Thoracic Endovascular Aortic Repair (TEVAR) in traumatic high-velocity blunt injury to thoracic aorta

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INTRODUCTION
Blunt trauma to the thoracic aorta is rare but has been implicated as the second most common cause of death in trauma patients, after intracranial haemorrhage. It accounts for <1% of adult admission to level I trauma centres in the USA. In the whole of Great Britain, for the year 2003, only 21 cases of traumatic thoracic aortic injury were operated on.

Blunt trauma to the thoracic aorta occurs typically in a high-velocity or high-impact motor vehicle accident when there is a combination of sudden deceleration and shearing at the relatively immobile aortic isthmus; the area distal to the left subclavian artery and proximal to the third inter-costal artery, representing the junction between the relatively mobile aortic arch and the fixed descending aorta. Hence, the isthmus is the most common location for rupture (50% to 70%), followed by the ascending aorta or aortic arch (18%) and the distal thoracic aorta (14%).

Motor vehicle accidents (MVA) are a major cause of mortality and morbidity in the country with a total of 28,269 road accident injuries in 2010 (6872 deaths, 7781 major injuries and 13616 minor injuries). In 2010, there were 24.2 road fatalities per 100,000 inhabitants and 3.4 road fatalities per 100,000 motor vehicles. Thoracic aortic injury often goes undiagnosed unless there is a high degree of suspicion by health care providers.

CASE SERIES
We report a series of 5 patients with traumatic blunt injury to the thoracic aorta, secondary to high-velocity MVA, which have been managed successfully in the Vascular Unit, HKL from 2008-2011. They are all male, ranging from 17-34 years old. Their injuries were mainly thoracic aortic pseudoaneurysms secondary to tears or dissection of the descending thoracic aorta (Stanford B).

All patients underwent a Thoracic Endovascular Aortic Repair (TEVAR) using a Medtronic Valiant delivery device and thoracic stent graft. This is performed via an arterial cutdown, commonly femoral, to allow for the delivery device. A guidewire and catheter is negotiated into the ascending aorta and the guidewire is kept in place throughout the procedure. The follow up period is up to 5 years currently, success rate is 100% and there are no 30 day mortalities thus far. One patient had his left subclavian artery (LSA) covered and was found to have reduced left radial and ulnar pulses post-operatively. However, his latest follow up did not reveal any ischaemic changes of his left hand. None had paraplegia, spinal ischaemia or cerebrovascular events. No endoleaks were observed as yet in all patients in the follow-up period.

Case 1:
A 20 year old male was involved in an MVA. His Glasgow Coma Scale score (GCS) on arrival to a general hospital was 10/15 and BP labile. He underwent a splenectomy for multiple splenic laceration on day 1 post-trauma. A CT Thorax/abdomen and pelvis showed mediastinal haemotoma with bilateral haemothorax, a focal dissection at 2cm distal to left subclavian artery with re-entry 2cm from entry site, multiple spleen laceration, with left perinephric haemotoma. CT angiogram of the thorax revealed a pseudoaneurysm proximal to descending thoracic aorta, 2.8cm distal to origin of left subclavian artery, pointing posterior-medially. He was then transferred from Hospital Kuala Lumpur (HKL) on day 2 post-trauma. Apart from a lacerated spleen and thoracic aortic injury, his other injuries included brain contusion, bilateral lung haemothorax, multiple long bone fractures and left conductive hearing loss. His injury severity score (ISS) was 41.

At HKL, he underwent TEVAR on day 3 post-trauma, with access for the delivery device via his left CFA (common femoral artery). A covered Valiant stent graft was used. Unfortunately his LSA was covered by the stent and he was found to have reduced radial and ulnar pulses post-operatively. He was nursed in ICU for 4 days before being discharged on day 17 post-trauma. Nevertheless, upon follow-up so far, there has been no further ischaemic change of his left hand.

Case 2:
An 18 year old male was transferred to HKL from a state hospital on 12 September 2009, 4 days post trauma, for further management of his post-traumatic pseudoaneurysm of descending thoracic aorta. He sustained an MVA (motorbike vs car) and complained of abdomen and chest pains, associated with difficulty breathing. A chest X-ray showed a widened mediastinum. A CT thorax, abdomen and pelvis suggested a pseudoaneurysm at the descending thoracic aorta, distal to the origin of the LSA, which was confirmed on CT angiogram on day 4 post-trauma. His other

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injuries included a grade 1 liver injury, bilateral haemothorax and a stable L2 fracture. His ISS was 17.

At HKL, he underwent TEVAR. Access for the delivery device was via patient’s right EIA (external iliac artery) as his femoral artery was small. He recovered well and has no complications to date.

