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Outcomes of Endovascular Repair of Acute Thoracic Aortic Injury: Interrogation of the New Zealand Thoracic Aortic Stent Database (NZ TAS)

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Abstract *Objectives:* Report the New Zealand national experience of endovascular repair of acute traumatic thoracic aortic injuries (TTAIs).
Design: Retrospective analysis of the New Zealand thoracic aortic stent database between December 2001 and December 2007.
Materials and methods: Of the 134 patients on the database, 27 patients (20%) underwent endovascular repair of TTAI. Data collected included age, sex, cause of injury, details of the procedure, complications and mortality.
Results: Most patients were young, median age 20 (15—78), male ($n = 19$, 70%), and involved in motor vehicle accidents ($n = 23$, 85%). Median length of aorta stented was 117 mm (77—200 mm). Great vessel origins were covered intentionally in 23 (85%) patients, four (17%) requiring a hybrid procedure. Average procedure time was 98.3 min (35—180). Primary technical success was 96%, secondary technical success 100%. Endoleaks were observed in four (15%) patients, one requiring a second endovascular procedure. There were no conversions to open surgery. Procedure-related complications occurred in four (15%) patients. No patient developed cord injury. All cause mortality at 30 days is one (4%) and at discharge is two (7%) due to associated poly-trauma.
Conclusion: Our results add further evidence of the safety of endovascular repair of thoracic aortic injury and compare favourably with those of other centres.

Introduction

Traumatic injury to the thoracic aorta (TTAI) is a condition with very high mortality. At the scene of the accident, 85% of patients die from exsanguination.[1] Of the 15% that survive and make it to hospital, 33% die within the first 6 h[2] and most die within a few days from rupture.[1] After head

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injury, TTAI is the most common cause of death from blunt injury.[3]

Open surgical repair has been the traditional method of treating TTAI with thoracotomy and interposition of an aortic conduit. This carries significant risk with mortality as high as 30%.[4] In addition, there is significant morbidity such as cord injury which is seen in up to 19% of patients after surgical repair.[4] With the introduction of endovascular techniques to repair the aorta, there has been a shift in the management of these patients away from open surgery toward aggressive management of blood pressure and endovascular repair of the aorta.[5]

In New Zealand, endovascular repair of the thoracic aorta has been recorded on a national database since 2001. The aim of this study was to analyse the data available to date and compare the results in New Zealand with other centres from around the world.

Materials and methods

The New Zealand thoracic aorta stent database (NZ TAS) began data collection in December 2001. It involves collaboration between the six centres across New Zealand carrying out endovascular repair of the thoracic aorta. The centres are Auckland Hospital, Christchurch Hospital, Dunedin Hospital, Greenlane Hospital in Auckland, Waikato Hospital in Hamilton, and Wellington Hospital. A standardised form is filled in for each patient at the time of implantation. Completed forms are sent to Christchurch Hospital where the data are collated and added to the central electronic database. In addition to this, a paper copy of all entries is stored for back up. The database is administered by The Vascular Society of New Zealand. Ongoing funding is from an agreed fixed sum of money contributed by the company supplying each stent graft on a case-by-case basis. None of the supplier companies contributed to the study itself.

The NZ TAS database was retrospectively analysed between December 2001 and December 2007. This has been approved by the ethical committee of our institution. Of the 134 patients on the database, 27 patients (20%) had TTAI treated acutely (within 14 days of injury) by endovascular repair. Outcome measures included primary technical success (exclusion of the injured segment of aorta during the initial procedure), secondary technical success (exclusion of the injured segment of aorta required further intervention after the initial procedure), graft-related complications, procedure-related complications/mortality and post-procedure complications/all cause mortality up to 30 days after the procedure.

Results

Nineteen patients (70%) were male and eight patients (30%) female. Mean age of the patients was 34 years, median age 20 years (15—78). TTAI was sustained as a result of motor vehicle accident (MVA) in 23 patients (85%). Of the remaining four patients, three (11%) had fallen from a height and one (4%) had been crushed. Surgery was not felt to be survivable in 12 (44%) patients due to the severity of their co-existing poly-trauma. The details of the co-existing injuries are not available from the database.

