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Endovascular Treatment of Type A Aortic Dissection

Ivo Petrov*, Zoran Stankov, Gloria Adam

ACIBADEM City Clinic Cardiovascular Center, Sofia, Bulgaria

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***Correspondence:**
Prof. Ivo Petrov, MD, PhD, FESC, FACC, Head of Cardiology, Angiology and Electrophysiology Department, ACIBADEM City Clinic Cardiovascular Center, Sofia, Bulgaria; Telephone No: +359 2 903 80 22; Email: petrovivo@hotmail.com.

Introduction

In patients with acute type A aortic dissection (ATAAD), the natural mortality may reach as high as 65%, based on the International Registry of Acute Aortic Dissection (IRAD)[1,2]. Open chest surgery with resection of the dissected aorta may reduce the expected fatal outcomes to 10% as soon as the treatment is provided in the first 24 hours and 20% for the next 14 days[1]. Therefore, operative management of ATAAD is still the accepted “gold standard” for the management of this perilous condition[3]. Type A aortic dissection is further classified as acute in the first 14 days after the debut of symptoms and chronic (CTAAD) if more than 90 days have passed since the onset of the symptoms. Some authors classify aortic dissection as subacute in the period between 14 and 90 days[3,4].

While open surgical management dramatically reduces mortality, 20% of the patients are deemed to be inoperable due to very high surgical risk and usually are left on medical treatment alone[5]. Furthermore, some authors conclude that surgical outcomes are worse in octogenarians with similar unfavorable long-term outcomes when comparing medically and surgically managed patients[6,7]. Therefore, it is suggested that this cohort of patients should be managed only medically when presenting with complicated type A aortic dissection, because of the expected unfavorable prognosis. It is more than evident there are unmet needs among the patients presenting with ATAAD. After the first interventionally treated patient presenting with ATAAD in the year 2000, the concept of interventional management as an alternative to surgery was suggested[8]. Compared to open repair, endovascular therapy carries several potential advantages: lower trauma, no need for cardiac arrest and extracorporeal circulation, less risky for elderly and comorbid patients, expected faster recovery. Of course, this type of therapy has its valid limitations: the complex anatomy of the aortic root, ascending aorta, and aortic arch with the challenge to preserve the patency of the aortic valve and blood flow of the brachiocephalic branches and coronary arteries. The lack of proximal landing zone for stent-graft implantation restricts the broader applications of endovascular techniques. Also, there are no dedicated endovascular devices for the management of thoracic aortic aneurysm and dissection, situation which often requires the elaboration of custom-made and locally fenestrated grafts or using available grafts on off-label fashion in emergency settings. The modest experience in this field of interventional medicine leads to a shortage of standardized protocols and a lack of extensive expertise. Complications, such as device migration, branch vessels coverage and acute aortic regurgitation have been reported[9]. We present short overview of the current practice and our local experience regarding ATAAD completely endovascular intervention.

Overview of Published Data

Current data in the field of interventional management of ATAAD comes mainly from case reports and case series, as there are still no trials comparing open surgery to endovascular therapy. Furthermore, endovascular therapy is still mainly implemented in patients who are assessed as unfit or too risky for surgery and in which the anatomy of the aorta is suitable for this novel management strategy[10].

In a review of 686 patients with acute type A aortic dissection, 53 (7.7%) were considered as inoperable. Thirty-five of these 53 patients (66%) had very high and 18 (34%) prohibitive operative risk. While being managed only medically, 35 (66%) of these inoperable patients died within the first month of follow-up, and the estimated Kaplan-Meier survival at six months and one year were respectively 25% and 23%. Twenty-eight of these patients had a high-quality computed tomography aortography (CTA) available, and further investigation showed that endovascular dissection primary entry sealing was deemed possible in 19 (79%) of these 28 patients. The authors addressed the need for viable alternatives for these most complex cases in which the risk of open surgery is obviously unacceptable.

