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Thoracic Endovascular Aortic Repair for Blunt Thoracic Aortic Injury: Single-Center Experience in a Developing Country

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Abstract

Background: Blunt thoracic aortic injury (BTAI) is a lethal condition. The most common intervention is no longer open aortic repair (OAR), it has been almost entirely replaced by thoracic aortic endovascular repair (TEVAR).
Objectives: In the present study, we aimed to share our experience in emergency TEVAR and address some difficulties that have been encountered.
Methods: In this retrospective study, all patients with blunt chest trauma between July 2014 and April 2020 were identified. Only patients with BTAI who were treated by emergency TEVAR were included. Demographic and clinical data were collected and analyzed.
Results: A total of 657 cases of blunt chest trauma were identified. Only 7 cases were found to have BTAI who underwent emergency TEVAR; six patients (85.7%) were males, with a mean age (±SD) of 29.5±8.5 years and one as a 39-year-old female. Motor vehicle accident (MVA) was the mechanism of injury (100%). Two patients (27.6%) had grade-II, 4 patients (57.1%) had grade-III, and 1 patient (14.2%) had grade IV aortic injuries. Technical success was achieved in all cases (100%). No peri-procedural-related mortality and morbidity. No graft related complications or re-interventions during the average follow-up of 23.3±8.6 months.
Conclusions: Despite our lack of experience in OAR for BTAI, TEVAR has provided us with an alternative treatment option for this life-threatening condition. Considering the challenges that may be encountered in developing countries, our results were similar to what has been reported in the literature.

Keywords: Chest Trauma, Aorta, Injury, Open Aortic Repair, TEVAR.

Introduction

Blunt thoracic aortic injury (BTAI) is caused by abrupt deceleration during a motor vehicle or motorcycle crash, a fall from a significant height, or other traumatic accidents.[1] The pathophysiology of BTAI relates to the transition from the relatively mobile aortic arch into the comparatively fixed thoracic aorta.[2] Ninety percent of injuries occur at the aortic isthmus within 2 cm of the origin of the LSA, where the aorta is tethered by the ligamentum arteriosum.[3] It has been reported as the second most common cause of death in individuals aged 4 to 34, following intracranial hemorrhage (ICH).[4-6] BTAIs represent only 10% of all thoracic vascular traumas.[7] Although they account for less than 1% of trauma admissions ,[8] they are immediately lethal and up to 85-90 % of patients involved in such incidents die before reaching a hospital.[1,3] For patients who survive to hospital arrival, 50% will die within 24 hours.[6] The most common types of BTAIs are false aneurysm (58%), dissections (25%), and intimal tears (20%).[2] Of the survivors, 29% demonstrate concomitant major abdominal injury, and 31% present with a major head injury, which creates significant challenges in the management of BTAI.[4,5] Proper diagnostic approach is of paramount importance for BTAI patients because the clinical presentation is non-specific and may range from absence of symptoms to severe hypovolemic shock.[8] Computed tomography angiography (CTA) enables rapid screening, 100% sensitivity, specificity that matches or exceeds that of conventional aortography, inclusion in a whole-body protocol to detect other injuries, and ability to plan for thoracic endovascular aortic repair (TEVAR).[9] Nowadays, TEVAR has become the treatment of choice because of lower rates of mortality, paraplegia, and stroke compared with open aortic repair (OAR).[10] Treatment of BTAI has evolved, however, multicenter data are lacking.[11] The majority of

management guidelines are from meta-analysis and systemic review articles performed in high volume, multi-centric, and expert trauma centers in the developed countries. These guidelines may not be applicable in low volume less expert centers in a developing country. Therefore, we tried our best to follow these guidelines despite the challenges that have been encountered.

Objectives

In our hospital, we were not able to manage BTAI by OAR before shifting toward TEVAR. In the present study, we share our short experience, low volume, and single center experience in dealing with BTAI. To the best of our knowledge, this is the first study in Jordan and surrounding regions that addresses the results of emergency TEVAR for BTAI.

Materials and Methods

Study population: All patients presented directly to our emergency department or referred from other hospitals with blunt chest trauma (isolated trauma or as part of multi-trauma) between July 2014 and April 2020 were identified. Only patients with BTAI who were treated by emergency TEVAR were retrospectively included in this study.