Case 3:
A 24 year old male presented to HKL after an MVA (car vs car), with GCS 10/15 on arrival. He was brought to emergency laparotomy due to haemodynamic instability and splenectomy was carried out for splenic laceration. A CT of the brain, thorax, abdomen and pelvis were carried out on day 3 post-trauma and this showed a pseudoaneurysm at the descending thoracic aorta, distal to the LSA. His other injuries included right temporal intraparenchymal haemorrhage and contusion of bi-frontal lobes, 3rd to 5th rib fractures with left haemothorax, lower dentoalveolar fracture, and splenic laceration with splenectomy on day 2 post-trauma. His ISS was 41.

The patient underwent TEVAR on day 9 post-trauma. The access was via his common iliac artery, using a retroperitoneal approach. As per the previous two cases, a covered Valiant stent graft was inserted.

Case 4:
A 17 year old male was transferred from another state hospital, nearly 3 weeks post-trauma. An alleged MVA occurred where GCS on arrival was 7/15. He sustained polytrauma with right temporobasal extradural haemorrhage and contusion of bi-frontal lobes, 3rd to 5th rib fractures with left haemothorax, lower dentoalveolar fracture, and splenic laceration on day 3 post-trauma. His ISS was 32. A right temporal craniotomy and clot removal was carried out, followed by open reduction and internal fixation of his left femur. Following this, his conscious level improved and his GCS returned to normal (15/15). A CT abdomen and pelvis on day 3 post-trauma showed a focal bulge on the anterior aspect of proximal descending aorta (1.9x1.5x3.5cm). A CT angiogram confirmed an aortic pseudoaneurysm at the isthmus. However, the patient was asymptomatic of chest pain or difficulty breathing and remained stable. He was transferred to HKL once he was deemed free from other injuries.

At HKL, he underwent TEVAR on day 24 post-trauma and access was via left EIA, as patient has a small left femoral artery.

Case 5:
A 34 year old male, involved in a high-velocity MVA on 4 February 2011, was found to have hilar hazing and haemothorax on Chest X-ray. CT angiogram confirmed a dissection of the descending thoracic aorta. Otherwise, there were no other injuries. His ISS was 5.

TEVAR was carried out on day 3 post-trauma and access was via his right CFA.

DISCUSSION
The first comprehensive review of thoracic aortic injury was in 1958 by Parmley et al, showing an out of hospital mortality of 86.2% of the 275 cases analysed. Regrettably, the mortality has not reduced much in 4 decades despite considerable advances in pre-hospital management. In 1994 Williams et al showed, mortality is 75% from aortic injury secondary to blunt trauma at the time of insult as a result of either aortic transection or acute rupture. The timing of a transected thoracic aorta progressing naturally to subsequent rupture is unpredictable. The presiding anxiety of such a consequence happening is founded, as out of the 25% of cases that arrive to the hospital on time, their prognosis remain poor, with nearly 30% dying within 6 hrs, and 50% dying within the first 24 hrs.

Blunt thoracic aortic injury does not occur alone, with Galli et al recording only three cases out of 42 patients in their series with sole thoracic aortic injury. Much more commonly, it is associated with other organ injury, as the mechanism of injury would suggest.

Smith et al found that patients who died had four associated injuries on average compared to two incurred by those who survived.

Any organ is susceptible to injury and the injuries include closed head injury with or without intra cranial haemorrhage, pulmonary contusion with multiple rib fractures, long bone fractures, pelvic injury, intro-abdominal solid organ injury, spinal fracture and cord injury, maxillofacial injury, diaphragmatic rupture and cardiac contusion. Fabian et al and Wahl et al recorded a high incidence of multi-organ injury. In the study by Fabian et al, the mean injury severity score (ISS) was 42.1, and the mean Glasgow coma scale (GCS) was 12.1.

OPEN REPAIR
Conventional open repair of a thoracic aortic injury involves a high posterolateral thoracotomy, with or without cardiopulmonary bypass, associated with significant blood loss, which affects the pulmonary, cardiac, and neurological status of the patient. Hence, emergency open repair presents a therapeutic challenge and is associated with significant morbidity and mortality with a reported 28% mortality rate and a 16% paraplegia rate. Ott et al noted that the open surgical group had a 17% early mortality rate, a paraplegic rate of 16%, and an 8.3% incidence of recurrent laryngeal nerve injury. Paraplegia, being the most feared complication following open repair, has been attributed to aortic cross-clamping for more than 30 minutes during the procedure. Due to the high mortality rate of immediate repair, some have advocated delaying intervention with antihypertensive therapy until the patient is more stable. Fabian et al showed there were no deaths from rupture prior to surgery in 71 patients. This innovative practice is a key aspect in a delayed management strategy and has enabled surgery after recovery from the acute trauma. Despite this, complications remain high and delayed open surgery may lead to in-hospital death in 2 - 5% of patients.