In another series, twenty-two, high-risk patients with acute aortic syndrome were treated using thoracic endovascular repair. Five patients had ATAAD, with the other having intramural hematoma, pseudoaneurysm, chronic dissection, or aorto-cardiac fistula. Declaring survival at 30 days to be 86%, 80% at 1 year and 75% at 5 years, the authors concluded that, when surgery is not a reasonable option for managing such patients, endovascular techniques could be implemented with favorable procedural and long-term effects[11,12].

Thoracic endovascular aortic repair (TEVAR) was used in twelve patients with acute (n=6), subacute or chronic type A aortic dissection by *Nienaber e al*[13]. The primary entry tear in all cases was detected in the segment between the coronary arteries and the innominate artery. One intraprocedural death was reported, which lead to a procedural success of 91.7%. All the remaining patients were alive by the end of the first month after the procedure, with a mean survival of 24 months. In the follow-up period four patients passed away due to non-aorta related causes.

A case series of 15 patients with TAAD was presented by *Li et al*[14]. Of the mentioned patients; one was with ATAAD, seven were with subacute, and seven were with CTAAD. The technical success of the procedure was reported in all patients, and the mean follow-up period was 72 months. Although the authors reported eight complications and four reinterventions, significant true lumen expansion and false lumen reduction was observed, no significant aortic valve dysfunction was described, and all patients were reported alive in the mentioned follow-up period.

Presenting the largest experience in the field so far, *Lu et. al* reported endovascular treatment of 56 patients with TAAD – 7 (12.5) with acute aortic dissection (within 14 days), 30 (53.57%) with subacute (14 days to 6 weeks) and 19 (33.93%) in chronic phase (over six weeks) of the disease[15]. All patients included in the study were first deemed as high-risk for open surgery, based on the overall condition at presentation and after using validated perioperative risk score calculators (average EURO Score II = 41.3 ± 12.08%). Anatomical suitability for endovascular treatment was evaluated in every patient after performing a CT aortography (CTA). The location of the dissection entry site and the availability of proper landing zones were among the most important technical aspects. The authors emphasized on several crucial points for endovascular treatment decision. Proper graft sizing was mentioned as crucial for proper device-aorta alignment and for preventing future complications as endoleaks, device migration, and retrograde dissection. Custom-made endo-grafts were recommended in cases where no distal proximal zone was available, and patency of the major branches of the aortic arch was to be kept. Understanding the anatomical characteristics of the ascending aorta was considered to be of major importance for electing a proper graft. In the majority of the treated patients, the entry site was located in the middle segments of the ascending aorta - 31 (55.36%) patients. Sixteen (28.57%) patients showed dissection entry site at the distal part of the ascending aorta, 7 (12.5%) at the level of the aortic arch, and 2 (3.57%) in the descending aorta. Propagation beyond the left subclavian artery (LSE) was observed in 38 (64.4%) patients, while in 9 (16.7%), it was confined within the ascending aorta and in another 9 (16.7%) it extended to the LSA itself. The reported procedural success was as high as 96.43%, with a total of 62 stent-grafts being deployed. The average proximal diameter of the stent-grafts was 39.30 ±4.13 mm, and the average length was 92.05 ± 31.00mm. Oversizing was kept in the range of 15.74%±3.94%. Out of 62 used devices, 50 were Zenith TX2 stents (Cook Medical, Bloomington, Indiana), 4 were Hercules stents (Microport, Shanghai, China), and eight were branched Castor stents (Microport, Shanghai, China). All patients were followed for adverse events occurrence and aorta remodeling. Events were further classified as early (within 30 days) and late (after 30 days). Seven (12.5%) early events occurred in the same number of patients: one (1) patient died on the second day after the procedure due to device-related cardiac tamponade; one (1) patient had new dissection probably due to over-vigorous oversizing; one (1) patient died suddenly and with unknown reason; one (1) developed acute respiratory failure, and three (3) patients experienced cerebral infarctions. Twenty eight (50%) late events were observed in 27 patients, most notably – 8 (14.29%) retrograde dissections (RD), 5 (8.93%) type I endoleaks, 2 (3.57%) new dissections, 1 (1.79%) stent graft migration, 3 (5.36%) coronary artery stenosis, 3 (5.36%) cerebral infarctions. Again, the importance of choosing proper stent graft and careful device oversizing was underlined, especially when RD and endoleaks are concerned. The mean follow-up period was 39.92±34.42 months (11 to 140 months). Eleven (19.64%) deaths were reported, with two of them being aorta related. The other nine patients died of various reasons: pulmonary failure, cerebral infarction, gastrointestinal bleeding, or heart failure. The reported median survival time was 102.33 ± 9.67 months, and the free from aortic-related death period was 131.43 ± 6.26 months. The 5-year overall survival rate was 80.9% and was estimated to be 98.2% if only aorta-related deaths were included. A significant false lumen reduction was observed in the 44 patients followed beyond the 12-th month of the procedure (p<0.0001). Additionally, the size of the aorta decreased, and the size of the true lumen increased significantly. False lumen (FL) thrombosis was observed in all patients at the level of the ascending aorta at 12 months. For the same time period, 78.72% had FL thrombosis in the descending aorta, which increased to 80.49% by the end of the study. The authors concluded that, in some high-risk patients with TAAD in which open surgery is too risky, endovascular treatment might prove to be a viable alternative. While this treatment method has its valid limitations and specific requirements that should be taken in mind, excellent procedural success was observed, and promising mid-term results were reported.

