

Late Radiological and Clinical Outcomes of Traumatic Thoracic Aortic Injury Managed with Thoracic Endovascular Aortic Repair

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Abstract

Purpose Patients treated with thoracic endovascular aortic repair (TEVAR) for traumatic thoracic aortic injury (TTAI) are often young and data on long-term durability of this treatment is not widely documented. The aims of this study were to report the New Zealand (NZ) national experience of TEVAR and to assess the durability of late outcomes and radiological follow-up of patients treated for TTAI.

Methods Consecutive patients treated with TEVAR during a 12-year period from all tertiary centers in NZ were included. Early (30-day), late survival and radiological imaging data were recorded to document late graft-related complications and re-interventions.

Results 88 patients with a median (range) age of 35 (15–87) year and 63 (71.6 %) males were included. Eleven patients (12.5 %) died within 30 days, of which three were aortic related deaths. The median (range) follow-up was 76.3 (0.3–164.6) months. Six (7.8 %) patients died during the follow-up period due to non-aortic-related causes. Nine (11.5 %) patients were lost to follow-up of which three emigrated overseas. Of those on surveillance, two patients required TEVAR re-intervention to previously treated aortic segments; one for a type 1b endoleak and the other for a symptomatic pseudo-coarctation. Both were treated successfully with a TEVAR.

Conclusions This multicenter study suggests that TEVAR is a durable option for treatment of traumatic thoracic aortic injury. Although, stent graft complications were uncommon, but when it occurred, it leads to re-intervention. Further radiological follow-up is required particularly in young patient to document late aortic/stent complications.

Introduction

Traumatic thoracic aortic injury (TTAI) is a life-threatening condition usually secondary to blunt chest trauma. 85 % of these injuries are fatal at the scene due to exsanguination [1]. Patients able to reach trauma centres can potentially be treated with open aortic surgery or more recently with thoracic endovascular aortic repair (TEVAR).

TEVAR was first used in 1987 as an alternate treatment to open repair for thoracic aortic aneurysms [2] but was later popularized by Dake et al. in the early 1990s with a larger case series [3]. TEVAR since has replaced open surgery for most thoracic aortic pathologies, but traumatic thoracic aortic injury patients seem to benefit the most from

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TEVAR with much lower associated morbidity and mortality compared to open surgery [4, 5]. This has brought a younger cohort of patients in comparison to patients previously treated with TEVAR for thoracic aortic aneurysms or dissection.

Little is known about the long-term outcomes of TEVAR following traumatic thoracic aortic injury and there is ongoing debate as to what the most suitable surveillance strategy for these patients should be. Patients treated with TEVAR are currently recommended to have computerized tomographic angiography (CTA) at 1, 6, 12 months post-procedure and then lifelong annual CTA, regardless of the aortic pathology [6]. However, there is ongoing concern with the cumulative radiation exposure and use of contrast for these patients due to the risks of radiation-induced malignancy [7] and contrast-induced nephropathy [8]. Most trauma patients have an otherwise normal aorta that has the potential to heal with time and therefore they may not require regular CTA follow-up [9]. On the other hand, there is little known about the long-term durability of TEVAR devices or the morphological changes to the aorta that can occur with age. Young aortas are likely to dilate by 20–30 % over a lifetime, which might lead to stent migration and subsequent endoleak or pseudoaneurysm formation [10]. Younger patients also tend to have smaller aortic diameters, and oversizing stent grafts has the potential to lead to endoleak, device infolding, endograft collapse, and death from acute aortic occlusion [10].

The aim of this study was to report the national experience of TEVAR for a cohort of TTAI patients and to document the late radiological and clinical outcomes.

Materials and methods

This was a multicenter study which included data from all tertiary hospitals (Auckland City, Christchurch, Dunedin, Waikato and Wellington Hospitals) in New Zealand (NZ) where TEVAR procedures are performed. All consecutive patients treated for TTAI with TEVAR between December 2001 and December 2013 were identified through the New Zealand Thoracic Aortic Stent (NZTAS) registry, local vascular and trauma surgery databases and hospital-coding units. The NZTAS is a multicenter registry reporting on the in-hospital morbidity and mortality of patients undergoing thoracic stent repair and preliminary results have been published previously [11]. Patient demographics, operation notes, and initial 30-day TEVAR complications were collected retrospectively from the NZTAS registry. Surveillance imaging (CT, MRI, or chest X-ray) was retrieved and reviewed from the picture-archiving communication system (PACS). Patients who have not been actively imaged

in the post TEVAR surveillance program were re-invited to undergo a follow-up CTA and chest X-ray during the course of this study. The retrospective nature of the study precluded individual patient consent. The national ethics board approved the study.

