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Left Subclavian Artery - Does it need attention during TEVAR for Blunt Traumatic Aortic Injury

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ABSTRACT

Introduction: Endovascular treatment for Blunt Thoracic Aortic Injury is currently an emerging alternative as compared to traditional open repair due to superior outcomes in terms of mortality and morbidity. However, the decision to revascularize the left subclavian artery remains controversial in cases requiring the coverage of the left subclavian artery. We report our experience with endovascular stent-graft repair for blunt traumatic thoracic aorta injury.

Methods: Medical records from 11 patients who underwent Thoracic Endovascular Aortic Repair (TEVAR) for Blunt Thoracic Aortic Injury (BTAI) between January 2017 to April 2019 were analysed

Results: Among the 11 patients who sustained BTAI, 10 of them have been caused by motor vehicle accidents with the exception of 1 patient who sustained a fall from height. The mean Injury Severity Score is 32.72. Time elapsed between injury and TEVAR ranged between 13 hours and 321.17 hours with a mean of 73.47 hours and a median of 31.5 hours. Technical success rate was 100%. The left subclavian artery (LSA) was covered in 6 patients while the rest had partially covered LSA to achieve adequate proximal landing zone. None of our patients had experience upper limb ischaemia. Two patients developed a cerebrovascular accident, while a Type 1a endoleak was seen in 1 patient. One patient underwent revascularization of the LSA due to atretic right vertebral artery. The mortality rate was (2/11) however the deaths were unrelated to TEVAR. Mean follow up was 8.88 months with a range of 1 to 23 months.

Conclusions: We concluded that TEVAR is a safe and viable option to treat blunt thoracic aortic repair within our inherently young patient sample. LSA could be safely covered in TEVAR without preoperative revascularization as long as of contraindications such as atretic right vertebral artery or aberrations of the left vertebral artery anatomy are ruled out in preoperative CT angiogram.

Key words: Endovascular Repair–TEVAR–Aortic Transection–Blunt Thoracic Aortic Injury–Left subclavian artery–Revascularization.

1 INTRODUCTION:

Aortic transection is a surgical emergency with up to 85% mortality rate typically seen in patients who sustained de-

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celeration injury or blunt trauma. [1] As result from the mechanical strain generated by the differential forces acting on the isthmus, of which the fixed aortic arch is connected to the relatively mobile descending aorta, aortic transection commonly occur within the proximity of the ostium of the left subclavian artery. Recent guidelines favour the use of Thoracic Endovascular Repair (TEVAR) over traditional open surgical repair due to significantly lower risk of death, end stage renal disease and spinal cord ischaemia [2–5] Yet the prospect of occluding the left subclavian artery to achieve adequate proximal landing zone projects upon the risk of posterior circulation stroke as well as other concerns regarding timing to operation, intra-operative anticoagulation and future stent graft related complications particularly associated with the uncertain natural history of the repair in younger trauma victims and the morphologic changes of the aorta that come with age. [2] Hence, this study aims to report our experience with TEVAR in Aortic transection in a tertiary hospital with particular emphasis on the management of the left subclavian artery (LSA).

2 MATERIALS AND METHODS:

Patient selection.

This is a retrospective study from January 2017 to April 2019. A total of 11 patients with aortic transection were managed by a multidisciplinary team at our centre consisting of surgeons and physicians from the cardiothoracic surgery, vascular surgery and the interventional radiology team. We define our inclusion criteria to include all patients in who sustained any aortic injury (Grade 1-4) as direct result of a blunt trauma and received subsequent TEVAR as treatment. These patients were recruited based on a retrospective search through existing electronic medical records from the University of Malaya Medical Centre (UMMC), Kuala Lumpur. All trauma patients admitted to our Emergency & Trauma department were managed by emergency staff according to the Advanced Trauma and Life Support protocols. Following the suspicion of BTAI seen by widened mediastinum on chest X-ray, a computed tomography arch aortogram (CT AoA) was done to visualise the aortic pathology and the anatomy of the vertebral arteries. As of 2017, all patients who were diagnosed at our centre with BTAI requiring intervention were offered TEVAR rather than open repair. Aortic diameters were measured, and a strict endograft oversizing factor of 10% was opted for our study group. Spinal drain was not performed in all patients due to the emergent basis of the procedure and low risk of spinal cord ischaemia. The proximal landing zone of at least 20 mm was considered prior graft deployment. Should the need for LSA coverage to achieve adequate proximal landing zone arises, we employ the practice of selective revascularisation based on the presence of aberrations in vascular anatomy.

