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Thoracic Endovascular Aortic Repair (TEVAR) in Proximal (Type A) Aortic Dissection: Ready for a Broader Application?

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Abbreviations

aTAAD acronym acute type A aortic dissection
CT acronym computed tomography
cTAAD acronym subacute or chronic type A aortic dissection
D acronym diameter
EKG acronym electrocardiogram
EuroSCORE II acronym European System for Cardiac Operative Risk Evaluation II
F acronym female
IRAD acronym International Registry of Acute Aortic Dissections
L acronym length
LCCA acronym left common carotid artery
M acronym male
N acronym number
NA acronym not applicable
NBS acronym non-bare stent
PA acronym pseudoaneurysm
RCA acronym right carotid artery
RFV acronym right femoral vein
SD acronym standard deviation
SG acronym stent-graft
TA acronym transapical
TAVR acronym transcatheter aortic valve replacement
TAX acronym transaxillary
TEVAR acronym thoracic endovascular aortic repair
TF acronym transfemoral
OBJECTIVE: Thoracic endovascular aortic repair (TEVAR) has demonstrated encouraging results and is gaining increasing acceptance as a treatment option for aortic aneurysms and dissections. Yet, its role in managing proximal aortic pathologies is unknown - this is important because in proximal (Stanford type A) aortic dissections, 10-30% are not accepted for surgery, and 30-50% are technically amenable for TEVAR. We describe our case series of type A aortic dissections treated using TEVAR.

METHODS: Between year 2009 and 2016, 12 patients with acute, subacute or chronic type A aortic dissection with the proximal entry tear located between the coronaries and brachiocephalic artery were treated with TEVAR at 3 centers. Various stent-graft configurations were used to seal the proximal entry tear in the ascending aorta under rapid pacing.

RESULTS: 12 patients (9 male, 3 female), mean age 81±7 years, EuroSCORE II 9.1±4.5, underwent TEVAR for the treatment of type A aortic dissection. Procedural success was achieved in 11/12 patients (91.7%). There was one intra-procedural death and one minor stroke. No additional deaths at 30 days. At 36 months, there were 4 further deaths (all from non-aortic causes). The mean survival of these 4 deceased was 23 months (range 15-36 months). Follow-up computed tomography demonstrated favorable aortic remodeling.

CONCLUSION: TEVAR is feasible and reveals promising early results in selected patients with type A aortic dissection who are poor candidates for surgical repair. The current iteration of stent-graft technology however needs to be adapted to the specific features of the ascending aorta.

Abstract word count: 248
Central Message
TEVAR in type A aortic dissection is feasible in selected patients. Favorable aortic remodelling occurs in type A (and B) dissections. Thus TEVAR may be an option in patients at high risk for surgery.

Perspective Statement
TEVAR offers a potential treatment option in a subset of patients with type A aortic dissection at high surgical risk but with suitable anatomy. With TEVAR, 30 day survival is >90% in these high surgical risk patients. With this proof of concept study, broader application may be possible with further specific technological advances.

Central Picture legend
Successful interventional treatment of a type A aortic dissection using TEVAR
The surgical mortality and morbidity remains high for proximal (Stanford type A) aortic dissections, particularly in the elderly with significant co-morbidities, despite recent strides to improve its surgical technique and management (1, 2). Considering the Western demographics with increasing aging population and variety of co-morbidities which portend inherent increased surgical risks, the concept of endovascular stent-grafting also known as thoracic endovascular aortic repair (TEVAR) (a catheter-based non-surgical technique) in patients with thoracic aortic disease is increasingly attractive, propelled by the desire to minimize surgical risks. TEVAR has been shown to initiate healing and remodelling of the dissected aorta, by excluding and depressurizing the false lumen (3-5). To date, TEVAR strategies appear encouraging in the treatment of various aortic pathologies (6-10). The technology has been embraced without level I evidence for the treatment of distal (Stanford type B) aortic dissections, and even used to treat acute proximal (Stanford type A) aortic dissections (11). However, the complexity of the anatomy in the ascending aorta continues to be a major obstacle for the use of endovascular technologies.