Definitions

In the NZ health system, patients are provided with a unique 6-digit personal identifier code that allows patients to be followed up accurately. Patient survival status was recorded from the respective institution and confirmed by a telephone interview with their family doctor. Death data were also validated from the Ministry of Health database and patients who were alive were censored on the September 22nd, 2015. For patients who had emigrated outside of NZ, the date of censoring was when they had no further medical visits documented in NZ. Proximal aortic landing zones were defined by the Ishimaru classification (Fig. 1) [12]. Traumatic aortic injury was defined as proposed by Azizzadeh et al.: type I intimal tear, type II intramural hematoma, type III pseudoaneurysm and type IV rupture [13]. Motor vehicle crash (MVC) was defined as any vehicle that collides with another vehicle, pedestrian or a stationary object. All procedures were performed in an interventional radiology suite by vascular surgeons and specialized vascular interventional radiologists. The majority of imaging surveillance post-TEVAR was a pre-discharge CTA and chest X-ray (posterior–anterior and lateral views) when possible, followed by a 3, 6, and 12 monthly scan followed biennially thereafter.

Statistical analysis

Data were collected from each of the five departments using a standardized data collection sheet. Data were entered into a Microsoft Excel (2011) and statistical analysis was performed using SPSS 22 for Mac (SPSS Inc,

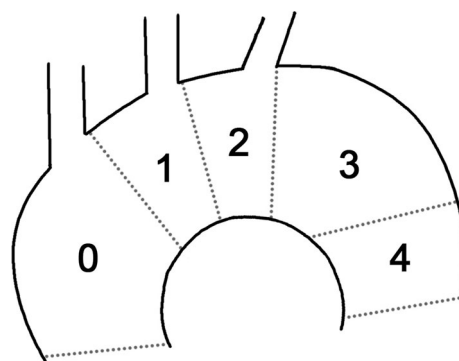


Fig. 1 Anatomical landing zones of the aortic arch as proposed by Ishimaru

Chicago, IL, USA). Kaplan–Meier methodology was used for survival, and freedom from intervention analysis and the log rank test was used for univariate group comparison for categorical variables. Continuous variables were entered individually into a Cox proportional hazard model to calculate hazard ratio (HR) and 95 % confidence interval (CI). Statistical significance was set at $P < 0.05$.

Results

During the study period, there were 88 patients with a median (range) age of 35 (15–87) years included, of which 63 (71.6 %) were males. The median injury severity score (interquartile range) was 38 (33–45). The mechanism of aortic injury was blunt trauma in all cases. The most prevalent aortic injury was grade IV 50 (56.8 %), followed by grade II 23 (26.1 %), grade III 10 (11.4 %), and grade I 2 (2.3 %). The majority of the patient injuries (76 patients, 86.4 %) were MVC-related and the rest were due to falls. There were 11 (12.5 %) patients that were transferred from other cities or hospitals and 72 (81.8 %) patients were treated within the first 24 h from the injury. Patient demographics and operative details are summarized in Table 1.

The in-hospital or 30 days mortality was 11/88 patients (12.5 %). Of these deaths, three were aortic-related mortality and involved aortic rupture post TEVAR. There was one conversion to open repair on the same operative day due ongoing uncontrolled bleeding. There were 14 (16.1 %) 30-day procedure-related complications (Table 2).

Late survival

The 1, 5, and 10 years (standard error, %) actuarial survival for the entire group was 86 (3.6), 81 (4.6), and 77 (5.9), respectively (Fig. 2). Six late deaths occurred during the follow-up period, of which two were due to cancer, two were multi-organ failures and one was due to a traumatic head injury and one was of unknown causes. After excluding early mortality, a 10-year increase in age was the only predictor of reduced late survival, (HR 4.79; 95 % CI 1.28–17.87; $P < 0.02$) when adjusted for gender, ISS, aortic grade, landing zone, coverage of the left subclavian or revascularisation and stent graft type, length or diameter. These potential confounders were not significant predictors of late survival.