TEVAR procedure

Our centre utilised the Valiant^{TM} endoluminal stent-graft with the Captivia^{TM} Delivery System (Medtronic Inc., Santa Rosa, CA, USA) for all patients treated for blunt thoracic aortic injury. Patients were placed in a supine position under general anaesthesia in the angiography suite as prophylactic antibiotics were administered. Subsequently, both left and right groin were prepared. The device deployment artery which is the right femoral artery for all our cases, we used the percutaneous access under ultrasound guidance with Perclose Proglide$^{rcledR;}$ (Abbott Vascular Devices, Redwood City, CA, USA) device for most of our cases . We did use open access to the right femoral artery for 3 cases where the femoral artery size was only 6 mm. A 9Fr sheath is then used for the right common femoral artery. A 6Fr sheath is then placed over the left common femoral artery under ultrasound guidance. Anticoagulation was administered with low dose of heparin with a range of 2500-5000 IU depending on the risk of bleeding. A soft tip wire with pigtail was then introduced via the right femoral access. This soft tip wire was then exchanged for a stiff wire and the pigtail was then removed. The pigtail and soft tip wire was then introduced to the left common femoral artery and advanced under fluoroscopic guidance into ascending aorta. The pigtail catheter is positioned in the ascending aorta via the left femoral artery cannula as dye introducer. The measured thoracic stent graft will be inserted under fluoroscopy guidance after serial dilatation of the right common femoral artery. An aortogram will be done at this stage and the junction between the left common carotid artery and left subclavian artery will be marked as the no landing area for the covered part of the stent graft.

Prior to stent deployment, the systolic blood pressure is brought down to 80 mmHg, and the ventilation is stopped for the stent deployment. Due to the focal nature of BTAI, we did not observe any issues with achieving distal seal. However, to achieve at least 20mm landing zone for adequate proximal seal we have had to partial or total cover the left subclavian artery ostium. Upon completion of deployment, contrast dye is injected to confirm the patency of the aortic arch vessels as also to rule out signs of endo-leak.

After the completion angiogram, the introducer sheath was removed carefully leaving the wire in the aorta. After that the guide wire was removed and the right femoral artery was sealed using the Perclose Proglide$^{rcledR;}$ (Abbott Vascular Devices, Redwood City, CA, USA) system followed by direct compression for the left femoral artery after the sheath was removed. We define technical success as deployment of the endograft in the correct position to exclude the aortic pathology without the presence of endo-leak on completion aortogram. [6] The presence of distal pulses was checked to rule out possibility of limb ischaemia.

LSA revascularization and LCCA chimney graft

LSA revascularisation was employed with left common carotid artery-left subclavian artery (LCCA-LSA) bypass method. This procedure was done with an end-to-side anastomosis of the LCCA and LSA using a Dacron Graft which sutured by 5/0 prolene sutures. In cases where the aortic stent graft migrated proximally to affect the LCCA circulation, A chimney graft method was chosen for revascularize the LCCA. In which case a BeGraft^{TM} peripheral endograft (Bentley InnoMed, Hechingen, Germany) was used as a chimney graft to revascularize the left common subclavian artery by left common carotid access to restore sufficient cerebral perfusion. In both the above cases, An Amplatzer^{TM} vascular plug (St Jude Medical, Inc, St Paul, MN, USA) was deployed into the left subclavian artery at the end of the procedures to occlude the LSA followed by a completion angiogram to rule out endoleak with a run of cerebral angiogram to confirm perfusion from both carotid arteries and complete circle of Willis.

Post-operative:

After the procedure was completed, the patients were nursed within our Cardiothoracic Intensive Care Unit (CICU) where continuous Electrocardiogram (ECG) monitoring was done to monitor any arrythmias after the procedure. The heart rate was maintained between 60-90 beats per minute. The systolic arterial blood pressure was maintained higher than 110 mmHg and central venous pressure between 8-10 mmHg. Adequate oxygenation was supplied to maintain oxygen saturations of >98 %. Distal circulation both upper and lower limbs were also monitored continuously.

