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[1]. 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[2].

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%)[3].

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)[4]. 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 haemoatoma 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 haematoma. 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 to 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

This article was accepted: 22 March 2013
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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 laparatomy 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 closed fracture of left acetabulum and left femur. 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 haziness 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[5]. 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[6]. 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[3].

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[7]. 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[8].

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, intra-abdominal solid organ injury, spinal fracture and cord injury, maxillo-facial injury, diaphragmatic rupture and cardiac contusion. Fabian et al and Wahl et al recorded a high incidence of multi-organ injury[9-10]. 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[11]. 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[11]. Paraplegia, being the most feared complication following open repair, has been attributed to aortic cross-clamping for more than 30 minutes during the procedure[12]. Due to the high mortality rate of immediate repair, some have advocated delaying intervention with antihypertensive therapy until the patient is more stable[9]. 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 [13] 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[14].

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

Cases	Age	Sex	Diagnosis and site	Other injuries	Injury severity score (ISS)	Symptoms
Case 1	20	M	Pseudoaneurysm proximal descending thoracic aorta, distal to origin of LSA	GCS 10/15 on arrival - contusion: intubated for transfer, bilateral haemothorax Left>Right - chest drain, multiple splenic laceration - splenectomy done, multiple long bone fractures, Left conductive hearing loss.	head - 3, face - 0, chest - 3, abdomen - 4, extremity - 4, external - 0. ISS = 41	chest pain
Case 2	18	M	Pseudoaneurysm proximal descending thoracic aorta, distal to origin of LSA	GCS 13/15 on arrival - contusion, bilateral small haemothorax - conservative, grade I liver injury - conservative, L2 fracture - conservative	head -3 , face-0, chest - 2, abdomen - 2, extremity - 2, external - 0. ISS= 17	chest pain
Case 3	24	m	Pseudoaneurysm descending thoracic aorta, distal to LSA origin 2ndary to desc thoracic aorta laceration	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.	head - 4, face - 2, chest - 3, abdomen - 4, extremity - 0, external - 0. ISS= 41	persistent Left haemothorax
Case 4	18	M	Aortic pseudoaneurysm at isthmus (1.2x3.3cm)	GCS 7/15 on arrival, Right temporobasal Extradural Haemorrhage – Right craniotomy with Intracranial Pressure monitoring catheter placement, closed fracture Left acetabulum + Left femur - ORIF.	head - 4, face - 0, chest - 0, abdomen - 0, extremity - 4, external - 0. ISS = 32	Asymptomatic
Case 5	34	M	Descending thoracic aortic dissection - stanford B	GCS 14/15 on arrival, CXR noted hilar hazziness, intubated due to hypotension, no other injuries.	head - 0, face - 0, chest - 2, abdomen - 0, extremity - 0, external - 1. ISS= 5	haemothorax, abdominal pain

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

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

CFA-Common Femoral Artery, EIA-External Iliac Artery, CIA-Common Iliac Artery

Fig. 1: Aortogram pre-stenting with a defect in the descending aorta.

Fig. 2: Artogram post stenting with a successful repair of the aortic injury.

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)[15-16]. 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[17] 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[18]. 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[19].

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 malopposition 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[20]. 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[21].

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 [22]. 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, intraoperative 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.(23) 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.

REFERENCES

1. Clancy TV, Gary Maxwell J, Covington DL, Brinker CC, Blackman D. A statewide analysis of level I and II trauma centers for patients with major injuries. J Trauma 2001; 51: 346-51. 2. Richens D, Field M, Neale M, Oakley C. The mechanism of injury in blunt traumatic rupture of the aorta. Eur J Cardiothorac Surg 2002; 21: 288-93.
2. The Society of Cardiothoracic Surgeons of Great Britain and Ireland: fifth national adult cardiac surgical database report; 2003. p. 46.
3. Jamieson WR, Janusz MT, Gudas VM, Burr LH, Fradet GJ, Henderson C. Traumatic rupture of the thoracic aorta: third decade of experience. Am J Surg 2002;183: 571-5. Peter H. Lin, *et al* Endovascular Repair of Traumatic Thoracic Aortic Injuries Anatomic considerations, therapeutic limitations, and clinical outcomes. ENDOVASCULAR TODAY I NOVEMBER 2007.