Acute type A aortic dissection usually requires very urgent surgical repair of the ascending aorta (12-14); selected cases however may qualify for TEVAR as an option in scenarios of unacceptably high surgical risk. According to the International Registry of Acute Aortic Dissections (IRAD), 86% patients qualify for surgical replacement of the ascending aorta, 23% or 12% require additional partial or total arch replacement, respectively (15). Overall, on aggregate 91% of patients in this registry underwent surgical repair under cardiopulmonary bypass with 25% in-hospital mortality (15, 16). A less traumatic repair of type A aortic dissection using TEVAR, where applicable, may potentially lower the procedural/in-hospital mortality risk, particularly as the technology improves.

Surgical repair leaves a patent false lumen in both the aortic arch and descending aorta in 75% patients, those who survive often require distal re-interventions (15, 16). One solution may be a two-stage hybrid procedure, whereby initially, surgery is performed to replace the ascending aorta together with aorto-brachiocephalic artery bypass without hypothermic circulatory
arrest. This is followed on a second occasion by surgery for left carotid artery bypass and TEVAR to retrogradely place an endovascular stent-graft in the thoracic aorta transfemorally in the same setting. The stent-graft excludes the retrogradely perfused distal false lumen (17). The objective of such an approach is to avoid surgery on the arch, and to complete the repair with an aortic stent-graft in a minimally invasive way. Such approach not only minimizes the procedural risks, but also enables careful evaluation of the distal false lumen prior to stent-graft placement. Alternatively, one-stage hybrid procedures combining open (surgical) insertion of a tube-graft in the ascending aorta with head vessel transposition and antegrade in the arch and descending aorta are feasible (18), but require the skills of both a cardiac and endovascular specialist and lack the precision of the two-stage hybrid procedure (19). Moreover, there is some resistance to apply such one-stage hybrid procedures in acute type A aortic dissections, because experts are aware that the fragile outer aortic wall and friable dissecting lamella are prone to injury or perforation by antegrade positioning of the stent-graft under conditions of circulatory arrest. At present there are no dedicated stent-grafts for the ascending aorta, in particular for the repair of aortic dissections; such challenges will certainly be addressed by customized stent-graft technology in the near future. Nevertheless, the concept of a one-stage hybrid repair with antegrade stent-graft placement may become part of a therapeutic armamentarium for complex type A dissections with distal malperfusion; while a multi-stage hybrid repair incorporating retrograde stent-graft placement may become a preferred option in stable situations.

From an anatomical perspective, 30–50% patients with type A aortic dissection are amenable to TEVAR (20, 21). Thus in the future more patients may be considered suitable for TEVAR with life-long follow-up. The ultimate goal is a fully catheter-based approach to repair the ascending aorta that minimizes procedural risk and initiates healing (as documented in type B dissections where interventional entry closure is associated with thrombosis of the false lumen and favorable aortic remodelling) (3, 4, 6, 7). Such approach is feasible with current technology (22-25). Here, we describe our 12-case series of type A aortic dissections treated using TEVAR.
METHODS

Patient selection

Between year 2009 and 2016, 12 patients with type A aortic dissection consisting of an isolated dissection entry in the ascending aorta, referred to the University Heart Centre (Rostock, Germany), CHU (Liege, Belgium) and Royal Brompton Hospital (London, UK) were selected and subjected to TEVAR. These patients were selected for TEVAR because of high co-morbidities and anatomic suitability, e.g. aortic dimensions suitable to accommodate a ready-made commercial stent-graft. All had elevated anesthetic risk score (American Society of Anesthesiologists classification IV or greater), New York Heart Association class III or IV, chronic lung disease and/or renal impairment. Decisions regarding treatment required consensus between cardiac surgeons and cardiologists, with the patients giving informed written consent. TEVAR in this setting was approved by the internal review board of each center. All patients had EKG-gated computed tomography (CT) (Figure 1) and echocardiography for the diagnosis and assessment of aortic dissection. Echocardiography allowed assessment of the aortic valve, left ventricular function, presence/absence of tamponade, and interrogation of the supra-aortic vessels.