Computed Tomography Angiogram of the Arch of Aorta (CTA AoA) was repeated at 1 week, 1 month, 3 months, then 6-monthly for first 2 years followed by annual CTA AoA subsequently to check for long term complications including signs of graft failure or endo-leak. Patients were not prescribed with any antiplatelet therapy as this were for polytaruma patients who also have other injuries elsewhere in their body.

3 RESULTS:

Preoperative managementTable 1

All patients sustained a high impact blunt trauma or deceleration injury resulting in their aortic pathologies. All but one patient (10/11) presented with a history of motor vehicle accident as the mechanism of injury, while one patient sustained a workplace incident of which he fell from a 2-storey height which lead to the BTAI. Mean Injury Severity Score (ISS) was 32.72. All patients in our study sustained either a Grade I (intimal tear), Grade II (intramural haematoma) or III (pseudoaneurysm) aortic injury, we did not encounter patients with Grade 4 BTAI (free rupture of the aortic wall). Location of the aortic injury occurs exclusively distal to the origin of the left subclavian artery (Zone 3).

Our study cohort consisted of all male patients that coincidently falls within a fairly young age group (17-57) with a mean age of 37.18 years old (range, 17-57 years). All patients were of Asian descent (4 Malays, 3 Chinese, 4 Indians). Associated injuries included open or closed fractures of the long bones, head injuries, abdominal organ contusions and lacerations, spine injuries and pulmonary injuries such as contusions and pneumothorax. Patient demographics were summarised in Table 1.

None of the patients had any severe comorbidities prior to event of injury apart from one patient who had a history of mitral valve replacement 21 years ago. The mean length of hospital stay and Intensive Care Unit (ICU) stay were 20.64 and 9.55 days respectively. It was generally observed that the additional length of hospitalisation and intensive care unit stay were associated with the severity of the associated injuries from trauma. The average time elapsed from injury to aortic repair is 73.47 hours with a median of 31.5 hours. The timing for TEVAR was made by a joint decision by the multidisciplinary team by assessing and addressing the injury with the highest threat to the life of the patient. This might have contributed to the longer time taken from injury to repair seen in some patients. All apart from 1 patient was treated on and emergency basis. Patient #2 underwent aortic repair 13 days after initial injury to treat multiple associated injuries first before TEVAR. During preoperative imaging, we noted that patient #9 had an anomalous left vertebral artery of which its origin lies just distal to the LSA. We decided to sacrifice the left vertebral artery in this patient as the posterior circulation was receiving supply from the circle of Willis.

Operative ManagementTable 2

The average diameter of the proximal and distal aorta was 24.45mm (range, 20-35mm) and 22.45mm (range, 20-31mm) respectively. The mean operating time was 112 minutes and the operative details were summarized in Table 2 . The stent grafts used in all patients aortic repair consisted of a single stent device. To achieve adequate proximal landing zone and adequate seal, the LSA was sacrificed in 6/11 (54.55%) of the patients.

The decision for revascularization was only carried forward in one patient (#10), which coincidently had an atretic right vertebral artery noted during preoperative-imaging. This procedure was done 19 days after initial TEVAR procedure after a follow up CT AoA 1 day prior. It was noted during the scans that the patient had developed a type 1a endo-leak and the decision to revascularize the LSA was due to the concern of occluding the LSA following Reliant^{TM} Balloon angioplasty to seal the endo-leak which would completely occlude the LSA and cause significant risk of hypoperfusion to the posterior circulation that would result in neurological complications such as stroke and paraplegia.

We encountered the need to revascularize the left common carotid artery in one patient (#3) in our study due to proximal migration of the covered area of the stent in migrated proximally to partially cover the left common carotid artery. There were concerns regarding the adequacy of circulation supplying left cerebral hemisphere with a partially obstructed left common carotid artery. Hence, left common carotid artery revascularisation was performed via chimney graft method to restore sufficient blood perfusion to the left cerebral hemisphere.