Data collection: Data regarding age, sex, mechanism of injury, comorbidities, associated injury, timing (immediate, early, and late), LSA coverage, type of anesthesia, need for anticoagulation, aortic arch variations, technical success, immediate major complications (paraplegia, left upper limb ischemia, access site complications, endoleaks), length of stay in ICU and hospital, postoperative needs for ventilation, mortality rate, need for re-intervention, and follow up imaging were collected.

Procedure: After primary and secondary trauma surveys and initial resuscitative maneuvers (by intravenous fluids and blood transfusions when needed). All patients who suspected to have BTAI by chest CT-scan underwent CTA to confirm the diagnosis and plan for TEVAR. All emergency EVAR procedures were performed in the Cath lab by both the vascular surgeon's team and the interventional radiologist's team. General anesthesia was used for all patients without cerebrospinal fluid drainage. The right common femoral artery was the access for the graft delivery system using an open cut down technique. The left brachial artery was percutaneously accessed by a 4F sheath with guide-wire and a diagnostic catheter was placed in the ascending aorta for angiogram and to locate the origin of the LSA. Self-expanding thoracic endovascular stent-grafts (Medtronic, Valiant/Captivia) were used for all patients. The choice of graft diameter was according to aortic size with 10-20% oversizing and 10 cm length. IV heparin was given before graft deployment in 6 cases, whereas, 1 cases had ICH that precluded anticoagulation. All patients were extubated immediately. Post-op CTA was performed during hospitalization and during out-patient follow up.

Results

A total of 657 cases of blunt chest trauma were identified during the 6 years. Only 7 cases were found to have BTAI who underwent emergency TEVAR. TEVAR for BTAI constitute 7/20 (35.0%) of total TEVAR performed for other indications (aortic dissections and aortic aneurysms). Six patients were males (85.7%), with a mean age (±SD) of 29.5±8.5 year (range, 23-45 years) and one 39-year old female. All of them were healthy without comorbidities. Three of them were smokers. Motor vehicle accident (MVA) was the mechanism of injury in all cases. Two patients (27.6%) had intimal flap with peri-aortic hematomas (grade-II), 4 patients (57.1%) had pseudoaneurysm (grade-III), and 1 patient (14.2%) had free rupture (grade IV) (Figure-A.1 and Figure-A.2). All injuries located within 2 cm distal to the LSA. Of them, 5 (71.4%) had major abdominal solid organ injuries, 1 (14.3%) had intracranial hemorrhage, and 1 (14.3%) had isolated chest trauma. Immediate TEVAR was performed in 5 (71.4%) and delayed TEVAR in 2 (28.6%). The delay was due to a delay in the diagnosis in one patient and the unavailability of the device in the other patient. Anticoagulation during the procedure was contraindicated in patient with ICH (14.3%) while the other 6 patients were given IV heparin during TEVAR device deployment. Technical success was achieved in all cases (100%) (Figure-A.3 and Figure-A.4). None of the patients underwent major surgeries (laparotomy, craniotomy, and spinal cord surgeries) before or after TEVAR. One patient who had major abdominal trauma (liver, spleen, and right kidney injuries) and severe head trauma died after 12 hours of TEVAR and it was non-TEVAR related mortality. All patients had the usual aortic arch anatomy (three major vessels; brachiocephalic, left common carotid, and LSA arise from aortic arch). LSA was preserved in all procedures. ASA was 4E in 5 patients and 5E in two patients. The mean (±SD)

LOS in intensive care unit (ICU) and hospital were 12±1.2 and 23±3.1 day respectively.

None of the patients had any procedure-related neurological deficit (stroke or paraplegia). There were no access site complications (bleeding, occlusion, and pseudoaneurysm). The thirty-day mortality was 1/7 (14.3%) (none was aorta or EVAR-related mortality), There were no grafts related complications (endoleak, graft collapse, and migration) in postoperative, pre-discharge CTA. Follow-up CTA demonstrated good endo-graft position, no endoleak, and complete peri-aortic hematoma resorption. During the mean (±SD) follow up of 23.3±8.6 month, no aortic re-interventions were needed (Table-1).