Patients were admitted to one of the six participating centres for treatment (Table 1). Diagnosis was made using computed tomography (CT) with multiplanar reconstructions. These images were used to plan the procedure and select the correct size of stent graft to deploy. In addition, imaging of the neck and cerebral circulation was performed in order to determine if an extra-anatomical bypass would be needed as part of the procedure. In all cases, the stent graft was deployed with the patient under general anaesthetic. Most procedures were carried out as combined cases by an interventional radiologist or cardiologist and a vascular or cardiothoracic surgeon in the interventional radiology suite. The time between the traumatic injury and endovascular repair of the aorta ranged from 0 to 4 days, mean 12 h.

Vascular access was gained through a common femoral arteriotomy in all but one patient (96%), the other patient requiring exposure of the right common iliac artery by an extra-peritoneal approach due to the small size (5 mm) of the common femoral arteries. Right brachial artery puncture was also carried out in 16 patients (59%) to allow imaging of the left subclavian artery origin thereby aiding accurate placement of the proximal graft.

Standard technique was used to deploy the stent grafts following manufacturer guidelines. Graft oversizing was not formally recorded on the database but had been noted for 14 patients (52%). The mean oversizing for the stents used in these 14 cases was calculated at 26.3% in these stent grafts (median 26.5%, range 9—50%). Twenty-two patients (82%) received Cook Zenith stents (William A. Cook Australia Pty Ltd, Brisbane, Australia; Obex Medical Ltd, Auckland, New Zealand) and five patients (18%) received Medtronic Talent stents (Medtronic Australasia Pty Ltd, Auckland, New Zealand). The mean length of aorta covered by stent graft was 110 mm, median 117 mm (77—200). Most patients (89%) required deployment of only one stent but two patients (8%) required two stents and one patient (4%) required three stents. Average procedure time was 98 min, median 94 min (35—180).

In order to obtain an adequate seal above the site of aortic injury, great vessel origins were covered intentionally in 23 (85%) patients (Table 2). A planned extra-anatomic bypass procedure was carried out in three (17%) of these patients. In one patient, pre-operative evaluation of the cerebral circulation led to a right common carotid to left subclavian bypass prior to the endoluminal procedure. In one patient, the trauma involved the transverse aorta to the level of the origin of the innominate artery, such that a de-branching procedure with moving of the origins more proximally was performed prior to the endoluminal

Table 1 Number of patients with TTAI treated in the different centres contributing to the NZ TAS database

Centre	Number of patients
Auckland Hospital, Auckland	10 (37%)
Christchurch Hospital, Christchurch	4 (15%)
Dunedin Hospital, Dunedin	0
Greenlane Hospital, Auckland	5 (18%)
Waikato Hospital, Hamilton	7 (26%)
Wellington Hospital, Wellington	1 (4%)

Table 2 Great vessel origins intentionally covered by the stent graft

Great vessel origin covered	Number of patients
None	4 (15%)
Left subclavian artery only	18 (66%)
Left subclavian and left common carotid arteries	3 (11%)
Left subclavian and aberrant left vertebral arteries	1 (4%)
Aberrant right subclavian artery	1 (4%)

procedure. Right to left common carotid bypass was performed in one patient. Two patients had anatomical variations in which the origins of an aberrant left vertebral and aberrant right subclavian artery were intentionally covered without consequence.

Primary technical success was achieved in 26 patients (96%). Secondary technical success was 100%. Endoleaks were observed in four patients (15%). Three of these had a proximal type 1 endoleak and one patient had a type 2 endoleak from the left subclavian artery that had been covered during the primary procedure. Of the patients with type 1 endoleaks, one underwent successful exclusion the day after the primary procedure, one resolved spontaneously and the other was discharged without further treatment (no data are available to know if this endoleak persists). Although not formally recorded on the database, graft oversizing data were available in two of these patients and varied from 13 to 15%. The type 2 endoleak resolved spontaneously without the need for further intervention.

