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Editor's Choice – Durability of Endovascular Repair in Blunt Traumatic Thoracic Aortic Injury: Long-Term Outcome from Four Tertiary Referral Centers

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WHAT THIS PAPER ADDS

In recent years TEVAR has emerged as the preferred treatment for patients with blunt traumatic thoracic aortic injury, regardless of age. However, there are very limited data on long-term outcomes. In particular, little is known about long-term device related complications and device integrity in the aging aorta. The present data support previous findings that in patients undergoing TEVAR most early deaths are unrelated to the aortic injury, but predominantly caused by brain damage. In patients surviving the trauma and the primary hospitalization, long-term survival is excellent, and the need for re-intervention is very rare after 1 year, albeit fairly common during the first year.

Objectives: To analyze the early and long-term survival and re-intervention rate in patients undergoing TEVAR for blunt traumatic thoracic aortic injury.

Methods: This was a consecutive case series. Between the years 2001 and 2010, a total of 74 patients underwent TEVAR for blunt traumatic thoracic aortic injury at four tertiary referral centers, three in Sweden and one in Switzerland. The median age of the patients was 41 years, and 16% were women. Demographic, procedural, and outcome data were collected and reviewed retrospectively. The patients were followed up during 2013–2014.

Results: Early (30 day) mortality was 9% (7 patients), with only two cases directly related to the aortic injury; in hospital mortality was 14% as three patients died during the primary hospital admission within the first 6 months. Most patients had sustained severe injuries to other organ systems, and among all in hospital deaths brain injury was the predominant cause. Five year survival in the whole group was 81%. Re-intervention was needed in 16% (12 patients) during the first year, half of them within the first month. Only one patient underwent re-intervention more than 1 year after the initial procedure. Infolding and partial stentgraft collapse was the reason for the secondary procedure in five of the 13 patients; in three it occurred within 3 weeks of the acute TEVAR.

Conclusion: TEVAR allows rapid and effective therapy in trauma patients with blunt aortic injury. The outcome is dependent on the severity of the concomitant injuries. The treatment is durable during the first decade after the procedure, but even longer follow up is needed to determine the impact of TEVAR in young patients on the degenerative changes that take place in the aging aorta.

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INTRODUCTION

Blunt traumatic thoracic aortic injury is the second most common cause of death from blunt trauma after head injury.[1,2] Blunt aortic injury most commonly occurs after sudden deceleration, such as in car or motorcycle crashes, falls or crush injuries.[2] In a landmark report by Parmley et al. in 1958, the regions of the aorta found to be most prone to blunt traumatic injury were the isthmus and the

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ascending aorta, as these are subjected to the greatest strain in sudden deceleration.[3] Parmley et al. also found that patients with injury to the isthmus had a higher probability of early survival than patients with more proximal aortic injuries, and that patients who were managed conservatively were at risk of developing false aneurysms and late rupture — findings that are still valid.

During the last decade there has been a paradigm shift in the management of patients with blunt traumatic thoracic aortic injury. The use of intra-luminal stent grafts, Thoracic EndoVascular Aortic Repair (TEVAR), has become the therapy of choice for most patients, based on single and multicenter trials. The clinical practice guidelines of the Society for Vascular Surgery (SVS) state that TEVAR is associated with better survival than open repair or non-operative management, and a lower rate of paraplegia than surgical graft replacement of the aorta.[1,2,4–6]

Not all traumatic aortic injuries are equally severe, as the extent of damage to the aortic wall varies from an intimal tear to complete transection and rupture. A classification system grading the seriousness of the injury was suggested by Azizzadeh et al. and endorsed by the SVS: type I (intimal tear), type II (intramural hematoma), type III (pseudoaneurysm), and type IV (rupture).[1,7] Moreover, as victims of high impact collisions often have multiple injuries they are initially managed according to the Advanced Trauma Life Support (ATLS) concept, and, as the aortic injury is rarely an isolated finding, the timing of TEVAR, if indicated, must be decided while taking other injuries into consideration.

There is no doubt that the use of TEVAR for traumatic aortic injuries has revolutionized the management of such patients, but as these patients are often young there are several concerns regarding long-term outcome, such as device integrity, aortic degeneration and expansion with progressive age, and cumulative radiation exposure. The aim of the present study was to analyze the long-term outcome of TEVAR in patients with traumatic aortic injuries with respect to survival and rate of re-intervention by merging data from four European tertiary referral centers.