Table-1. Demographics, characteristics and outcomes of the patients with blunt thoracic aortic injury (BTAI) (n=7)

Variables	
Mean age in years ± SD	29.5 (8.5)
Males (%)	6 (85.7)
Mechanism of blunt injury, %	
Motor vehicle accident	7 (100)
Vital Signs on Admission	
Blood Pressure ≤ 100 mm Hg systolic (%)	3 (42.9)
Heart Rate ≥ 110/min	5 (71.4)
Respiratory Rate ≥ 30/ min	7 (100)
Duration from presentation to diagnosis, Hours Mean ± SD	7.1 (2.1)
Location of aortic injury, %	
Isthmus	7 (100)
Extent of aortic injury, %	
Grade II:	2 (27.6)
Grade III:	4 (57.1)
Grade IV:	1 (14.2)
Associated traumatic injuries, %	
Lung	7 (100)
Rib fracture	6 (85.7)
Abdominal injury	5 (71.4)
Head injury	1 (14.3)
Pelvic fracture	2 (28.6)
Spine fracture (stable)	1 (14.3)
Patients with blood transfusion (%)	4 (57.1)
Mean ISS score ± SD	38.7 ±13.7
ASA Risk Score	4E-5E
Duration from injury to TEVAR, Hours Mean ± SD	23.9 (7.1)
Mean ICU days ± SD	12 (1.2)
Mean Hospital days ± SD	23 (8.6)
Re-intervention (%)	0 (0)
Procedure related complication (%)	0 (0)
Mortality (%)	1 (14.3)
TEVAR related Mortality (%)	0 (0)
Mean Follow-up months ± SD	23.3±8.6

SD. Standard Deviations, ISS: Injury Severity Score, ASA: American Society of Anesthesiologists, TEVAR: Thoracic Endo-Vascular Aortic Repair.

