia.

The mean duration of follow-up for patients who were alive at 30 days was 25.9±11.49 months (range, 3–53 months). So far, there have been no late deaths after 30 days. Patients are doing fine and MDCT scans showed thrombosis of the false lumen of the stented segments of thoracic aorta in patients with type-B ADs. Complete thrombosis of the false lumen is achieved in 54.5% of the patients. The patient discharged with paraparesis is now walking with a cane after rehabilitation and still has significant numbness.

Discussion

This study shows that endovascular repair can be considered as a first-line approach under emergency circumstances for all subgroups of ATAS with encouraging results and acceptable complication and mortality rates, especially when open surgical repair cannot be implemented due to prohibitive conditions.

Since unknown numbers of patients die before an exact diagnosis is reached in a healthcare center, the true prevalence of ATAS is not certain; but the incidence seems to be increasing (2). Hypertension is the most common risk factor for ATAS followed by smoking and trauma. (4). In our series, 74.2% of the patients were on antihypertensive medication and 51.6% of them were active smokers.

In this cohort, complicated acute type-B AD, symptomatic chronic dissection, IMH, PAU, and symptomatic aneurysm accounted for 35.5%, 9.7%, 12.9%, 6.5%, and 6.5% of the patients, respectively. The most common cause of transection is motor vehicle accidents or deceleration trauma (6). In our series, 25.8% of patients had traumatic transection, 19.3% of whom were motor vehicle accident victims and the remaining 6.5% had serious falls.

Pain is the most common presenting symptom of ATAS regardless of the underlying condition (2). In our series, the main symptom of conscious patients at admission was abrupt pain with initially severe intensity, consistent with the literature. The second leading symptom was dyspnea.

Depending on the availability, any diagnostic method will work for stable patients. For patients with suspected ATAS and unfit for transportation, bedside transthoracic echocardiography and transesophageal echocardiography with duplex ultrasonography are first priority; but these modalities may overlook abdominal lesions (7). In contrast, MDCT acquires high-resolution images of the entire thoracoabdominal aorta and helps to differentiate IMH from PAU and AD, but requires stable hemodynamic conditions and transport to the diagnostic suite (8). In our center, MDCT is the first-line diagnostic modality, as mentioned above.

ATAS limited to the descending aorta is subject to medical therapy unless complicated by malperfusion, impending rupture, progression of dissection, unmanageable pain, or uncontrolled hypertension (2). Large randomized controlled trials are not available in these aortic pathologies; thus, most recommendations are based on Level C evidence (2).

Currently, endovascular repair appears as an appealing alternative to conventional surgery for treatment of ATAS. The evidence for efficacy and safety has been mainly derived from large multicenter registries (9, 10). Single center retrospective studies evaluating individual diseases within ATAS, have revealed better outcome compared with open surgery with regard to complicated type-B AD, aortic transection, and ruptured descending thoracic aneurysm (11–14). The debate on timing of aortic intervention is currently ongoing. A recent meta-analysis demonstrated that endovascular treatment of descending aortic trauma is a better option to surgical repair and associated with lower postoperative morbidity and mortality (15).

The objective of stent-graft placement in patients with acute type-B AD is the closure of the primary entry tear to decompress the true lumen and enhance distal perfusion. Moreover, stent placement could be used to prevent retrograde extension of a type-B AD into the proximal aorta. Amongst patients with acute type-B AD, more than half of associated deaths are due to rupture of the false lumen (16). It has been clearly shown that shrinkage of the false lumen is advantageous in acute type-B AD, with the aim of remodeling of the dissected aorta and thrombosis of the false lumen (17). Stabilization of the injured segments of aorta by stent-graft placement is an additional aim of this procedure, with the purpose of prevention of late aneurysm formation and rupture. Therefore, six patients with type-B ADs received two stent-grafts.

Dissection stents were implanted in nine patients, and all deployments were technically successful. Sample size is too small to investigate the relationship of dissection stent implantation (nine patients) and neurologic complications (one patient). By placing the dissection stent in the aorta along the length of the compressed section, we aimed to restore normal circulation and achieve early remodeling. Rapid reapproximation of intima to aortic wall following dissection stent deployment might help long-term false lumen exclusion. Moreover, re-entry tear exclusion might be facilitated by dissection stent implantation. Previous data revealed that, as a treatment for organ malperfusion complicating acute type B dissections, dissection stents are safe and effective with satisfactory clinical results in the short term. The long-term effect of this composite treatment on aortic remodeling remains to be determined (18).