With the introduction of endovascular repair for chronic infrarenal abdominal aortic aneurysms in the 1990s, this new technique has evolved rapidly and its benefits well-recognised; offering lower complication rates, quicker
### Table I: List of patients

<table>
<thead>
<tr>
<th>Cases</th>
<th>Age</th>
<th>Sex</th>
<th>Diagnosis and site</th>
<th>Other injuries</th>
<th>Injury severity score (ISS)</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>20</td>
<td>M</td>
<td>Pseudaneurysm proximal descending thoracic aorta, distal to origin of LSA</td>
<td>GCS 10/15 on arrival - contusion, bilateral haemothorax Left &amp; Right - chest drain, multiple splenic laceration - splenectomy done, multiple long bone fractures, Left conductive hearing loss.</td>
<td>head -3, face -0, chest - 3, abdomen - 4, extremity - 4, external - 0. ISS = 41</td>
<td>chest pain</td>
</tr>
<tr>
<td>Case 2</td>
<td>18</td>
<td>M</td>
<td>Pseudaneurysm proximal descending thoracic aorta, distal to origin of LSA</td>
<td>GCS 13/15 on arrival - contusion, bilateral small haemothorax - conservative, grade I liver injury - conservative, L2 fracture - conservative</td>
<td>head -3, face-0, chest - 2, abdomen - 2, extremity - 2, external - 0. ISS = 17</td>
<td>chest pain</td>
</tr>
<tr>
<td>Case 3</td>
<td>24</td>
<td>m</td>
<td>Pseudaneurysm descending thoracic aorta, distal to LSA origin &amp; distal to thoracic aorta laceration</td>
<td>GCS 10/15 on arrival - intubated, Right temporal Intraparenchymal Haemorrhage + contusion of bi-frontal lobes, 3rd-5th rib fractures with Left haemothorax - chest tube inserted, lower dentoalveolar fracture, splenic laceration - splenectomy.</td>
<td>head - 4, face - 2, chest - 3, abdomen - 4, extremity - 0, external - 0. ISS = 41</td>
<td>persistent Left haemothorax</td>
</tr>
<tr>
<td>Case 4</td>
<td>18</td>
<td>M</td>
<td>Aortic pseudaneurysm at isthmus (1.2x3.3cm)</td>
<td>GCS 7/15 on arrival, Right temporobasal Extradural Haemorrhage – Right craniotomy with Intracranial Pressure monitoring catheter placement, closed fracture Left acetabulum + Left femur - ORIF.</td>
<td>head - 4, face - 0, chest - 0, abdomen - 0, extremity - 4, external - 0. ISS = 32</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>Case 5</td>
<td>34</td>
<td>M</td>
<td>Descending thoracic aortic dissection - stanford B</td>
<td>GCS 14/15 on arrival, CXR noted hilar haziness, intubated due to hypotension, no other injuries.</td>
<td>head - 0, face - 0, chest - 2, abdomen - 0, extremity - 0, external - 1. ISS = 5</td>
<td>haemothorax, abdominal pain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cases</th>
<th>Duration of symptoms</th>
<th>Timing of surgery from diagnosis</th>
<th>Access</th>
<th>Procedure</th>
<th>Complication</th>
<th>ICU stay (days)</th>
<th>Duration of Hospital stay (days)</th>
<th>Length of follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>3 days</td>
<td>3 days</td>
<td>Left CFA</td>
<td>Medtronic Valiant covered stent. LSA covered.</td>
<td>Reduced pulses-radial and ulnar but no ischaemic sequelae, nil - no endoleak</td>
<td>4 days</td>
<td>16 days</td>
<td>5 yrs 2 months</td>
</tr>
<tr>
<td>Case 2</td>
<td>3 days</td>
<td>3 days</td>
<td>Right EIA (small femoral artery)</td>
<td>Medtronic Valiant covered stent. LSA covered.</td>
<td>Reduced radial artery pulsation (1+) but no symptoms. No endoleak. nil - no endoleak</td>
<td>1 day</td>
<td>11 DAYS</td>
<td>3 years 6 months</td>
</tr>
<tr>
<td>Case 3</td>
<td>9 days</td>
<td>&lt;24 hrs for laparotomy, 9 days for TEVAR</td>
<td>Right CIA retroperitoneal approach</td>
<td>Medtronic Valiant, covered stent.</td>
<td>nil - no endoleak</td>
<td>2 days</td>
<td>17 days</td>
<td>2 years 6 months</td>
</tr>
<tr>
<td>Case 4</td>
<td>0 days</td>
<td>3 weeks</td>
<td>Left EIA (small Left fem)</td>
<td>Medtronic Valiant covered stent</td>
<td>nil - no endoleak</td>
<td>2 days</td>
<td>9 days</td>
<td>2 years 1 month</td>
</tr>
<tr>
<td>Case 5</td>
<td>3 days</td>
<td>3 days</td>
<td>Right CFA</td>
<td>Medtronic Valiant covered stent</td>
<td>nil - no endoleak</td>
<td>5 days</td>
<td>8 days</td>
<td>2 years</td>
</tr>
</tbody>
</table>