Methods in Our Local Practice for Totally Endovascular TAAD Treatment

Our experience in endovascular treatment of TAAD consists of two different strategies. The first one is illustrated by several clinical cases of successful implantation of non-covered multilayer flow-modulation stents, starting from the coronary arteries and reaching the descending aorta (3 cases), with more than two years of uneventful follow-up and complete false lumen resolution[16]. The application of this strategy is illustrated by the first case presented here.

Case 1

Compassionate implantation of two overlapping Multilayer flow modulation (MFM) stents from the coronary arteries to the descending aorta.

Patient presenting with type A acute aortic dissection treated by immediate endovascular implantation of two Multilayer flow modulation stents starting from

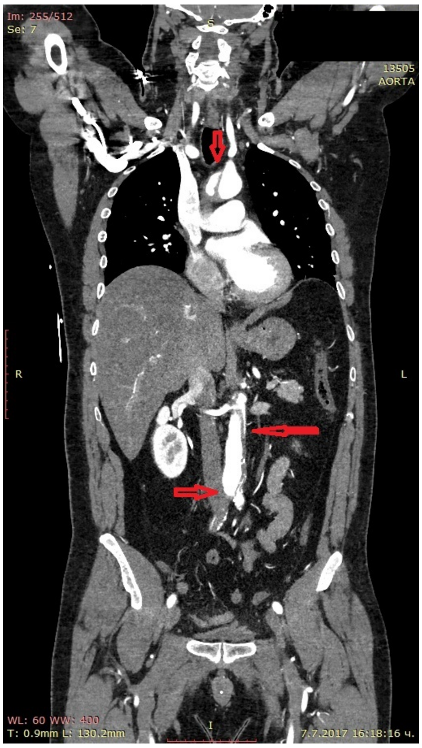

Figure 1: Dissection flap is visible in the aortic arch (upper arrow), propagating through the abdominal aorta causing subtotal compression of the true lumen (middle arrow) and reaching iliac arteries bilaterally. Note that the true lumen in the abdominal aorta and right iliac artery (lower arrow) is almost completely obliterated.