Patients with uncomplicated type-B AD have a 30-day mortality of 10% (10). However, patients who develop ischemic complications or contained rupture require emergent aortic repair, which carries a 30-day mortality of 25% (10). Acute IMH accounts for 5%–20% of all acute aortic syndromes, with progression to AD in 28%–47%, and has a risk of rupture in 20%–45% (19).

Published data show a significant mortality rate for complicated type-B ADs as well as in-hospital mortality rates of 17%–45% after surgical repair. The risk of irreversible spinal cord injury and operative mortality for acute type-B AD can range from 14% to 67% (10, 14). A meta-analysis of endovascular treatment of acute type-B AD demonstrated an in-hospital mortality rate of 9%. The incidence of other major complications like stroke, paraplegia, conversion to type-A AD, and bowel infarction were 3.1%, 1.9%, 2%, and 0.9%, respectively. The authors concluded that endovascular repair of complicated acute type-B AD is an important therapeutic alternative with favorable early outcomes (20).

In our series, eight patients with acute traumatic aortic transections were treated successfully with stent-graft. All of these patients exhibited multiple fractures and/or solid organ injuries. Thus, these patients were not suitable candidates for total heparinization as required for open surgical repair. Based on our experience, stent-graft is an outstanding treatment option, especially for polytrauma patients who are high-risk candidates for conventional surgical repair. PAU is another major indication for placement of a stent-graft. One of the PAU patients treated at our clinic presented with hemoptysis indicating an aortobronchial fistula. Although most of the patients with PAU have a calcified aorta, the culprit lesion is limited to a small atherosclerotic segment (21). Therefore, sealing of this plaque using a stent graft is suggested to be an effective and feasible method, and a perfect alternative to surgical repair.

This study has shown that endoluminal repair of patients presenting with ATAS is associated with a 30-day mortality rate of 9.7%, and this compares favorably with the results from open surgery where mortality is in the region of 17% to 45% (5, 10, 22, 23). All three deceased cases had important risk factors such as advance age, obesity, rupture, malperfusion, or shock.

The risk of neurologic complications may be increased in the emergency setting because the hypovolemic state and hemodynamic instability of the patient may contribute to cerebral and spinal cord hypoperfusion. In this series, the rate of stroke and permanent paraparesis were encouragingly low (6.5% and 3.2%, respectively) and compared favorably with the rates in conventional surgical treatment (5). Two patients had temporary paraplegia, which resolved after CSF drainage. The majority of reviews and cohort studies support revascularization of the SCA prior to planned coverage (24). However, in the acute setting of an unstable patient with aortic rupture this is not always possible. We performed left SCA-to-carotid artery bypass prior to stent-graft placement in 16.1% of patients. We observed one permanent neurologic complication in our series.

A reason for concern about the endovascular management of ATAS is the occurrence of graft-related complications during the follow-up. Cautious surveillance is important as aortic-related deaths continue to occur during the follow-up period. Therefore, our patients underwent CT imaging prior to discharge and at postoperative three months and 12 months, and then yearly thereafter.

This study has some limitations. The data presented in the manuscript represent a single center experience in the endovascular management of patients presenting with ATAS over a period of four years. The tertiary nature of the referrals may introduce a bias with case selection, and the expertise of a specialist referral center may not be applicable to less experienced centers. The follow-up of patients from tertiary centers like our institution is limited by patient compliance. Our sample size is too small to investigate patient and procedural factors that predict mortality and morbidity. Randomized, comparative multicenter studies with large number of patients should be conducted to reveal the safety and efficacy of endovascular repair in ATAS and demonstrate if it is superior to medical and surgical alternatives.

In conclusion, endovascular repair of ATAS can be considered as a first-line treatment method under emergency circumstances with encouraging results, especially when conventional surgical repair cannot be implemented due to prohibitive comorbidities. Close follow-up is indicated and long-term results should be awaited to evaluate the continued safety and efficacy of this technique.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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