MATERIALS AND METHODS

All patients undergoing TEVAR for traumatic thoracic aortic injury were registered in the local registries of the four participating tertiary referral centers; one in Switzerland (Zurich), and three in Sweden (Malmö, Uppsala, and Stockholm). Data from all four centers were available for the period January 1, 2001 through December 31, 2010, which constituted the study period. The study period was not extended beyond 2010 to permit follow-up of all patients. During the 10 year period, 74 patients underwent TEVAR for blunt traumatic injury to the thoracic aorta; 29 patients were treated in Zurich, 21 in Malmö, 17 in Uppsala, and seven in Stockholm. The medical records of the patients were identified and reviewed with respect to demographics, concurrent injuries with assessment of the Injury Severity Score (ISS),[8] and operative variables. The ISS, in turn, was calculated by way of the Abbreviated Injury Scale (AIS), allocating the injuries to one of six body regions, ranking the injuries on a scale of 1 to 6, with 1 being minor, 5 critical, and 6 unsurvivable.[9] Early and long-term survival, as well as complications and re-interventions were documented. The arch landing zone was categorized according to the Ishimaru classification.[10] The severity of the aortic injury was grouped according to the SVS scheme.[1]

All patients were initially managed according to the ATLS guidelines. The initial evaluation was followed by computed tomography (CT) according to a trauma protocol, including CT of the head, spine, chest and abdomen, and further specific radiological examinations whenever necessary. The patients were evaluated by a team of trauma, cardiothoracic, vascular surgeons, anesthesiologists, and radiologists. The aortic injury was characterized with respect to location, diameter, and length of the lesion, along with concomitant injuries, so as to decide the timing and effectuation of the procedure. In patients with concurrent injuries that were considered to be more life-threatening than that of the aorta, those were managed prior to TEVAR. Arterial access was established through surgical exposure or percutaneously, and the stent grafts were deployed over a stiff wire. Oversizing of 15–60% was applied, depending on device availability at the time of the trauma and on the instructions for use (IFU) of the manufacturers. All four centers followed the same patient management principles and had 24/7 on call systems with readiness to perform TEVAR around the clock. The Uppsala protocol for trauma patients with blunt aortic injury has been reported previously,[11] and so has an early Zurich series of patients.[12]

The patients were monitored by CT angiography before discharge and at 1 month, after 3–6 months, and at 12 months, and annually thereafter. As a unique 10 digit personal identity number is allocated to all Swedish citizens and permanent residents, long-term survival can be followed accurately in all patients. Two of the Swedish patients were lost to follow up, however, as they were foreign nationals. The Swiss patients were followed up by way of phone calls or reports from local hospitals if they were not Zurich residents. Three Swiss patients had relocated and could not be retrieved. During the course of 2013–2014 all the 69 remaining patients were followed up with respect to survival and re-interventions and could be assigned a date of death or identified as being alive. The study was ethically approved by the local/regional ethical review boards.

Continuous variables were summarized with medians and ranges, and categorical variables with frequencies. The Kaplan–Meier method was used to estimate the survival function. SPSS for Windows 22.0 was used for data processing and statistical analyses.

RESULTS

Of the 74 patients undergoing TEVAR for blunt traumatic aortic injury there were 12 women (16%) and 62 men. Median age was 41 years (range 16–89). Nearly half of the patients, 36 (49%), had sustained the aortic trauma in association with car accidents, the second most common cause

was motorcycle or other motor vehicle accidents, accounting for 16 cases (22%). Thirteen patients (18%) had fallen from heights, four (5%) had crush injuries connected to work, and two had been injured during sports practice, one skier and one mountain bike cyclist. Finally, two pedestrians were hit by cars, and one cyclist had been hit by a tram.

The majority of the patients (64 patients; 86%) were treated within the first 24 hours of the trauma. Seven patients underwent TEVAR after 2–7 days; and three patients had delayed repair, two after 2 weeks, and one after 6 weeks. All patients had suffered concomitant injuries to the chest and most patients had damage to several regions. The median ISS was 41 (interquartile range 34–50). A total of 16 patients (22%) had sustained serious head injuries, including cerebral contusion or intracranial hemorrhage, 32 (43%) had serious abdominal injuries, including damage to the liver, spleen or kidneys, or intra-abdominal hemorrhage, and 44 (59%) patients had fractured one or more long bones, pelvis or vertebral bodies. There were seven patients (9%) whose injuries were confined to the chest, including rib fractures, pneumothorax, and hemothorax, in addition to the injury to the aorta. In the whole cohort of 74 patients, one patient had a type I injury, 10 (14%) had type II injuries, 55 (74%) type III, and eight (11%) type IV.