TEVAR procedure

Procedural planning was based on contrast-enhanced EKG-gated CT (Figure 1), which was evaluated using standard software (TeraRecon, or 3Mensio) to select the appropriate stent-graft size; the diameter of the stent-graft was chosen according to an estimate of the previous (before dissection) aortic dimension to avoid oversizing. The stent-grafts used were usually ZENITH TX2 (Cook, Bloomington, Indiana), GORE C-Tag (Gore Ltd. London, UK) or Relay NBS (Bolton, Barcelona, Spain). They are made of a self-expanding nitinol stent platform covered with polyester fabric. They are packed and mounted onto a catheter-based delivery system. Figure 2 and Videos 1-3 show a typical TEVAR procedure. With the patient under general anesthesia, a temporary pacing wire was placed in the right ventricle and vascular access for the TEVAR device (22-
24F) obtained via right femoral arterial cut-down. The true lumen of the aorto-ilio-femoral arterial route was navigated using a soft long hydrophilic guide wire (Terumo, Inc.) protruding ahead of a pigtail catheter to reach the left ventricle under fluoroscopy and ultrasound guidance (transesophageal echocardiography) (26). Once the pigtail is in the left ventricle, the soft hydrophilic guide wire was exchanged to a stiff 270 cm length guide wire through the pigtail catheter. The stiff guide wire has a soft spiral tip that sits within the left ventricular cavity. The stent-graft was then delivered along the stiff guide wire to its intended position, where its distal landing zone is between ‘distal to the coronary ostia’ and ‘proximal to the brachiocephalic artery’ in the ascending aorta. In this position, the distal tip of the delivery system may cross the aortic valve. For stent-graft deployment, rapid right ventricular pacing at 180 bpm was used to reduce the systolic blood pressure to ≤50 mmHg in order to avoid displacement (windsock effect) of the stent-graft during its deployment, thus enabling its precise placement. At the end of the procedure, the temporary pacing wire was removed, the femoral artery access site closed, and the patient extubated and transferred to the coronary care unit. Procedural success was defined as successful placement of the stent-graft in its intended position with sealing of the entry tear.

Follow-up

Overall aortic and true lumen diameters were assessed at the level of sinotubular junction, ostium of the brachiocephalic artery and left subclavian artery. Follow-up CT scans were performed approximately at 6 months and then annually post TEVAR.

Statistical analysis

Descriptive statistic was used to characterize patients, procedural data and individual survival.

RESULTS

A total of 12 patients with proximal (type A) aortic dissection were
selected for TEVAR (Table 1). There were 10 DeBakey type II and 2 DeBakey type I dissections. The mean age ± standard deviation (SD) was 81 ± 7 years; male:female ratio was 9:3. All patients were of advanced age with chronic lung disease, coronary artery disease and/or renal impairment. The mean EuroSCORE II was 9.1 ± 4.5 (SD). The median time from onset of symptoms/diagnosis to TEVAR was 24 days. There were 6 cases of acute (≤14 days after symptom onset) and 6 cases of subacute (15 days to 3 months) or chronic (>3 months) aortic dissections. The false lumen of the dissection expanded significantly causing various complications, including dyspnoea, hoarseness or laryngeal nerve dysfunction. There was a history of chest and back pain in all cases. There were no significant aortic insufficiency, no clinically apparent distal malperfusion syndromes and no distal interventions required.

Procedural success was 91.7% (11/12) (Table 1). There was one death due to cardiac tamponade from wire induced perforation of the left ventricle. All remaining 11 patients were discharged alive within 2 weeks of TEVAR. The mean procedural time was 86 ± 33 (SD) minutes. Stent-grafts were deployed under rapid right ventricular pacing which achieved a mean systolic pressure of 34 ± 15 (SD) mmHg. The mean follow-up time was 21.1 ± 11.8 (SD) months (range 0 - 36 months) post TEVAR. There were 4 deaths, one each at 15, 19, 23 and 36 months (Table 1). All appeared to have died from natural causes. The mean survival in those who died during follow-up was 23 months.

Follow-up CT scans revealed thrombosis or remodelling of the stent-graft excluded false lumen. The diameter of the aorta at the sinotubular junction was not enlarged and remained similar to the normal aorta post TEVAR (Figure 3).