There were no complications related to the graft itself however, mal-deployment of the top end of the graft occurred in one patient. This patient had a left vertebral artery origin between the left common carotid and the left subclavian arteries. The intention was to cover the left subclavian but not the left vertebral artery. Due to the mal-deployment, the stent graft covered the left vertebral artery origin and partially covered the left common carotid artery origin. A right to left common carotid extra-anatomical bypass was performed. No revascularisation of the vertebral artery was performed without adverse consequence.

Procedure-related complications were observed in four patients (15%). Common femoral artery thrombosis occurred in one patient requiring immediate thrombectomy. In the second patient there was inadvertent occlusion of the left vertebral artery (arch origin) and partial occlusion of the left common carotid artery requiring a right to left common carotid artery bypass graft. In the third patient, there was no flow within the conduit of a right to left common carotid artery bypass conduit requiring re-exploration to restore patency. The fourth patient had a posterior fossa haemorrhage prior to stent graft implantation but was noted to have developed a new low density area in the left posterior fossa on a follow up scan that was not present on the pre-operative scan. This was almost certainly as a result of occlusion of the left vertebral artery but was asymptomatic. No deaths occurred during the endovascular procedure.

Other complications were observed in nine patients (33%) and related to their poly-trauma. These included pulmonary contusions with subsequent collapse/consolidation, chest infection, atrial fibrillation, confusion, oliguria, intra-abdominal haemorrhage and bile leak. No patients developed paraplegia. Mean length of hospital stay after the procedure was 24 days, median 23 days (3—42).

One patient died the day after stent graft implantation from intra-abdominal haemorrhage due to multiple visceral injuries related to their poly-trauma. All cause mortality at 30 days was therefore one (4%). A second patient died 59 days after the procedure from sepsis and complications related to head injury. All cause mortality at discharge is therefore 7%. No patient died from the thoracic aortic injury as a result of the endovascular repair of the injured aorta.

Discussion

The population of patients who sustained TTAI in our group is interesting when compared to the population of New Zealand as a whole. There is a predominance of young patients with median age of 20 years. Male patients represent 70% of our population but in the 2006 population census (www.stats.govt.nz) the estimate of male/female ratio in New Zealand was 0.95. In addition, most patients sustained their TTAI in a motor vehicle accident. The young age of the patients presents a number of problems. The aortic diameter is often smaller in these patients such that correct graft sizing may be difficult. Most grafts are designed to treat aneurysms of the thoracic aorta in which the diameters are greater. Oversizing may increase the risk of endoleak with wrinkles in the fabric. In our series, the degree of oversizing in those patients with type 1 endoleaks was 13—15%, well within the recommended limits of 10—15%. In young patients, the stent graft is likely to remain in situ for many years. The long-term durability of these grafts is not known at present and may pose problems in the future. In addition, there may be problems with long-term monitoring the graft. This usually requires annual plain films to look for graft migration and strut failure. The patients may not comply with such monitoring and may be lost to follow up. In addition, it is not clear what the implications of graft migration or strut failure in these patients are.

Our results compare favourably with the results from other case series of similar size (Table 3),[6—17] especially when considering the relatively small number of patients treated by each of the participating centres in our study over the last 6 years. The comparison studies have a total of 256 patients treated for TTAI. Overall technical success is 99.2% ($n = 254$), incidence of endoleak 6.6% ($n = 17$), paraplegia 1.6% ($n = 4$), and mortality 8.6% ($n = 22$). One of the difficulties comparing these results is that most of the authors do not distinguish between primary and secondary technical success. This is an important measure of outcome because of the obvious burden on resources and the patient of having to have multiple procedures to obtain successful exclusion of the aneurysm. Our 30-day mortality is also very low particularly when considering the small numbers of patients treated at each individual centre.