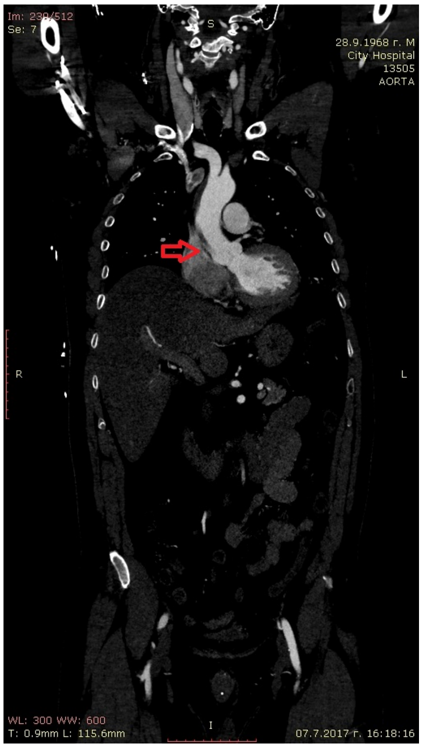

Figure 2: Dissection entry is present in the proximal ascending aorta, distal to the sinuses of Valsalva.

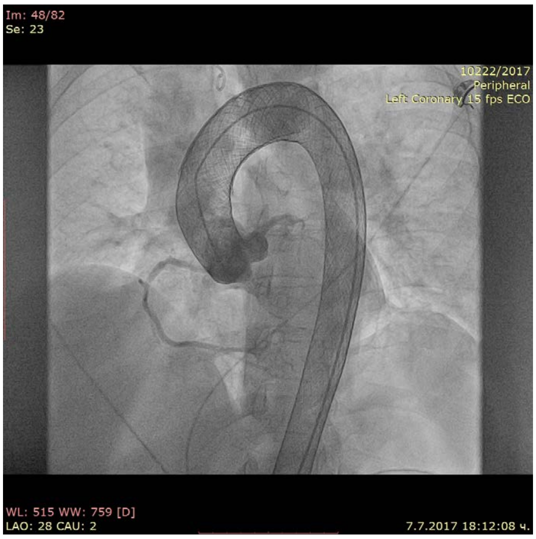

Figure 3: Aortography after two overlapping MFM stents implantation from the proximal ascending to the distal descending aorta. Marked true lumen expansion was achieved and blood flow centralization. Normal blood flow was preserved in all branches of the aorta that were covered by the stents.

Figure 4: 3D CT aortography reconstruction 1 month after the procedure: Optimal stents position in the thoracic aorta is noted with good true lumen expansion and reduction of the size of the false lumen. Supraaortic, visceral and lower extremities vessels are all patent with good blood flow.

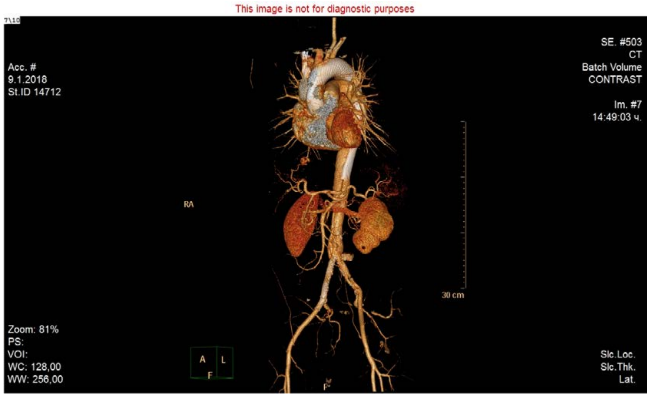

Figure 5: 3D CT aortography reconstruction 6 months after the procedure: Blood flow centralization is well maintained in the stented areas from the ascending to the descending aorta. All branch vessels of the aorta are optimally supplied by the true lumen and no signs of ischemia were observed.