ISS-Injury Severity Score, LSA – Left Subclavian Artery, ORIF – Open Reduction and Internal Fixation

CFA-Common Femoral Artery, EIA-External Iliac Artery, CIA-Common Iliac Artery
operating times and high success rates. The benefits of endovascular repair for elective thoracic aneurysms are equally acknowledged.

Currently, it is proving to be an effective treatment option for blunt thoracic aortic injury in the form of Thoracic Endovascular Repair (TEVAR). Taylor et al were the first to report the clinical benefit of using commercially available thoracic endografts in the management of blunt aortic injury in 2001 and therefore devices for endovascular surgery which were previously being used off-label for use in the emergency/trauma setting are being continually refined to suit the requirements of this group of patients.

**BENEFITS OF TEVAR**

TEVAR is a fairly understated procedure and the benefits of TEVAR over conventional open repair of thoracic aortic injury are many.

Since most of the injuries affect the aortic isthmus, and provided that there is adequate proximal and distal landing zones in patients with traumatic thoracic aortic injury, exclusion of an aortic tear with a stent can be carried out rather smoothly. In the endovascular setting, the usual physiological dilemmas that occur with open repair such as thoracotomy, aortic cross-clamping, cardiac bypass, and single-lung ventilation can all be circumvented. TEVAR does not require cross-clamping of the aorta and therefore avoids major blood pressure variation and coagulopathy. This in turn, decreases intra-operative blood loss which lessens the risks of ischaemic events that may lead to spinal cord ischaemia and paraplegia, ischaemic bowel or kidney failure. So far, all available endovascular studies on traumatic aortic injuries showed that the feared paraplegic complication does not occur. TEVAR offers better post-operative recovery as it is a minimally invasive procedure, which essentially involves a cutdown and an arterial puncture, and does not require a large incision like a thoracotomy. This is advantageous in trauma patients with concomitant injuries such as pulmonary contusion, where a thoracotomy wound could prolong their recovery.

Also, as patients typically have multi-organ injuries, TEVAR, being minimally invasive, can be performed in tandem with other surgical interventions of these injuries. Otherwise, for open aortic repair, patients will need to recover from any other life-threatening major operations or intensive therapy first. In TEVAR, the use of systemic anticoagulation with heparin is much less or sometimes even omitted, which is particularly beneficial in patients with concomitant intracranial or abdominal bleeding.

Lastly, in patients with adequate femoral artery access, this procedure can even be performed under local anaesthesia without incurring significant cardiopulmonary stress.

In our case series, the timeline varies between patients but it is of note that TEVAR is carried out after all necessary life-threatening injuries have been dealt with. This has a great impact on mortality rate.

**LIMITATIONS**

Although the argument so far, appears to put TEVAR in a positive light, there are some issues to be considered. The Vascular Unit at HKL is a tertiary referral centre, and is the only level 1 trauma centre in the country. The referrals are nationwide and with this, come the problem of logistics. It is dreadful enough that these patients may be suffering serious multi-organ injuries, transporting them through a possible 3-4 hour ambulance journey predisposes them to even greater jeopardy.

Other problems include anatomical issues, device and stent-graft availability, natural history and morphologic changes of the aorta, complications (early, such as endoleaks; late, such as endograft migration; device infection due to fistula formation), the lack of long-term durability studies with this relatively new technique and follow-up strategy.