4. Perangkaan Kemalangan Jalan Raya Bagi Tahun 2001-2010 http://www.jkjr.gov.my
5. Parmley LF, Mattingly TW, Mariom WC, Jahnke EJ. Nonpenetrating traumatic injury of the aorta. Circulation 1958;17: 1086-1101.
6. Williams JS, Graff JA, Uku JM, *et al.* Aortic injury in vehicular trauma. Ann Thorac Surg. 1994; 57: 726-30.
7. Galli R, Pacini D, Di-Bartolomeo R, Fattori R, Turinetto B, Grillone G et al. Surgical indications and timing of repair of traumatic rupture of the thoracic aorta. Ann Thorac Surg 1998;65: 461-4.
8. Smith RS, Chang FC. Traumatic rupture of the aorta: still a lethal injury. Am J Surg 1986; 152: 660-3.
9. Fabian TC, Richardson DJ, Croce MA, Smith SJ, Rodman G, Kearney PA et al. Prospective study of blunt aortic injury: multicentre trial of the American Association for the Surgery of Trauma. J Trauma Injury Infect Crit Care 1997; 42: 374-83.
10. Wahl WL, Michaels AJ, Wang SC, Dries DJ, Taheri PA. Blunt thoracic aortic injury: delayed or early repair? J Trauma Injury Infect Crit Care 1999; 47: 254-9. Peter H. Lin, *et al* Endovascular treatment of traumatic thoracic aortic injury—should this be the new standard of treatment? JOURNAL OF VASCULAR SURGERY Volume 43, Number A, February Supplement 2006.
11. Ott MC, *et al.* Management of blunt thoracic aortic injuries: endovascular stents versus open repair. J Trauma 2004; 56: 565-70. W. Anthony Lee, MD, *et al,* Endovascular repair of traumatic thoracic aortic injury: Clinical practice guidelines of the Society for Vascular Surgery, ARTICLE IN PRESS, JOURNAL OF VASCULAR SURGERY 2010 Volume !!, Number !!
12. Von Oppell UO, Dunne TT, DeGroot MK, Zilla P. Traumatic aortic rupture: twenty-year meta analysis of mortality and risk of paraplegia. Ann Thorac Surg 1994; 58: 585-93.
13. E.S. Xenos, *et al.* Endovascular versus open repair for descending thoracic aortic rupture: institutional experience and meta-analysis/ European Journal of Cardio-thoracic Surgery 35 (2009) 282-6.
14. Le Bret F, Rual P, Rosier H, Goarin J, Riou B, Viras P. Diagnosis of traumatic mediastinal haematoma with transoesophageal echocardiography. Chest 1994; 105: 373.
15. Fattori R, Napoli G, Lovato L, *et al.* Indications for, timing of, and results of catheterbased treatment of traumatic injury to the aorta. Am J Roentgenol. 2002;179: 603-9.
16. Lachat M, Pfammatter T, Witzke H, *et al.* Acute traumatic aortic rupture: early stentgraft repair. Eur J Cardiothorac Surg. 2002; 21: 959-63.
17. Taylor PR, Gaines PA, McGuinness CL, *et al.* Thoracic aortic stent grafts—early experience from two centres using commercially available devices. Eur J Vasc Endovasc Surg. 2001; 22: 70-6.
18. Peter H. Lin, *et al* Endovascular treatment of traumatic thoracic aortic injury—should this be the new standard of treatment? JOURNAL OF VASCULAR SURGERY Volume 43, Number A, February Supplement 2006.
19. Peter H. Lin, *et al* Endovascular Repair of Traumatic Thoracic Aortic Injuries Anatomic considerations, therapeutic limitations, and clinical outcomes. ENDOVASCULAR TODAY I NOVEMBER 2007
20. White RA, Donayre CE, Walot I, *et al.* Endovascular exclusion of descending thoracic aortic aneurysms and chronic dissections: initial clinical results with the AneuRx device. J Vasc Surg. 2001; 33: 927-34.
21. Murad MH, Rizvi AZ, Malgor R, Carey J, Alkatib AA, Erwin PJ, et al. Comparative effectiveness of the treatments for aortic transaction: a systematic review and meta-analysis. J Vasc Surg
22. W. Anthony Lee, MD, *et al,* Endovascular repair of traumatic thoracic aortic injury: Clinical practice guidelines of the Society for Vascular Surgery, ARTICLE IN PRESS, JOURNAL OF VASCULAR SURGERY 2010 Volume !!, Number !!
23. Matsumura JS, *et al;* Society for Vascular Surgery. The Society for Vascular Surgery Practice Guidelines: management of the left subclavian artery with thoracic endovascular aortic repair. J Vasc Surg 2009; 50: 1155-8.
24. Tehrani HY, Peterson BG, Katariya K, Morasch MD, Stevens R,DiLuozzo G, *et al.* Endovascular repair of thoracic aortic tears. Ann Thorac Surg 2006;82:873-7.
25. O. Nzewi, R.D. Slight, V. Zamvar. Review: Management of Blunt Thoracic Aortic Injury Eur J Vasc Endovasc Surg 31, 18-27 (2006)
26. Feczko JD, Lynch L, Pless JE, Clark MA, McClain J, Hawley DA. An autopsy case review of 124 non-penetrating (blunt) injuries of the aorta. J Trauma 1992; 33(6): 846-9.