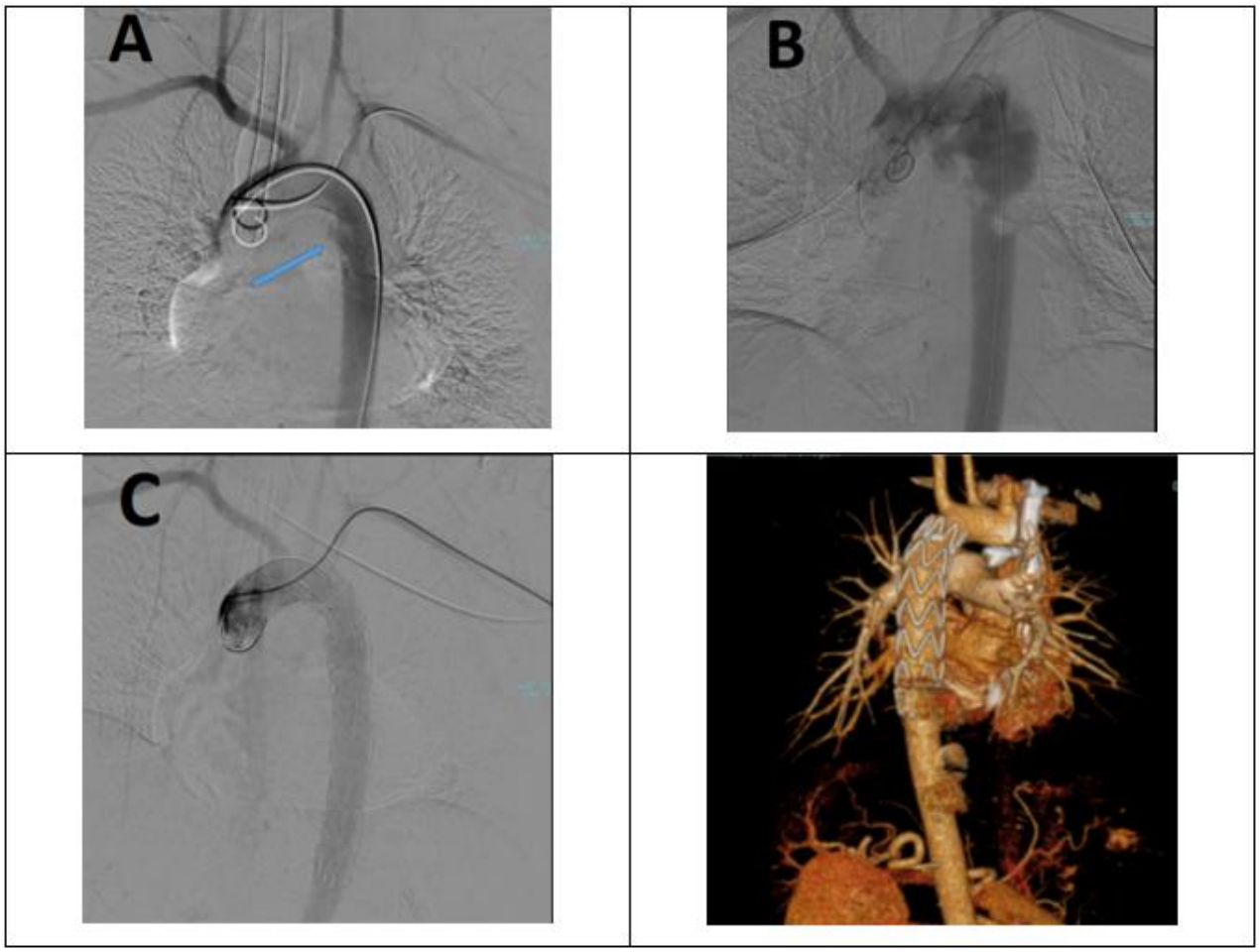

Figure-1. 1a. Grade III injury, 1b. Grade IV injury, 1c. Stent graft deployment, 1d. Follow-up CT-angiogram

Discussion

Techniques for operative repair of BTAI evolved since Parmley's seminal work. The "clamp and sew" method, although simple and expeditious, was associated with mortality and paraplegia rates of 16% to 31% and 10% to 23%, respectively.[9] In the mid-1990s, Dake et al explored the possibility of repurposing grafts used in abdominal endovascular aortic aneurysm repair (EVAR) for use in aneurysmal descending thoracic aortas, and in 1994 reported the first successful implantation of an endo-graft as a TEVAR and it was approved for human implantation by the United States Food and Drug Administration (US FDA) in 2005.[5,10] No commercially available stent-graft exists, which is specifically designed for TEVAR in patients with BTAI, but off-label use of endografts designed for elective TEVAR cases could potentially be used to treat these gravely injured acute patients.[14] The potential benefits of TEVAR over open repair include: no thoracotomy, no need for single lung ventilation, decreased use of systemic anticoagulation, avoidance of aortic cross clamping, less blood loss, less postoperative pain, and lower paraplegia rate.[15] During the past years, there have been rapid advances in the management of BTAI.[6] Despite the lack of randomized controlled trial (RCT) evidence, clinicians are moving forward with endovascular treatment of BTAI on the basis of meta-analyses of cohort studies and large clinical series.[16] However, certain specific considerations related to TEVAR, such as the timing of the procedure, the type and oversizing of the endograft, heparinization during the procedure, the necessity of cerebrospinal fluid drainage, type of anesthesia, and the necessary follow-up strategy remain to be clarified.[14]

Patients who survive to hospital admission, most commonly have incomplete or non-circumferential injury to the media and intima. The morphology of the aortic lesion reflects the severity of the injury and has been incorporated into several grading systems, which are used to aid clinical decision making and the reporting of studies on BTAI.[2] A classification scheme for grading the severity of aortic injury has been proposed: type I (intimal tear), type II (intramural hematoma), type III (pseudoaneurysm), and type IV

(rupture).[17] This grading system, while straight forward and descriptive, does not guide therapy or predict stability.[9,18] Therefore, the development and implementation of an optimal consensus grading system and treatment algorithm for the management of BTAI requires multi-institutional study.[19] However, the complexity of the severely injured blunt trauma patient can complicate management decisions.[19] Treatment of patients with BTAIs may be interventional (immediate or delayed, surgical or endovascular repair) or conservative (medical therapy), and this is largely dependent on clinical judgement on an individual basis.[8] Although the quality of evidence is very low, some studies suggest expectant management with serial imaging for type I injuries, while types II to IV should be repaired.[17]