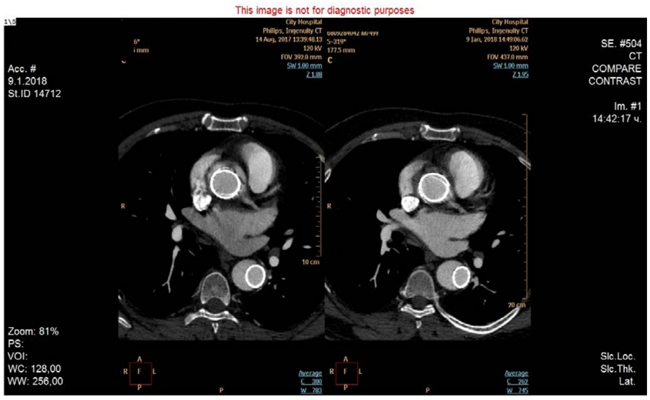

Figure 6: Comparative results from CT aortography performed at 1st and 6th months after the procedure: true lumen is well expanded in the ascending and descending aorta with further almost full obliteration of the false lumen in the ascending aorta at six months.

the coronary arteries and finishing above the visceral vessels. This acute treatment was performed during the night on a young male patient with uncontrollable chest and abdominal pain (presumable impending rupture) and deteriorating visceral and kidney function with unacceptably high perioperative open surgical risk.

The second strategy is combining primary entry tear closure with a stent-graft telescoped with non-covered stents across the arch and descending aorta (1 case) or initial chimney technique with stent grafts (introduced by right brachial approach for the brachiocephalic trunk and by direct retrograde puncture of the left common carotid artery for the stenting of the latter) providing perfusion to the supra-aortic vessels, immediately followed by stent-graft implantation in the ascending aorta, aortic arch and proximal descending aorta with (or without) prolongation of the stented zone with bare stents (custom made "Petticoat" maneuver). This hybrid technique combining covered and non-covered stents is performed with the aim to close the primary entry tear and at the same time centralize the flow in the distal true aortic lumen and decrease the pressure (and shear stress) on the false lumen wall, thus presumably reducing the subsequent risk of rupture (8 cases) and keep the flow in the side branches. During the implantation of the proximal endovascular device, in order to preserve the functionality of aortic valve and coronary arteries' patency we routinely use a technical maneuver borrowed from TAVI procedure, namely the placement of a pigtail catheter (introduced by right radial access) in the non-coronary sinus followed by controlled implantation of the stent just above the sinotubular junction. In all these cases, we have applied a minimalistic approach regarding anesthesia and surgical trauma, namely: conscious sedation and local anesthetic as a method of anesthesia and percutaneous vascular access with final anterior vessel wall restoration with a closure device for all puncture sites (including the left common carotid artery used in 5 cases for chimney insertion). Periprocedural mortality was zero, and the follow-up (between 2 months and two years) results are as shown on the table 1.

This technique is illustrated by the second clinical case, presented bellow.

Case 2

We performed totally percutaneous endovascular treatment (under conscious sedation and local anaesthesia) of a male patient with type A aortic re-dissection, 3 months after surgical correction of the primary proximal entry tear. This 68 years old male patient presented with voice lost, dizziness, chest pain and bowel dysfunction, after the open surgical repair performed in another hospital. He was considered by the multidisciplinary heart team too risky for second open surgical intervention in such short period of time and he accepted our proposal for complex endovascular intervention.