Follow-up

The median (range) follow-up period of the 77 survivors was 76.3 (0.3–164.6) months. Of the surviving patients, 9 (11.7 %) patients were lost to follow up, three of whom

Table 1 Demographics of 88 traumatic thoracic aortic injury patients treated with TEVAR

	N (%)
Age, median (range)	35 (16–86)
Males	63 (71.6)
Region/hospital	
Auckland	39 (44.3)
Christchurch	12 (13.6)
Dunedin	1 (1.1)
Waikato	24 (28.4)
Wellington	11 (12.5)
Traumatic aortic injury grade ^a	
I Intimal tear	2 (2.3)
II Intramural hematoma	23 (26.1)
III Pseudoaneurysm	10 (11.4)
IV Rupture	50 (56.8)
Injury severity score ^b (IQR)	38 (33–45)
Mechanism of injury	
MVA related	76 (86.4)
Falls	12 (13.8)
Landing zone	
0	1 (1.1)
1	2 (2.3)
2	51 (58.0)
3	33 (37.5)
4	1 (1.1)
SCA covered	
Yes	56 (63.6)
SCA revascularized	8 (9.1)
Cause of pathology Blunt injury	88 (100)
Stent graft	
Type ^b	
Cook	69 (78.4)
Medtronic	14 (15.9)
Gore	4 (4.5)
Mean diameter in mm (SD) ^c	28.2 (4.4)
Mean length in mm (SD) ^b	119.6 (29.8)
Mean length stented in mm (SD) ^b	119.6 (30.0)
Aortic arch anomaly	
Arch left vertebral artery origin	3 (3.4)
Bovine arch	1 (1.1)
Number of prosthesis	
Single stent graft	81 (93.1)
>1	6 (6.8)
Time from injury to TEVAR (days)	
<24 h	72 (81.8)
24–48 h	13 (14.8)
>36 h	3 (3.4)
Median length of hospital stay ^d (range)	16 (2–365)
Lost to follow up ^d	9 (11.5)