Most patients with acute traumatic aortic transection show no evidence of aortic injury until hemodynamic instability occurs.[20] Rupture usually occurs within a few hours of admission 5-7 thus, requiring the treating physician to have appropriate treatment available in an expeditious manner.[15] In fact, for patients who survive, prognosis is still poor, because even in a properly-monitored unit, there is a 30% mortality rate within the first six hours and up to a 50% mortality rate within the first twenty-four hours.[7] The minimally invasive nature of TEVAR has allowed for earlier aortic repair in stable patients, emergent treatment of unstable patients, and easier concomitant management of both aortic and non-aortic injuries. In patients without other serious injuries, the trend has been to treat grade II or III injuries within 24 hours of admission to avoid progression to rupture (grade IV) and the potential deleterious effects of aggressive impulse control in certain patient populations.[5]

Considering our low experience in open treatment of thoracic aortic injuries and in the absence of strong quality of evidence regarding which lesion to treat and given the 46% mortality rate noted in non-operatively managed patients with BTAI,[26] we decided to be more aggressive in managing patients with BTAI. Therefore, we considered TEVAR for any periadventitial defect of the thoracic aorta (grade II, III, and IV) after addressing other injuries. Urgently (<24 h) TEVAR for grade II and immediate (as soon as the patient is table) repair for grades III and IV.

Although, expectant strategy with thorough imaging surveillance and proper pharmaceutical treatment might be appropriate for "minimal aortic injury" cases showing limited periadventitial defect or hematoma,[14] the aortic rupture is immediately life-threatening.[9] Many factors in developing countries preclude this expectant strategy of management. Firstly, due to the high price, we don't have on-shelf availability of the thoracic endograft. Secondly, our hospital cannot afford a 24-hours in-hospital radiology interventional team. Thirdly, TEVAR were performed in the Cath lab where the surgical equipment and staff should be prepared. Lastly, due to the paucity of vascular surgeons in Jordan, the vascular service is lacking in the majority of hospitals. All these factors will delay the TEVAR if sudden deterioration of the patient occurs. Taking into account that open surgical repair is not an option in our hospital, expectant management could be risky especially in critical multi-trauma patients (Table-2).

Table-2. Challenges and consequences in BTAI management.

	Issue	Consequences
1.	No trauma team	Absence of coordination and prioritizations
2.	No hybrid theater	Delay in equipment transfer from OR to Cath lab
3.	No in hospital IR staff at night and weekends	Delay in on-call staff gathering
4.	No on-shelf endograft	Delay in endograft availability
5.	High endograft price	Uninsured patients acceptance
6.	No OAR experience	Expectant management is risky
7.	Insurance policies	Temporary or Procedure-specific insurance can lead to loss of patient follow-up
8.	Paucity of vascular surgeons in Jordan	Not all hospitals have vascular service, In ability to provide every day vascular surgeon on duty.
9.	Only one endografts supplier.	Shortage in case of supply chain problems, unavailability of different sizes and lengths.

BTAI. Blunt Thoracic Aortic Injury, OR: Operation Room, OAR: Open Aortic Repair.

Generally, co-morbid injuries, rather than surgical technical factors, represent the primary cause of mortality in patients with BTAI.[7] However, bad opposition of the stent graft due to sever arch angulation and excessive oversizing can lead to endoleak, migration, and collapse. Stent-graft collapse is a life-threatening complication that could lead to acute aortic occlusion and distal organ malperfusion.[14] No consensus could be reached regarding optimal oversizing for these cases, and opinions were equally divided among minimal to no oversizing, 5% to 10% oversizing, and standard oversizing per manufacturer's recommendations.[17] More aggressive oversizing should be applied in gravely hypotensive patients, but it should not exceed 20%.[14] In our cases, we oversized the endografts by 10% to 20% according to manufacturer's recommendations and the availability of different sizes.