DISCUSSION

There is general consensus that proximal aortic dissection or any major pathology involving the ascending aorta should be subjected to surgical repair. However, 10-30% of patients with acute type A aortic dissection are considered too high risk for surgical repair and would therefore receive only medical therapy with associated high mortality of ≈60% in the intermediate term (13, 15, 27, 28). Surgical mortality is 10-25% (16, 27) depending on the complexity of the
operation and the clinical status of the patient. In our hands, the procedural mortality of TEVAR was 8%, which compares favorably with the published early endovascular mortality of 11% [18, 19]. Interestingly, the most anticipated complications such as major stroke did not occur. One minor stroke (transient) and one death from guidewire perforation of the left ventricle leading to fatal tamponade occurred.

We estimate the number of TEVAR procedures performed in this study relative to all emergency surgeries for type A aortic dissection in our 3 centers to be ≈2%, or 6-17% of inoperable type A cases (assuming the incidence of type A dissection ≈40 cases/year for a typical aortic center; therefore across 3 centers spanning the study period of 6 years, the total number of cases = 40 cases x 6 years x 3 centers = 720 cases; generally 10-30% of type A dissections are inoperable [15]).

Successful sealing of the false lumen entry with no development of proximal type I endoleak were achieved. During follow-up, no cases of endoleak were identified which is encouraging and different to ≈10% incidence reported elsewhere [29]. In selecting the appropriate size of stent-grafts, we chose the diameter of the stent-grafts according to an estimate of the previous (before dissection) aortic dimension to avoid oversizing. The goal was to re-shape the dissected ascending aorta, cover the entry tear and depressurize the false lumen (30, 31); there is a fine balance between fixation to the aortic wall and the degree of intimal injury caused by the self-expanding stent-graft. However, once precisely deployed, the process of remodelling of the false lumen appears similar between the proximal and distal dissection, and takes place usually within one year, similar to that reported elsewhere [32, 33]. Most of our cases were DeBakey type II dissections, and even in the 2 cases of type I dissection (patients 2 and 3 in Table 1), favorable aortic remodelling of the descending aorta were observed. It seems that the therapeutic concept of closing the entry and depressurizing the false lumen in type B (distal) aortic dissection holds true also in type A (ascending) aortic dissection [3, 4]. As long as the false lumen is thrombosed and depressurized, survival even with type A aortic dissection can be improved by TEVAR [34]. In addition, the patients’ exposure to unacceptable risk of surgery is minimized.
Current literature (mostly single or small case series) underlines the feasibility of proximal endovascular procedures over more than 10 years, performed by surgeons and interventionalists (Table 2). Our series over 6 years with a mean follow-up of >20 months (range up to 3 years) underlines the fact that in the setting of significant co-morbidities representing high surgical risk but with suitable anatomy, TEVAR can be a viable alternative to surgical repair. In other words, it is feasible to avoid high risk/complex surgery, and apply a less traumatic intervention to obtain a similar or better short-term outcome in a subset of elderly patients with significant co-morbidities. The advantages of TEVAR includes the avoidance of thoracotomy, cardiopulmonary bypass, selective head perfusion and associated surgical risks in an elderly population, often in a critical condition (35). If the high initial ≈60% mortality of type A aortic dissection can be successfully lowered by TEVAR, such less traumatic strategy may potentially become an option in a broader spectrum of patients (27). As TEVAR is a fairly expensive procedure, its associated lower risks/complications and shorter lengths of hospital stay compared to surgery may potentially demonstrate its advantages in terms of cost and clinical outcome over surgery.

TEVAR will not be feasible in every patient; the most suitable anatomy is where the entry tear of the dissection is located in the middle portion of the ascending aorta. Entry tears close to the coronaries or aortic valve lack a suitable length of landing zone. Entry tears close to the brachiocephalic artery would require complex branching/fenestration strategies. Currently, only a limited number of choices are available regarding the type of stent-graft and delivery system because relatively large diameter and short length stent-grafts are required. Existing delivery systems need to be modified for ascending aorta intervention: a long nosecone can either damage the aortic valve or increase the chance of left ventricular perforation by the stiff guidewire, as occurred in one of our patients.