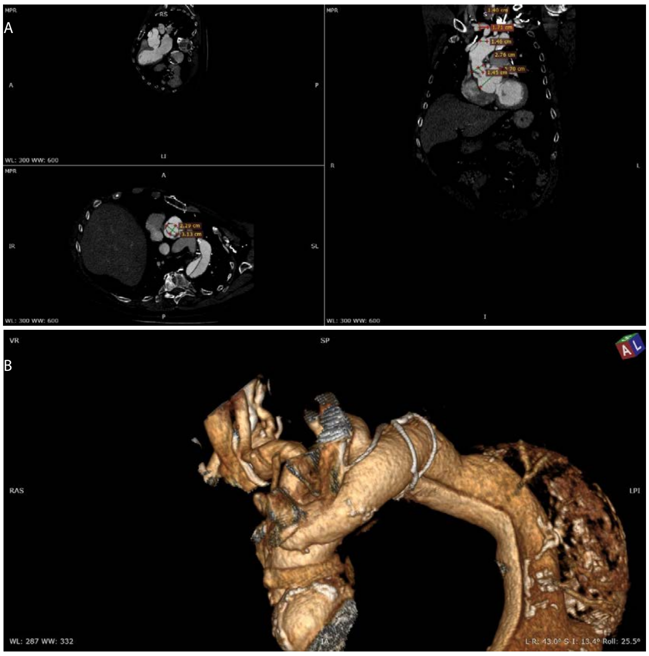

Figure 7:
7A) CT aortography showing dilatation at the level of the Sinuses of Valsalva with dissection flap distal to the prosthesis in the ascending aorta. Multiple dissection flaps can be seen propagating in all of the supraaortic vessels. Severe compression of the true lumen with significant reduction of its size is also observed.
7B) 3D CT aortography reconstruction of the dissected thoracic aorta demonstrating diffuse aneurysmal remodeling with dissection flap engaging all the branches of the aortic arch and propagating distally in the descending aorta, causing severe compression of the visceral vessels.

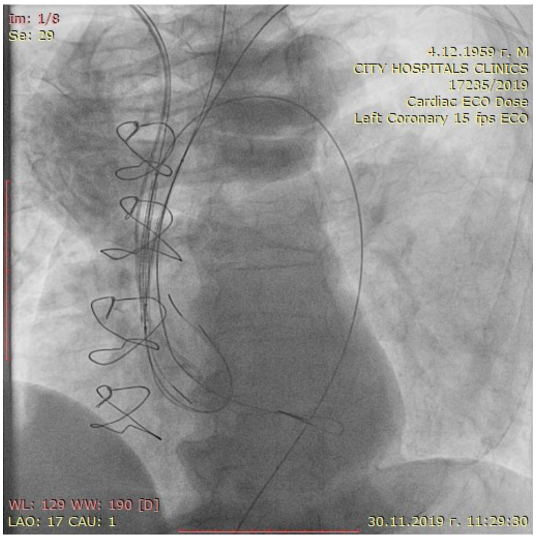

Figure 8: "Fluoro" image in left anterior oblique 15 degrees (LAO, 15) showing three Wholey guide wires 0.035''/300 cm (Covidien, USA) in the aortic root, introduced respectively through the right (7 F introducer were used) and left(14 F introducer) subclavian arteries, and the left common carotid artery (LCCA)(7 F introducer was used). A 5F Pigtail catheter for intraprocedural angiographic control was advanced through the right radial artery. An extra stiff Lunderquist guide wire 0.035''/260cm (COOK Medical, USA) was positioned in the left ventricle to support the placement of the endografts in the ascending and thoracic aorta.

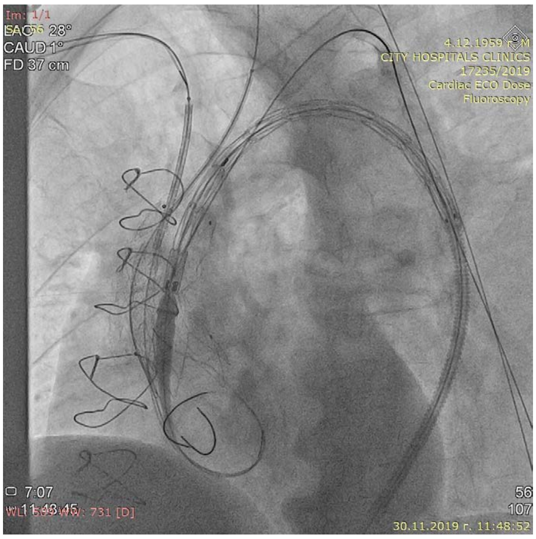

Figure 9: Fluoro image in left anterior oblique 30 degrees (LAO, 30) demonstrating a Valiant Thoracic stent graft (38/38/200mm) (Medtronic Medical, USA) that is about to be implanted from the ascending aorta within just implanted Endurant II 36/36/70 artery (Medtronic Medical, USA) to the descending aorta. Two BeGraft stent grafts (Bentley Medical, Germany) are placed in the brachiocephalic trunk (12/59mm) and in LCCA (8/57mm) and are protruding within the Endurant II and ready to be expanded. A 5F Pigtail catheter is placed in the aortic root through the right radial artery.