In all but two patients, one stent graft was sufficient to seal the injured part of the aorta. Median stent graft length was 135 mm (interquartile range 100–150 mm), and median graft diameter was 28 mm (interquartile range 26–34 mm). The TAG device (WL Gore & Associates, Inc, Flagstaff, AZ, USA) was used in 43 cases, the Zenith stent graft (Cook Medical Inc, Bloomington, IN, USA) was implanted in 13 patients, the Talent or Valiant (Medtronic, Inc, Minneapolis, MN, USA), respectively, in 10, and the E-vita (JOTEC GmbH, Hechingen, Germany) in six. One patient received a homemade device, and in one case the type of stent graft was not documented. The left subclavian artery (LSA) was covered in 37 patients (50%), and in four (5%) the left common carotid artery (LCCA) also had to be covered, which in two cases was managed by placing a stentgraft into the LCCA as a chimney graft, and in two by way of a right to left carotid-carotid bypass.

Early (30 day) mortality was 7/74 (9%). Data on those seven patients are presented in Table 1. In hospital mortality was 10/74 (14%) as a further three patients died during the primary hospitalization, after 1.5, 2, and 6 months, respectively. The causes were multiple organ failure, brain damage, and pneumonia in another patient with severe brain damage. All deaths related to the trauma occurred within the first 6 months. Five year survival was 81% ± 5%; half of the patients were followed for 5 years or more (Fig. 1).

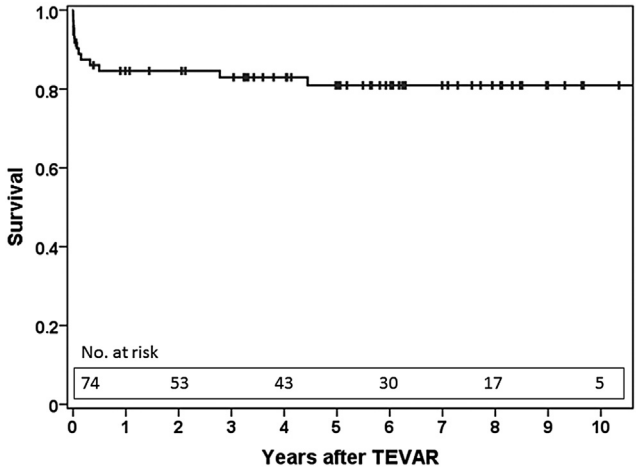

Figure 1. Long-term survival after TEVAR for blunt traumatic thoracic aortic injury.

During the first year after TEVAR, 12 (16%) patients underwent re-intervention, half of them within the first month. Only one additional patient needed re-intervention after the first year, a man who was re-operated on after 58 weeks. That patient, in turn, was one of two young patients who eventually had their stent grafts surgically explanted. After the initial procedure, the 23 year old man subsequently developed claudication. Based on the CT findings, there was suspicion of thrombus within the stent graft, but at removal of the device massive fibrous hyperplasia was found to be the cause. The second patient who underwent surgical removal of the stent graft was a 31 year old woman, who at discharge after the primary admission already had a mal-alignment of the stentgraft along the lesser curvature of the aortic arch. Three months later she had recovered from all other injuries including an unstable pelvic fracture. Because of her young age, arch anatomy,

Table 1. Characteristics of seven patients who died within 30 days of TEVAR.

Sex	Age	Trauma mechanism	Aortic injury type[a]	Stent graft	ISS	Survival (days)	Cause of death
M	37	Car crash Driver	III	Gore TAG 28 × 150	25	0	Died intra-op
F	38	One car accident	IV	Cook Zenith 22 × 114	57	1	Multiple organ failure
M	78	Fallen 4 m	III	Gore TAG 34 × 150	45	4	Stroke
M	42	Car crash Passenger	II	Gore TAG 34 × 200	57	8	Brain damage
M	89	Fallen 10 m	III	Medtronic Valiant 34 × 150 + 34 × 200	57	11	Orotracheal + nasal bleeding
M	20	Motorcycle accident	III	Cook Zenith 22 × 110	41	26	Multiple organ failure
M	79	Fallen 4 m	III	Gore TAG 37 × 150	41	Died <30d, date n/a	Stroke