On a technical note, with the use of rapid ventricular pacing no misplacement of these short stent-grafts was seen. Pacing is probably the most efficient method to avoid windsock effect of the left ventricle, enabling precise stent-graft placement. Transoesophageal echocardiography is also useful in
guiding stent-graft positioning and assessing sealing of the entry tear (26).

It should be emphasized that a multidisciplinary team, consisting of cardiac and vascular surgeons and cardiologists, should select suitable patients for the procedure, similar to transcatheter aortic valve replacement (TAVR).

Looking forward, we believe TEVAR in the ascending aorta is a definitive solution for patients not accepted for surgery, or a bridging solution in case of unclear neurological diagnosis (e.g., major stroke) to buy time for reconstructive surgery. Selection process in patients not suitable for surgical valve replacement may even be conceivable for combined TAVR-TEVAR technology, in an attempt to treat variants of aortic dissection including those with compromised aortic valve function. It should also be emphasised that in the acute setting there is a need to identify and transfer type A aortic dissection patients to a specialized unit as quickly as possible; once the dissection has produced coronary obstruction (usually the right coronary artery) with ensuing (right) ventricular infarction and heart failure, it is a difficult situation to retrieve by either endografting or conventional surgery.

Study limitations

While we could demonstrate proof of concept and feasibility of TEVAR in the ascending aorta with encouraging results, we did not examine possible detrimental effects such as stiffening of the ascending aorta by the stent, lowered vascular compliance, negative effects on the aortic valve function or hypertension in this observational study. Our sample size is relatively small, but it represents one of the biggest case-series in the field and supports the feasibility of TEVAR in practical terms. We have no control group (medically treated or surgery) for comparison, but historical data suggests that surgery confers 25% peri-operative mortality, and medical treatment is associated with 60% mortality (13, 15, 27, 28). A propensity-matched comparison prior to any randomized study would probably be the next step to strengthen the data on TEVAR in the proximal aorta; current technology is unlikely to allow a broader application yet.

Conclusion

TEVAR is feasible and reveals promising early results in selected patients.
with proximal (type A) aortic dissection who are poor candidates for surgical repair. The current iteration of stent-graft technology however needs to be adapted to the specific features of the ascending aorta before TEVAR as a concept emerges for broader applications in the proximal aorta.
Figure legends

Figure 1. From top to bottom: 2-dimensional transverse and coronal section of a localized proximal aortic dissection (type A) with a large entry between the aortic valve and brachiocephalic artery; 3-dimensional reconstruction prior to treatment.

Figure 2. TEVAR procedural sequence for placing a covered stent-graft to treat a type A aortic dissection. (A) Aortogram and set-up showing a right ventricular pacing wire and transesophageal echo probe; (B) Stent-graft deployment during rapid pacing; (C) Completed deployment of the stent-graft; (D) Aortogram demonstrating procedural success.

Figure 3. From top to bottom: 2-dimensional transverse and coronal sections of a proximal (type A) aortic dissection before (left) and after stent-grafting (right), demonstrating TEVAR reconstruction and remodelling of the aorta. The bottom panels demonstrate the successful intervention in 3-dimensional reconstruction.

Video 1. Before TEVAR. Digital subtraction angiogram showing a large tear in the ascending aorta, and a marker pigtail, pacing wire and tranoesophageal echocardiography probe in place.

Video 2. During TEVAR. Fluoroscopic display of the launch of a self-expanding Viabahn stent-graft in the brachiocephalic artery followed by a self-expanding C-Tag stent-graft covering the ascending aorta under rapid pacing.

Video 3. After TEVAR. Completion angiogram after placement of the Viabahn stent-graft in the brachiocephalic artery and C-Tag stent-graft in the ascending aorta; the entry to the dissection is sealed and flow is preserved to the brachiocephalic and coronary arteries.
References


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Abbreviations: aTAAD (acute type A aortic dissection), cTAAD (subacute or chronic type A aortic dissection), D (diameter), F (female), L (length), M (male), NBS (non-bare stent), SG (stent-graft), TAVR (transcatheter aortic valve replacement). † indicates deceased.
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Abbreviations: LCCA (left common carotid artery), N (number), PA (pseudoaneurysm), RCA (right carotid artery), RFV (right femoral vein), TA (transapical), TAx (transaxillary), TF (transfemoral).