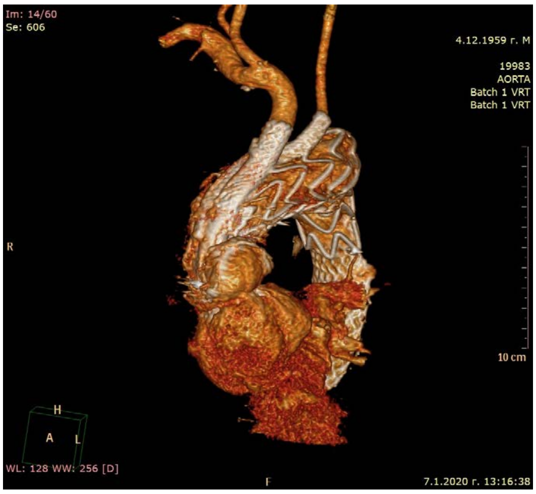

Figure 10: 3D CT aortography reconstruction of the thoracic aorta 1 month after the procedure. Optimal position of all implanted devices in the thoracic aorta, brachiocephalic trunk and LCCA is noted, with normal blood flow, marked true lumen expansion and no endoleaks. The left subclavian artery blood flow is provided by the steal phenomenon right-to-left vertebral indirectly speaking about the normal flow in the brachiocephalic artery chimney.

Discussion

The Advantages and Challenges of Endovascular Treatment of TAAD

The potential advantages of endovascular treatment lay in its minimally invasive nature, lack of surgical trauma, no need for extracorporeal circulation, short hospital stay, and can be considered as an alternative option to medical treatment for high surgical risk patients.

Challenges for endovascular treatment of ATAAD is the lack of specific ascending aorta stent-grafts, the challenge to provide sufficient proximal landing zone for the implantation of existing stent-grafts, missing sizes of stent-grafts and bare stents for patients with concomitant ascending aorta dilation and aneurysms, the inapplicability of the method in patients with concomitant valve pathology. In a recent publication by *Kubota H. et al. the authors* addressed this topic and called it “final frontier in the endovascular treatment of the aorta”[17]. Taking the potential of endovascular therapy even further, the so-called Endo Bentall procedure was first proposed

Patient	year	Euroscore II	sex	Type of treatment	Disease type	Device used	Fullow- up(clinical and CT aortografy)
1	2017	41,02%	Male	Uncovered stent	Acute TAAD	MFM Cardiatis 40/180 mm from ascending to descending aorta	2 years, uneventful
2	2017	42,06 %	Male	Uncovered stent	Acute TAAD	MFM Cardiatis 40/180 mm and 30/100 from acending aorta to distal thoracic aorta	2 years, uneventful
3	2017	46,63 %	Male	Uncovered stent	Acute TAAD	MFM Cardiatis 35/120 x 2, MFM Cardiatis 25/180 and Iliac extension MFM Cardiatsis 14/120 mm x 2 from ascending aorta to external iliac artery	2 years, uneventful
4	2017	56,06 %	Male	Short stent-graft and uncovered stent	Acute TAAD	Ascending Ao entry covered by short Stent-graft Endurant II 36/36/49 mm, telescope with bare stents Sinus XL 30/100 mm x 2 and 28/100 mm x 2 on arch level and proximal thoracic	died after 1 month from gastrointestinal bleeding
5	2018	48,62%	Female	Uncovered stent	Chronic TAAD	Sinus XL 36/100 mm from ascending aorta	2 years, uneventful
6	2019	53,62%	male	Chimney technique	chronic TAAD	Valiant Captiva 46/46 207 mm and 34/34/20 from ascendig aorta and chimney of supra aortic arteries Be Graft 8.0/57 and 6.0/58 mm	6 months, uneventful
7	2019	48,62%	male	Chimney technique	Subacute TAAD	Valiant Captiva 42/42 207 mm from ascendig aorta and chimney of supra aortic arteries be graft 10/57 and 7.0/57	6 months, uneventful
8	2019	58.64%	male	Chimney technique	Subacute TAAD	Valiant Captiva 44/44 207 mm from ascendig aorta and chimny of supra aortic artery Be Graft 10/57 and Be Graft 6.0/58	6 months, uneventful
9	2019	49,58%	male	Chimney plus sandwich technique	Subacute TAAD	Endurant II 34/34/49 mm in ascending aorta(implanted from left subclavian artery) , Valiant Captiva 38/38/207 from Endurant and Chimney of supra aortic arteries Be graft 12/59 x 2 and 8.0/57 x2	6 months, uneventful
10	2019	52,03%	male	Chimney technique	Acute TAAD	Valiant Captiva 34/34 150 mm from ascendig aorta and chimney of supra aortic arteries Be Graft 14/59 and Be graft 6.0/58 x 2	3 months, uneventful
11	2019	42,06%	Female	Chimney technique	Acute TAAD	Valiant Captiva 42/42 207 mm from ascendig aorta and chimney of supra aortic arteries Protégé 10/80 10/60	In hospital death from rupture of descending thoracic aorta, Ehlers-Danlos positive
12	2020	47,08%	Male	Chimney technique	Acute TAAD	Valiant Captiva 36/36/2017 and 32/32 207 mm from ascendig aorta and chimney of supra aortic arteries Be Grafts 10/57 mm and 8.0/57	3 months, uneventful