None of the patients in our study developed ischaemic limb pain or claudication after the procedure, including those with covered left subclavian artery. Distal pulses were also noted in all but one patient (#11) following the procedure. Our overall technical success was 100% and no patients were required to convert to open repair. The all-cause

Table 1. Patient Demographics

Patient	Sex	Age	Mechanism of Injury	Grade of Aortic Injury	GCS score on arrival	Injury Severity Score	Aberrant vascular anatomy
#1	m	21	MVA	2	15	25	No
#2	m	43	MVA	1	15	48	No
#3	m	35	MVA	3	15	25	No
#4	m	24	MVA	3	15	32	No
#5	m	17	MVA	3	7	48	No
#6	m	52	Fall from Height	3	15	20	No
#7	m	52	MVA	3	14	32	No
#8	m	29	MVA	2	15	25	No
#9	m	24	MVA	3	15	41	Anomalous left vertebral artery
#10	m	55	MVA	3	15	34	Atretic Rt Vertebral Artery
#11	m	57	MVA	3	15	25	No

Table 2. ProceduralInformation

Patient	Time elapsed between injury and repair (Hours)	Device size (mm)	Technical Success	Endoleaks	LSA coverage	LSA revascularization	Alive	Months Follow up since Injury
#1	72.25	22 X 22 X 100	Yes	No	Partial	No	Yes	6
#2	321.17	28 X 24 X 150	Yes	No	Total	No	Yes	2
#3	52.42	26 X 22 X 150	Yes	No	Total	No	Yes	23
#4	13	22 X 22 X 100	Yes	No	Total	No	Yes	N/A
#5	129	22 X 22 X 105	Yes	No	Partial	No	Yes	17
#6	13.87	30 X 26 X 150	Yes	No	Partial	No	Yes	15
#7	30.75	38 X 34 X 150	Yes	No	Partial	No	No	0
#8	87.33	26 X 22 X 150	Yes	No	Total	No	Yes	3
#9	28.17	22 X 22 X 100	Yes	No	Partial	No	Yes	4
#10	27.5	30 X 26 X 150	Yes	Yes (Type 1a)	Total	Yes	Yes	1
#11	31.5	28 X 28 X 100	Yes	No	Total	No	No	0

mortality in our study was 18.18% (2/11). Patient #7 succumbed to death 11 days after Aortic repair from multiorgan failure secondary to polytrauma with severe lung injury and intracranial bleed. Patient #11 developed a left sided middle cerebral artery, posterior cerebral artery and brainstem infarcts secondary from traumatic brain injury which ultimately resulted in uncal herniation and death 5 days after aortic repair. Despite so, none of the mortalities were TEVAR-related. We report 2 patients who had developed complications as a result from TEVAR. One (#4) developed an acute right lower limb ischaemia due to right external iliac artery thrombosis following accidental compression on the site of right femoral access, requiring thomboembolectomy on the same day following TEVAR procedure, while another patient (#10) developed a type 1a endo-leak as mentioned above. One patient (#3) developed an acute right middle cerebral artery infarction with a suspicion that the stroke occurred due to subsequent migration of air emboli during aortic manipulation and not caused by the occlusion of the left subclavian artery.

Mean follow up period is 8.88 months. Compliance to follow up was reduced in 1 patient. Patient #4 was of Sri Lankan nationality and a referral letter was written to local hospitals to proceed with timely follow-up imaging. Apart from that, there were no reports of late complications such as subclavian steal syndrome, posterior circulation stroke or limb ischaemia.

4 DISCUSSION:

Blunt thoracic aortic injury (BTAI) is considered a life-threatening condition second only to traumatic head injury in terms of causes of mortality in blunt trauma. [7–9] Traditional open repairs are risky and carries a 16% paraplegia rate [10] and 28% mortality rate [11] especially considering various other associated injuries from blunt trauma. In recent years there is a paradigm shift in management strategies for BTAI. Although there is yet a randomized controlled trial conducted to illustrate the benefits of TEVAR versus traditional open repair [12] , our centre's decision to treat all BTAI patients with TEVAR were based on various retrospective cohort studies and meta-analyses that overwhelmingly favour the use of endovascular stents as documented by their significantly lower post-operative mortality and complication rate. [13–16] Yet the prospect of utilising this rapidly evolving technology come with various caveats and controversies. Some of the issues raised from this new approach include the timing of TEVAR in stable patients, choice of repair in the young patient, suitability and safety profile of the off-label use of endovascular stents, management of the LSA during zone 2 coverage as well as the need for systemic heparinization. [17]