IQR interquartile range, SCA subclavian artery, SD standard deviation

^a 3 Details missing

^b 1 Patient missing

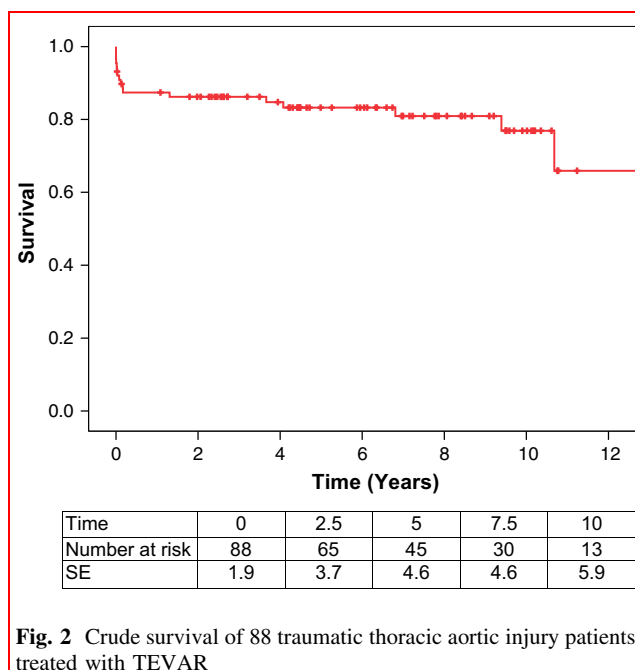
^c 4 Details missing

^d Excluding in-hospital mortality $n = 10$

Table 2 Procedural-related 30-day complications post TEVAR

Age	Sex	Stent graft	Complication	Treatment	Notes/outcomes
Endoleak					
73	F	Cook 34 × 152	Endoleak type 1	Resolved on post-op CT	Died after 2 months
55	F	Cook 26 × 77	Endoleak type 1b	Resolved	Alive
21	F	Cook 26 × 77	Endoleak type 1a	Carotid to carotid bypass and extension the next day	Resolved on 9 months CT
19	M	Cook 26 × 134	Endoleak type 2 From covered SCA	Conservative	Resolved on 30 days CT
17	F	Cook 22 × 80	Endoleak type 4	Conservative	Resolved
Technical					
21	M	Medtronic 32 × 115	Inadvertent occlusion of L aberrant vertebral artery	Carotid to SCA bypass	Alive
16	F	Medtronic 28 × 161	Partial coverage of left carotid	Conservative	Well and no sequelae
21	M	Cook 26 × 134	Vein graft thrombosis	Redo of carotid–carotid vein bypass	Alive
Neurological					
20	M	Cook 26 × 140	Posterior hemorrhage (small)	Conservative (patient asymptomatic)	SCA covered and not revascularized
21	M	Medtronic 28 × 157	Spinal cord ischemia	Conservative	Recovered
15	M	Gore 26 × 100	Posterior circulation stroke	Pre-stent carotid SCA transposition	Recovered
Access					
83	F	Medtronic 36 × 150	Femoral thrombosis	Surgical revision and vein patch	Died day 1 post op-head injuries
76	F	Cook 32 × 124	Femoral thrombosis	Surgical revision	Alive
42	M	Cook 30 × 80	Percutaneous infection	Drainage and washout	Alive
Other					
19	M	Cook 26 × 134	Aortic chest pain oversized stent	Conservative	Resolved

SCA subclavian artery

**Fig. 2** Crude survival of 88 traumatic thoracic aortic injury patients treated with TEVAR

had emigrated overseas. Median (range) age of this group was 25 (17–55) and eight were males. The summary of our results compared to recent similarly designed outcome studies reporting on long-term follow-up of TEVAR after TTAI is shown in Table 3.

Re-interventions

There were four late re-interventions observed during the follow-up period. Two patients developed late stent graft complications and required aortic re-intervention. The first was a 19-year-old man who was diagnosed with aortic transection at the level of isthmus with a landing zone 1 necessitating a carotid–carotid bypass. The transection was covered with a 26 mm × 134 mm Cook stent graft. He presented 13 months later with symptoms of cardiac failure, renal impairment and pulseless feet. CTA revealed a patent stent and a transesophageal echocardiogram (TEE) showed a “pseudocoarctation” in the native aorta distal to the stent. He was treated with relining and a stent graft

Table 3 Summary of current literature on late outcomes following TEVAR for traumatic aortic injury

Study author	Publish year	Study period	Country	No. of patients	Median age (range)	Sex-males (%)	30-day/inpatient mortality (%)	Survival	Late TEVAR re-intervention	Median (range) follow-up period ^b	Lost to follow up (%)
Sincos [27]	2011	Apr'01–Mar'09	Brazil	21	38.1 ^a	NR	4 (19)	81 % at 33.3 months	0	29.8 ^a (28)	2 (11.8)
Patel [28]	2011	'02–Feb'10	USA	19	49.3 (18.3)	16 (84.2)	0	NR	1	NR	NR
Lioupis [29]	2012	Jan'02–Feb'11	Canada	24	39.2 ^a (18.6)	17 (71.0)	0	88.7 % at 5 years	1	NR	5 (22.7)
Martinelli [30]	2013	'01–'11	Italy	27	NR (20–69)	22 (81.5)	2 (7.4)	79.1 % at 5 years	4	66.9 (6–110)	3 (11.1)
Marone [31]	2013	Feb'03–Dec '10	Italy	28	38.9 (20–67)	22 (78.6)	2 (7.1)	NR	0	37.3 ^a (17.5)	2 (7.1)
Piffaretti [32]	2013	Nov'00–Aug '12	Italy	46	39 ^a (17–92)	35 (76.1)	3 (6.5)	NR	0	66 ^a (±46)	0
Canaud [33]	2014	Jan'01–Jan'14	France	17	45.8 (18–78)	13 (76.5)	0	100 % at 10 years	0	11.6 (10.1–13.1)	0
Spiliotopoulos [34]	2014	Feb'02–Jul'13	Greece	76	39.7 ^a (17–85)	68 (89.4)	9 (9.2)	88 % at 10 years	0	38 months (25–66)	6 (8)
Azzazadeh [35]	2014	Sep'05–Jul'12	USA	82	39.5 ^a (20)	57 (70.0)	4 (5)	82 % at 5 years	2	2.3 (0–7)	69 (18)
Steuer [36]	2015	Jan'01–Dec '10	Sweden and Switzerland	74	41 (16–89)	62 (83.8)	7 (9)	81 % at 5 years	7	NR	5 (7.4)
Current	2015	Dec'01–Dec'13	NZ	88	35 (15–87)	63 (71.6)	11 (12.5)	81 % at 5 years and 77 % at 10 years	2	6.0 (0.2–13.6)	9 (11.5)