- Anatomical issues

When considering a trauma patient for TEVAR, a few anatomical limitations to this technique need to be brought forward. These patients are typically younger and therefore...
the sizes of their aorta are generally smaller compared to the 
aneurysmal population in elective EVAR/TEVAR. The other 
factor is the arch of the aorta which is more acute in the 
younger patient and therefore placement of stent has to be 
done accurately and safely to avoid malposition of the 
stent to the aorta. Manipulating bulky delivery devices in a 
sharp-angled and tight-spaced aortic arch have caused 
serious complications such as cardiac perforation, aortic 
valve injury, arch perforation, branch vessel rupture, and 
cerebral embolization. Improvement towards a more flexible 
shaft to accommodate the acute aortic arch will ensure safe 
delivery of the endografts. Haemodynamic factors in young 
trauma patients such as the tapering luminal diameter of the 
descending aorta and the high pulsatile velocity may affect 
conformation and risk destabilizing the graft. Gross over-
sizing can occur due to the mismatch of sizes in these patients 
with relatively smaller aortic diameters compared to the 
available endograft sizes manufactured, which are really 
meant for the aneurysmal cohorts. This can lead to problems 
including device fracture, endoleak, migration, and 
infolding. Some stent grafts may also adopt a fishmouth 
configuration with the superior-inferior diameter of the 
proximal graft shortening and the lateral diameter widening, 
thus decreasing graft-wall opposition superiorly and 
inferiorly.

The other obvious anatomical limitation concerns the access 
vessels. As our case series have shown, these young patients 
with smaller aortas naturally have smaller femoral arteries 
and therefore make access difficult, requiring more proximal 
cutdown on to the external iliac arteries or considering a 
retroperitoneal approach to access the common iliac arteries 
to limit the risk of iatrogenic arterial dissection or rupture of 
the small femoral vessels.

- Stent-graft availability 
A more proximal cutdown/retroperitoneal approach allow 
access of the commercially available introducer devices that 
delivers the stent-graft up into the thoracic aorta. As noted by 
Peter H. Lin et al. "Presently, the Achilles’ heel of 
endovascular treatment of traumatic aortic disruption relates to 
the limited availability of thoracic endografts in all sizes." 
A study by White et al noted a 27% incidence of access 
complication with iatrogenic femoral artery injury in TEVAR.
However, as endovascular devices undergo 
continual refinement and miniaturization with smaller 
introducer sheaths, the incidence of iatrogenic access 
complication will likely be decreased or possibly avoided.

- Aortic growth 
As mentioned previously, the cohort of patients are typically 
younger, and may even be paediatric, and thus the caution 
raised is of aortic growth. Therefore, having found a suitable-
sized stent-graft to place in these patients at the time of 
injury, we will then have to consider this carefully, as aortic 
expansion is expected and possible stent migration may 
occur. In these younger patients, TEVAR may be looked at as 
a temporary measure before a more definitive operative 
repair at a later stage.

Clinical guidelines 
Given the relatively new experience with this technique, even 
in the elective setting, there is little evidence available of 
randomised trials. However, of what anecdotal experience 
available, it appears the results are favourable for TEVAR to 
be used in a trauma setting.

The Society of Vascular Surgery has produced a guideline for 
clinical practice at the end of 2010 to offer guidance in the 
management of trauma patients with blunt thoracic aortic 
injury using TEVAR. They have raised a few issues. In 
particular, regarding the management of LSA during 
placement of the endograft, there is near unanimous 
consensus for selective revascularization (either before or 
after TEVAR) depending on the status of the vertebral 
anatomy. On the occasion that the LSA is covered, 
intraperoperative angiography of the right vertebral artery 
allows the quickest assessment of posterior circulation 
adequacy.

If the right vertebral artery is atherosclerotic or hypoplastic 
with or without an intact Circle of Willis, decision to 
revascularize the left subclavian artery must be 
individualized taking into account the availability of surgical 
expertise, condition of the patient, and other injuries.
Preservation of antegrade perfusion on the side of the 
dominant vertebral artery can specifically decrease the risk 
of posterior circulation strokes.

CONCLUSION 
Thus, after dealing with the traumatic injury in these young 
patients successfully, the issue of follow up and 
durability/longevity of the stent will need to be considered. 
Aneurysmal patients are typically elderly and many will/
tend to outlive their stents. However, in young trauma 
patients the question arises regarding the stent durability as 
they age and also the anatomical changes that will occur as 
they grow older. The jury is out regarding interval and length 
of follow-up for this new technique but it would appear that 
these patients will benefit from long-term follow-up to 
monitor any morbidity as time goes on such as stent-graft 
migration or fistulous formation.

As more patients with thoracic aortic trauma are being 
managed with TEVAR, the full selection of appropriately sized 
devices would gradually become available and clearer 
evidence would emerge to the risks and benefits of this 
procedure. Meanwhile, surgeons must be wary when 
performing TEVAR of traumatic aortic injuries, as this 
treatment should only be offered in appropriately selected 
patients.

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