The issue of LSA coverage is of particular concern when managing a patient that require total occlusion of the left subclavian artery to achieve adequate proximal landing zone, as some propose the coverage of up to 15-20 mm to avoid proximal type 1 endo-leak. [18] The anatomy of the aortic arch vessels dictates that the left vertebral artery stems from the left subclavian artery and its antegrade flow supplies the posterior circulation of the brain. Thus, various studies have associated neurological complications with the total occlusion of the LSA [19–25] , however this attribution is currently disputed and remains a topic of ongoing debate. [26–30] It is important to note that in most of the studies conducted to look into complications of LSA coverage consisted of a mixed sample of various descending aortic pathologies, including thoracic aortic aneurysms and aortic dissections. We propose that aneurysmal disease per se may have more atheromatous material and therefore more prone to embolization and stroke during aortic manipulation and thus the studies are less representative of BTAI patients who tend to be of a younger age group. [31] In addition to that, the presence of collateral flow through the branches of the left subclavian artery might suffice to provide adequate perfusion to the left upper limb and the posterior circulation. [24]

The decision to manage the LSA is dependent on evaluating the risks of neurological complications associated with reduced blood flow through the left vertebral artery. Despite low level evidence suggesting a correlation between LSA coverage and stroke, the current guidelines weakly suggest surgeons employ a selective revascularization strategy in managing the LSA, utilizing pre-operative imaging modalities to identify patients who have diminutive or atretic right vertebral artery, dominant left vertebral artery, incomplete circle of Willis or patent LIMA-LAD bypass or left axillo-femoral bypass and left arm arteriovenous fistula. [2, 31] Nevertheless, should patients develop a neurological complication following TEVAR, LSA revascularization was shown able to be performed safely when necessary with excellent short and midterm outcomes. [32] As the literature also suggest an increased risk of spinal cord ischaemia associated with length of stent graft [33] , this complication was not encountered as due to the focal nature of BTAI, none of our patients required stent grafts more than 150 mm long to achieve adequate repair. The proposed rationale is that shorter endoluminal devices tend to not occlude as much of the intercoastal arteries which supply the spinal cord as compared to longer devices used in aortic aneurysms.

Perhaps the risk of neurological complications associated with coverage of the LSA especially younger patients are overestimated as they usually have a lower risk of atherosclerotic disease and hence a better preservation of the LSA collateral supply. Our patients demographic portrays a younger age group (mean: 37.18 years) which in correlation to higher survival rates, which might explain the lack of post-operative complications associated with the coverage of the LSA. [34]

There are currently a few methods of revascularizing the LSA which include LCCA-LSA bypass, subclavian to carotid transposition and chimney grafts. Current guidelines did not provide a recommendation regarding the best method of revascularisation. Chimney graft method of revascularization may theoretically cause type 1a endo-leaks that may threaten the durability of this intervention, in addition to the concern of the lack of radial strength of the self-expanding endograft to resist the compression from the thoracic endograft that is deployed at the aortic arch. [35] Despite so, comparative studies between the 2 methods have seem to produce similar results in terms of safety and efficacy. [36, 37] Another study advocated for subclavian to carotid transposition when the aortic lesion is close to the origin of the LSA to prevent type 2 endoleaks. [38]

The limitation faced in our study was the small volume of patients that confine our ability to make solid conclusions. In addition, this single centre study was non-randomised. We hope to continue documenting and following up patients in a prospective manner to provide much needed insight into the long-term durability.

5 CONCLUSION:

According to our 2-year experience, we can make a safe assumption that the left subclavian artery can be sacrificed in emergency settings with regard to TEVAR for BTAI with minimal morbidities and neurological complications within the short-midterm period. Nevertheless, literature with a wider population of patients are required to confirm our results.

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