NR not reported, SD standard deviation

^a Presented as mean (standard deviation)

^b Follow-up period in years unless otherwise stated

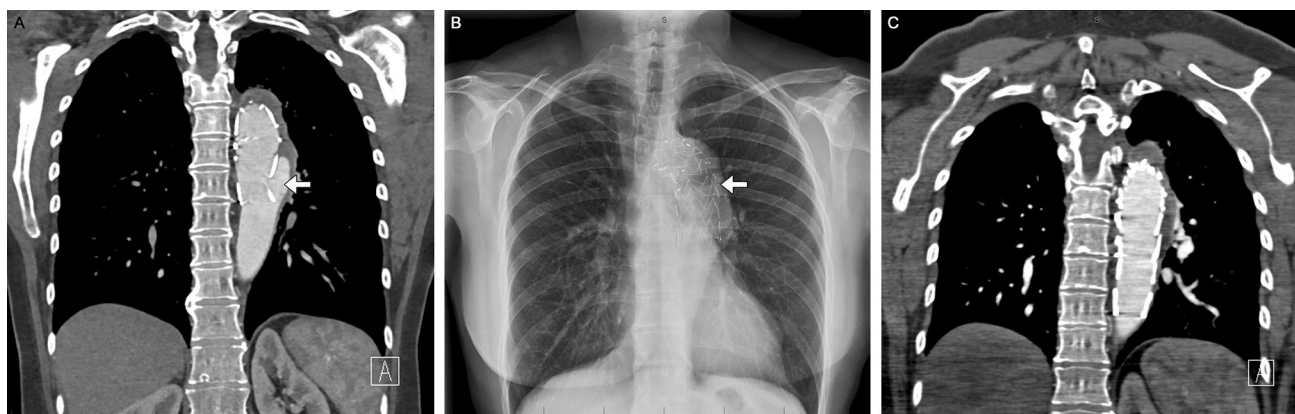


Fig. 3 Late type 1b endoleak developed >4 years seen on CTA (a) and chest X-ray (b) and resolution after stent graft extension (c)

extension. He remains well and free of stent complications. The second was a 47-year-old woman who was diagnosed with an aortic transection following an MVC. She was treated 6-h post-presentation with a 30 mm x 100 mm Valiant Medtronic stent graft. During surveillance, she developed a type 1b endoleak 5.5 years following the injury. Features of the endoleak were seen on X-ray and confirmed by CTA. She underwent relining of the stent graft and distal extension. Post-procedural CT showed resolution of endoleak (Fig. 3). Two patients required late revascularization of the covered left subclavian artery 12 months following the TEVAR due to symptoms. The first was a 19-year-old man who developed disabling arm claudication and the other patient was a 71-year-old man for a subclavian-steal syndrome causing compromise of a previous coronary bypass graft, which appeared occluded at the index TEVAR procedure.

Discussion

Traumatic injuries of the thoracic aorta remain a management challenge and are associated with a high mortality despite the introduction of TEVAR. This technology has brought specific concerns associated with long-term exposure to imaging surveillance, treatment of young patients with relatively normal aortas with a paucity of stent graft durability data and a relatively high proportion of patients lost to clinical and radiological follow-up.

In our series, late TEVAR was a durable procedure and stent graft complications occurred in two patients necessitating re-intervention. Both procedures were detected primarily by other modalities (chest X-ray and TEE) rather than CTA. Our surveillance program included chest X-ray as well as CTA and, similar to other institutions, patients several years post TEVAR, had solely multi-view chest X-rays rather CTA. We have not observed any late

complications with this strategy. A multi-view chest X-rays could potentially be a safe option to detect late complications in patients who had satisfactory initial imaging scans as stent graft collapse and migration could be potentially detected. This will require further confirmation in future studies. Acute graft collapse [14] or prosthetic stent infection or fistulization [15] remains rare complications and patients often present acutely. Such complications might not be apparent with surveillance.