There was considerable divergence of opinion about the "best" device for use in BTAI.[17] Medtronic (Valiant/ Captivia®) was the only "off-label" available device in Jordan. Our experience of this graft came from other indications mainly aortic aneurysms and acute aortic dissection which mostly reflect the larger size of aortic diameters that would be typically encountered in an older cohort with degenerative aneurysms.[17]

In BTAI cases, the landing zone requirements for TEVAR are different to that of thoracic aneurysmal disease, but the proximity of the isthmic injury to the LSA origin makes coverage necessary in up to 50% of BTAI patients.[14] Coverage of the LSA appears well tolerated in patients with BTAI, with low need for subclavian revascularization.[19] Possible complications of LSA coverage are distal arm ischemia, possible vertebrobasilar pathology, and possible occlusion of thyrocervical collateral arteries to anterior spinal arteries increase the risk of spinal cord injury (SCI).[14] Guidelines for TEVAR in BTAI suggest selective revascularization of the left subclavian artery with low quality of evidence.[17] In our reported cases, there were no need for LSA coverage due to the presence of adequate proximal landing zones.

Our local study showed that the sample of Jordanian population had aortic arch anatomy similar to those shown in the majority of different races. However, endovascular specialists should carefully examine the pre-procedural CTA in order to recognize aortic arch anomalies or variations, and consequently avoid complications such as cerebrovascular events, endoleaks, upper extremity ischemia, and SCI.[14]

Whereas heparinization is recommended, TEVAR can be performed without anticoagulation in patients in whom major bleeding is a concern, although with a risk for thrombotic complications.[9] However, published data partially support performing TEVAR without the use of heparin in BTAI cases with presence of grave concomitant injuries and high risk for bleeding.[14] Most patients in this study received IV anticoagulation during TEVAR, only one patient with ICH and multiple abdominal solid organ injuries did not given anticoagulation without any thrombotic complications.

There was a strong consensus favoring general anesthesia for EVAR. While it is possible to perform TEVAR under local anesthesia, unreliable cooperation of an agitated trauma patient and presence of concomitant injuries that may require additional surgery make this option less favorable.[14,17] Published data support that TEVAR for BTAI should always be performed under general anesthesia (Quality of evidence is low).[14,17] All of our patients underwent TEVAR under general anesthesia with smooth recovery without any anesthesia-related complications.

The long-term behavior of aortic stent grafts remains unclear.[21] The ideal strategy for long-term follow-up of BTAI patients after TEVAR is still in evolution.[14] Two specific aspects of BTAI should be considered: the younger age of these patients and the traumatic nature of disease, in which progression does not develop once treated successfully.[22] In the absence of any abnormalities on imaging (i.e., stable endograft position, no endoleak) in the first 12 to 36 months, some have suggested decreasing the frequency to 2 to 5 years, while others have expressed that, lacking any evidence to the contrary, follow-up for traumatic thoracic aortic injuries should be no different than those treated with TEVAR for other pathologies.[17] However, its long-term outcomes remain unclear. Endoleakage and migration might occur in the long term, especially when younger patients undergo endovascular aortic repair.[23] Our guideline for TEVAR follow up is CTA before hospital discharge and at 1, 6, and 12-month intervals followed by annual surveillance thereafter.[9] However, due to medical insurance policies which may cover patients temporarily or cover only specific procedures and specialties, applying this follow-up guideline is sometimes difficult and patients may lose follow up. The main limitation of this study was the small number of TEVAR which is due to limited number of patients.

Conclusions

Despite our lack of experience in OAR for BTAI, TEVAR has provided us with an alternative treatment option for this life-threatening condition. Considering the challenges that may be encountered in developing countries, our results were similar to what has been reported in the literature.

Acknowledgments

None.

Authors' Contribution

Nabil A. Al-Zoubi and coauthors conceived and designed the study, conducted research, provided research materials, and collected, organized data and wrote initial and final draft of article, and provided logistic support. Tagleb S. Mazahreh analyzed and interpreted data. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Conflict of Interests

No conflict of interest.

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Ethical approval

This study was approved by IRB of Jordan University of Science and Technology (JUST) and King Abdullah University Hospital (KAUH). Informed consent was waived due to retrospective nature of the study and absence of violation of patients' confidentiality. IRB ethical approval number: 697-2020 dated: 09/12/2020

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