Table 3 Summary of results of case series with more than 10 patients in the last 5 years including our results for comparison

Author	Year	Number	Success (%)	Endoleak	Cord injury	Mortality
NZ TAS	2008	27	96	4 (15%)	0	1 (4%)
Neschis DG	2007	20	100	3 (15.8%)	0	4 (20%)
Orend KH	2007	34	100	4 (11.8%)	0	3 (8.8%)
Hoornweg LL	2006	28	100	1 (3.6%)	0	4 (14.3%)
Marcheix B	2006	33	100	3 (9.1%)	1 (3%)	0
Pratesi C	2006	11	100	0	0	1 (9.1%)
Tehrani HY	2006	30	100	0	0	2 (6.6%)
Peterson BG	2005	11	100	0	0	0
Leurs LJ	2004	50	96	0	3 (6%)	3 (6%)
Dunham MB	2004	16	100	0	0	1 (6.3%)
Karmy-Jones	2003	11	100	2 (18.2%)	0	3 (27.3%)
Lachat M	2002	12	100	1 (8.3%)	0	1 (8%)

Endovascular repair is attractive in this group of patients because the physiological stress on the patient is less. The technique has been shown to have lower risk of death and paraplegia and stroke when compared with open surgery.[18–24] Low rates of paraplegia are likely to be due to the short length of aorta stented. The threshold for increased risk of paraplegia appears to be 205 mm.[25] None of the patients in this series had stents greater than 200 mm. Another explanation is that the aorta is not cross-clamped and there is no prolonged hypotension avoiding long ischaemic time.[26]

In our series, most patients were treated within the first 12 h following injury. Timing of endovascular repair of TTAI is a matter of debate. For open repair there is evidence that delaying surgery until associated injuries have been treated whilst maintaining aggressive blood pressure management and close monitoring with imaging is associated with better outcomes.[27,28] The timing of endovascular repair appears to be less critical. Early treatment offers advantages such as the ability to manage associated injuries and stabilise the patient.[29] Delayed endovascular repair, however, allows more time to treat injuries that may cause graft infection as well as coagulopathies.[29]

One of the limitations of our study is absence of data regarding the number of patients treated with open surgery during the time of our study and their outcome. A study by Baguley et al. gives some insight.[20] In their study, 29 patients were treated at Greenlane Hospital in Auckland between 1995 and 2004. Of these patients, 30-day mortality was 10%. In addition, complications included hemiplegia ($n = 1$) and recurrent laryngeal nerve palsy ($n = 5$). One of their patients underwent endovascular repair without complication. This is the closest comparison group to our study and provides further evidence of the safety of endovascular compared to surgery.

The analysis of the NZ TAS database has highlighted some weaknesses in the data collected by the NZ TAS database. This includes lack of data regarding co-existing injuries in the trauma patients and diameter of the stent graft deployed (although the length was recorded). Both these are to be addressed by simple modification of the data collection forms. In addition to this, there are no data regarding follow up beyond 30 days. Phase 2 of the database will be to develop a method of collecting this information.

Because of the multiple centres involved in the study, we are dependent on the other centres providing information on all the patients treated with endovascular repair. One way to ensure all the patients who have had endovascular repair of their thoracic aorta are entered onto the NZ TAS database is to audit the manufacturer's records of stent grafts sold/deployed against the patients entered into the NZ TAS database. Such an audit has been carried out in Christchurch and Auckland hospitals demonstrating 100% concordance. At the current time, permission is being sought from the remaining participating centres to complete this audit.

Endovascular repair is well established in many major trauma centres and there has been a shift in management away from surgery toward endovascular repair.[5] There are no prospective randomised control trials comparing endovascular with open repair of TTAI. It is unlikely that such a trial will occur because the current data demonstrate lower major adverse outcomes (such as mortality/cord injury/stroke) in the endovascular patients compared with open surgical repair.[24] As a result, few clinicians have clinical equipoise.[30] The exact role of endovascular repair remains to be determined but may be offered to all patients, reserved for those patients who cannot be heparinised, or used as a temporary fix with open surgery carried out when the patients have fully recovered.[24] This could resolve the issue of long-term durability. In the absence of level 1 evidence it is important that complete and accurate data are kept so that decisions can be evidence based. The NZ TAS registry makes a useful contribution to this data set.

Conflict of interest

No conflict of interest to declare.

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