ISS = Injury Severity Score.
[a] Taken from reference.[1]

and patient preference, the stent graft was explanted 5 months after the initial trauma and replaced with a Dacron graft. On the initial acute admission, the diameter of the proximal descending aorta was 16 mm, and she was treated with a 26 mm stentgraft because of limited availability of more appropriately sized grafts at the time of surgery. There was yet another young patient, who was re-admitted with claudication; a 27 year old man, who had a very sudden onset of inguinal and thigh pain 3 months after TEVAR, with a walking distance of only 10 m. CT showed proximal infolding of the stentgraft. This was remedied by deployment of two bare stents proximally, one self expanding, and one balloon expandable stent. The symptoms subsided after the procedure. In summary, the principal reasons for re-intervention were endoleak ($n = 5$ patients), infolding ($n = 5$), left arm ischemia ($n = 2$), and fibrous hyperplasia ($n = 1$). The characteristics of the patients undergoing re-intervention are shown in Table 2.

DISCUSSION

In recent years there has been a paradigm shift from open repair to TEVAR as the preferred treatment for patients with blunt traumatic thoracic aortic injury, regardless of patient age. This is supported by several studies demonstrating lower mortality than after open repair.[1,2,4,5] However, there is concern about a fairly high risk of device related complications with previous generations of stent grafts, requiring either endovascular or open re-intervention.[5,13] In the present report, early mortality was 9%, but only two of seven deaths were directly attributable to the aortic injury per se. Most patients had sustained severe injuries to other organ systems, and among all in hospital deaths, brain injury was the predominant cause of death.

The optimal timing of TEVAR in patients with concurrent brain injury is poorly defined. Even though acute TEVAR in most cases can be performed without high level systemic heparinization, a recent study demonstrated a higher risk of progressive brain injury in trauma patients undergoing early TEVAR, compared with patients having delayed (>24 hours) repair.[14] With the advent of CT scans with improved resolution, and the ensuing detection of aortic injuries that would previously have been undetected, it has also been suggested that some patients with type I and type II injuries could be managed medically, with no need for subsequent repair.[15,16] During the first decade of the millennium, the study period, however, operative management was routinely chosen in patients with blunt aortic injury at the participating centers. Furthermore, as patients with traumatic aortic injury commonly have other, potentially life threatening injuries, the timing of TEVAR must be chosen taking all the injuries into consideration.[2] On the other hand, in hybrid operating theatres there is now a chance to treat multiple injuries in the same environment, making the need to prioritize among injuries less crucial.

Patients sustaining blunt traumatic thoracic aortic injury are often considerably younger than those who are treated for aortic dissection or aneurysm. In the present patient group, the median age was 41 years. This is consistent with other series, documenting that most patients are male in the age range 30—45 years.[13,15,17] This poses several technical and logistical challenges as young patients tend to have a more acute curvature of the aortic arch with the risk of poor apposition of the stentgraft, thereby a tendency to

Table 2. Characteristics of patients who underwent re-intervention after TEVAR.

Sex	Age	Trauma mechanism	Aortic injury type[a]	Stent graft	Indication for re-intervention	Time to re-intervention (weeks)	Operation
M	56	Car crash	IV	Gore TAG 28 × 100	Hemodynamically unstable, proximal endoleak	0.1	Gore TAG 31 × 150
M	24	Car crash	III	Gore TAG 28 × 100	Infolding	1	Palmaz stent
M	60	Snowmobile accident	II	Gore TAG 34 × 150	Proximal endoleak	1	Gore TAG 34 × 150
M	39	Motor cycle accident	III	Gore TAG 31 × 150	Left arm ischemia	1	Bypass LCCA-LSA
M	44	Fallen 16 m	III	Gore TAG 28 × 100	Infolding	2.5	Gore TAG 34 × 150 + bypass LCCA-LSA
M	17	Car crash Passenger	III	Gore TAG 28 × 150	Stent graft collapse	3	Palmaz stent
M	43	Motorcycle accident	IV	Gore TAG 28 × 100	Retrograde endoleak through LSA	6	Coiling LSA
M	27	Terrain vehicle accident	III	Gore TAG 28 × 150	Stent graft collapse, claudication	14	Sinus-XL stent + Palmaz stent
M	69	One car accident	III	Gore TAG 37 × ?	Proximal endoleak	17	Proximal re-lining
F	31	Car crash Passenger	III	Gore TAG 26 × 100	Malalignment, claudication	22	Surgical explantation
M	27	Pedestrian hit by car	III	Gore TAG 28 × 150	Left arm ischemia	42	Bypass LCCA-LSA
M	62	One car accident	III	Gore TAG 34 × 200	Proximal endoleak	43	Palmaz stent
M	23	Motor cycle accident	III	Medtronic Valiant 24 × 112	Fibrous hyperplasia, claudication	58	Surgical explantation