Table 1. Our experience with type A aortic dissection, showing the application of a totally endovascular approach to treat patients with acute, subacute and complicated chronic type A aortic dissections in the last three years.

for patients unsuitable for TAVR due to ascending aorta aneurysm with transapical approach[18]. The idea of a single valve-carrying endovascular conduit was first suggested by *Rylski et al.* and further developed by *Kreibich et al.*[18,19]. In brief, the device is constructed of transcatheter aortic valve that is connected to an uncovered portion of an aortic stent-graft. The uncovered portion of the conduit is intended to allow free flow to the coronary arteries. Our opinion is the proximal part such a device, after the coronary arteries zone, should have the design of a covered stent-graft, allowing exact position and efficient dissection entry sealing, even in aneurysmal portions of the aorta. In theory, this should provide one of the most essential conditions for proper endovascular prosthesis placement – an appropriate landing zone. The feasibility of the endovascular treatment in such a scenario was demonstrated by the same team using it in a swine model. The device was successfully implanted in the ascending aorta of the animal using a transapical approach[20].

In a similar way, in a recent publication, a team from Sao Paulo showed the feasibility of the so-called Endo Bentall technique treating a patient with TAAD using custom made complex fenestrated stent-graft (for coronary arteries chimneys) attached to a TAVI valve. The main body (consisting of stent-graft and TAVI was introduced and implanted via a transapical approach, whereas the coronary chimneys were introduced by the percutaneous approach), representing first in human experience[21].

We present our experience in 12 patients showing acceptable results in a very complex group of patients (by clinical and anatomical point of view) using totally percutaneous strategy with low periprocedural complication rate and encouraging midterm results and utilizing the only available in our country non branched and not-fenestrated thoracic aortic stentgrafts. In some cases we combined on a compassionate way the ascending aorta implantation of "abdominal" straight cuffs and non-covered stents not indicated for this aortic zone.

Conclusion

The open surgery remains the gold standard for the treatment of ATAAD. In complex, high surgical risk cases, endovascular approach can be considered as an alternative. Small series of hybrid and totally endovascular treatment show promising results for alternative minimally invasive approaches. Our totally endovascular experience combining dense mesh non-covered stents, stent-grafts proximal entry coverage combined with chimney technique to provide supraraortic vessels perfusion showed an encouraging short and midterm results. The invention and introduction in the practice of dedicated stent-grafts for ascending aorta and aortic arch can increase the applicability of endovascular treatment methods for ATAAD.

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