There are ample published case reports and case series of late TEVAR interventions and graft complications in trauma patients. However, such reports might suffer from publication bias and the prevalence of late aortic and non-aortic re-interventions due to graft complications might be misrepresented. In addition, stent grafts have improved and continue to do so; hence historical complications might not be relevant with newer stent grafts. TTAI are the least common indication for TEVAR in many institutes [16]. This is also evident by the fact that all published series have less than 100 patients. A comprehensive review in 2010 of thoracic stent graft collapse revealed 60 cases of which 65 % were diagnosed in patients with traumatic aortic injuries and the median time for collapse was 15 days from the procedure [17]. 10-year follow-up data of TEVAR for traumatic thoracic aortic injuries are emerging, but the true incidence of late graft complications might not be apparent until another a decade or two, when younger patients in their teenage or twenties reach the age where the thoracic aortic diameter starts to expand.

Management of the left subclavian artery (LSCA) is also a controversial topic in thoracic dissection and aneurysmal diseases. In the trauma setting, there is general acceptance that covering the LSCA to achieve adequate proximal sealing zone and performing revascularization in patients with dominant left vertebral artery is appropriate [6]. In our series, 57 (65.5 %) of the patients required coverage of the LSCA and of these, 8 patients had perioperative

revascularization. During follow-up, two patients required LSCA revascularization 1 year following the procedure for symptoms (one for disabling claudication and the second for steal syndrome). In a review by McBride et al., the impact of subclavian artery coverage was assessed by interviewing patients and comparing the influence of LSCA coverage with those who had perioperative revascularization. A statistical significance was not found between groups and two patients required late LSCA revascularization [18].

Surveillance strategies and the radiological modality to be used post TEVAR for aortic injury is another controversial topic [19]. There is acceptance that re-intervention rates following TEVAR for thoracic aortic injuries are lower than other pathologies [16].

Less invasive imaging modalities such as MRA have recently been proposed by the European Society of Cardiology to be the most appropriate modality for TEVAR surveillance in those with a MRA compatible stent graft [20]. MRA would eliminate the risk of radiation and risk of cumulative iodinated contrast on renal function. Multi-view chest X-ray could potentially reduce the cumulative radiation risk and contrast exposure introduced by CTA.

Follow-up rates following endovascular aortic repair have not been optimal and in one study, it was neither linked to socioeconomic status nor distance lived away from the institution [21]. We observed a slightly higher number of patients lost to follow up than other recent studies summarized in Table 3. However, a recent systematic review suggested that loss to follow up at 1 year was 26.5 % [22]. From our data, one possibility might be due to the fact that this young group might be more likely to relocate to other cities/countries. In our study, 11 (14.3 %) patients have relocated to different cities within NZ and 3 (3.9 %) patients have emigrated overseas. Although some patients might have received imaging in the community, details of the TEVAR scans were not always relayed back to the treating corresponding vascular surgery departments. A recent report from Houston, Texas revealed that TEVAR patients were more likely to be uninsured than the general vascular population treated at their hospitals [23]. In NZ, traumatic aortic injuries as well as all other accidents are covered by the Accident Compensation Corporation where all associated costs and services related to the accident are covered.

This study is not without limitations. Demographic data were collected from the NZTAS which is a thoracic stent database and does not capture specific injury scores assigned to trauma patients and presently there is no national trauma registry in NZ. Trauma-specific reporting guidelines have been suggested [24, 25] as the Society for Vascular Surgery documents for reporting standards for TEVAR do not include specific trauma related entries [26].

Although this was one of the largest series reporting long-term outcomes, the number of patients and events occurring remains too small to allow powerful statistical analysis and conclusions.

Conclusions

This multicenter study suggests that mortality due to blunt TTAI is still high but comparable with the published literature. TEVAR is a durable treatment and stent graft complications were uncommon but when it occurred, re-intervention was required. Further long-term information and more efforts to improve follow-up are required.

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