LCCA = left common carotid artery; LSA = left subclavian artery.
[a] Taken from reference.[1]

develop a bird beak configuration with an increased risk of subsequent endoleak and stent graft collapse.[1,11] In the present cohort, five of the 13 patients who underwent re-intervention had infolding and partial stent graft collapse; in three of them it occurred within 3 weeks of the acute TEVAR. Plausibly, some of the re-interventions related to oversizing could have been avoided if more suitably sized stent grafts had been obtainable. Moreover, in otherwise healthy young patients the aorta is smaller in size compared with the average patient with degenerative aneurysmal disease.[1,18] Until recently, small diameter thoracic stent grafts have not been available, which, in the authors' experience, as well as in the experience of others, may result in excessive over-sizing. At worst, this might also lead to proximal endoleak, infolding, migration, stent graft collapse, and even acute aortic occlusion.[1,13,19] A potential study limitation is the lack of data on patients treated during the most recent years, and with some of the most newly developed devices, but, on the other hand, intentionally, there was a span of time from the last endoprosthesis implantation to the commencement of data extraction.

The need for endovascular re-intervention after TEVAR in this setting has been reported in other series to be in the range 0—18%, with most complications occurring during the first year.[4,13,20,21] All re-interventions in the present cohort were carried out within approximately 1 year, half of them within the first month. Late re-interventions (>1 year) have been reported, and include stent graft infolding and migration, and the need to revascularize the LSA.[4,21] Whether the development of the currently available low profile, conformable thoracic stent grafts obtainable in more sizes, will decrease the re-intervention rate even further remains to be seen, but, no doubt, TEVAR, even with the previous generations of stent grafts, has revolutionized the management of this patient group. As TEVAR has become a relatively swift and safe method in harmony with the principles of damage control surgery,[22] it is now even more important to note that the outcome is highly dependent on the overall injury pattern.

Evidence is accumulating on mid-term outcome of TEVAR in cohorts of patients treated for traumatic lesions,[13,15,17,18] but a large number of reports still only have 1 year follow up data, albeit more recent reports often deal with a larger number of patients. Moreover, financial and insurance reasons, as well as young people having a more migrating lifestyle, are reported to be impediments of long-term follow-up.[4,18] Thus, the long-term durability of TEVAR in young patients remains to be elucidated, and depends among other things on changes of the aortic configuration that take place over time, and on how aortic remodeling of the affected segment is influenced by the placement of a stent graft. On the other hand, however, it is not known whether the stented aorta behaves differently from the non-stented thoracic aorta. There may be a potential for adaptation of the aorta with depressurization of the aortic wall.

Long-term follow up with cumulative radiation exposure is yet another important concern in this patient group, particularly if CT imaging is used. The SVS committee argued that in the absence of any complications on imaging during the first 12—36 months, the frequency of repeat imaging could be decreased, but that, on the other hand, there is not enough support for the idea that trauma patients should be followed up any differently from other post-TEVAR patients. Based on the authors' experience and the review of the literature, the incidence of complications seems to be highest during the first year, and the need for endovascular re-intervention or the occurrence of aortic related death much lower after that first year, suggesting a more infrequent follow up regimen over time. By way of multiple view chest X-ray or magnetic resonance imaging (MRI), radiation exposure can be reduced. As all of the most commonly used stent grafts today are MRI compatible, that is safe to scan under pre-specified scanner conditions, long-term follow up using MRI would be an attractive alternative, especially in young patients.

In conclusion, TEVAR is a rapid, safe, and effective therapy in patients with blunt traumatic thoracic aortic injury. The initial outcome is highly dependent on the severity of other injuries, and most deaths are unrelated to the aortic injury per se, once the stent graft is in place. Long-term survival in patients discharged from the primary hospital admission is excellent. Early re-intervention is fairly common, whereas late re-interventions are very uncommon. Even though long-term device related adverse events seem to be rare, little is still known about aortic remodeling of the affected segment in the long run over decades, which warrants continued surveillance of this still fairly novel treatment modality.

CONFLICT OF INTEREST

None.

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None.

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