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Original Article

Endovascular therapy in blunt traumatic aortic injuries

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Abstract

Aim: Blunt traumatic thoracic aortic injury (BTTAI) is a catastrophic life-threatening surgical emergency and the second most common cause of death in trauma patients. We retrospectively revealed our results for endovascularly treated BTTAI with early and long-term results.
Material and Methods: During January 2009 and January 2022, patients from the emergency department with diagnosed BTTAI were retrospectively revealed. 38 patients all male except two, experienced BTTAI. 5 patients had grade IV, and 21 patients had grade III aortic injuries.
Results: Mean age of the patients was 41.7±12.5 years. Technical success was 100%. Early mortality was 7.9%. The mean follow-up period was 49.7±18.3 months. In the follow-up period, there were no TEVAR-related complications.
Conclusion: TEVAR is the most suitable treatment for BTTAI in the modern era. Left subclavian artery (LSA) intentional coverage may be performed however surgeon modified fenestrated stent graft (SMFSG) is an effective, economic, fast, and readily available technique for LSA revascularization without additional time.

Keywords: TEVAR, BTAI, BTTAI, intentional LSA coverage, SMFSG

INTRODUCTION

One of the main causes of death in trauma patients is blunt traumatic thoracic aortic injury (BTTAI), a catastrophic surgical emergency that poses a serious risk to life [1]. 80% of patients with traumatic aortic injury, sadly, died at the site [2]. Dramatic situations are typically brought on by falling from heights or car accidents.

Open repair replaced surgical repair as the main form of treatment after the first successful BTTAI repair in 1959 [3]. The first endovascular procedure was described by Kato in 1997 [4]; thereafter, TEVAR—which is less invasive—took the place of open surgery as the preferred treatment. Over the past 20 years, endovascular techniques have replaced open surgery as the primary therapeutic method [5-7]. For grade (G) II to IV BTTAIs, the Society of Vascular Surgeons (SVS) Clinical

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Practice Guidelines recommend immediate (24 hours) TEVAR [8]. The majority of BTTAI occurs at the aortic isthmus, where the more mobile aortic arch meets the comparatively fixed aorta [9,10]. For the purpose of estimating mortality, the Injury Severity Score (ISS), a quick assessment of the anatomical seriousness of injuries in trauma patients, is crucial [11–13]. If there is anatomic appropriateness, endovascular operations are the first line of treatment in every area of vascular surgery. According to The American Association for Surgery of Trauma (AAST) trials [14,15], TEVAR's less intrusive nature gave it a substantial benefit when treating the poly-traumatic patient population and yielded positive early results for BTTAI. Patients experiencing traumatic aortic injury are usually younger and have a smaller aortic diameter. Therefore, long-term durability results should be of great concern. We retrospectively revealed our results for endovascularly treated BTTAI with early and long-term results.

MATERIAL AND METHODS

The study was conducted in accordance with the guidelines established by the regional ethics committee. Retrospective data revealed 38 emergency department patients with BTTAI diagnoses between January 2009 and January 2022. There were 36 male patients. Mostly motor vehicle or motorcycle accidents that occur as a result of abrupt high impact braking. Six patients suffered long-term car accidents and chronic aortic pseudoaneurysms at the isthmic location (Figure 1 A-B). By using a computerized tomographic angiography (CTA) scan, we measure the centerlines and choose the endograft size. The diameter of the healthy aorta at the proximal and sealing locations as well as the length of the wounded aorta were among the specific measures and factors that were discovered. The left hemothorax and mediastinum expansion, which are common chest radiography findings, were crucial in proving thoracic rupture. Patients with blunt trauma should always be evaluated with CTA and BTTAI must be ruled out.

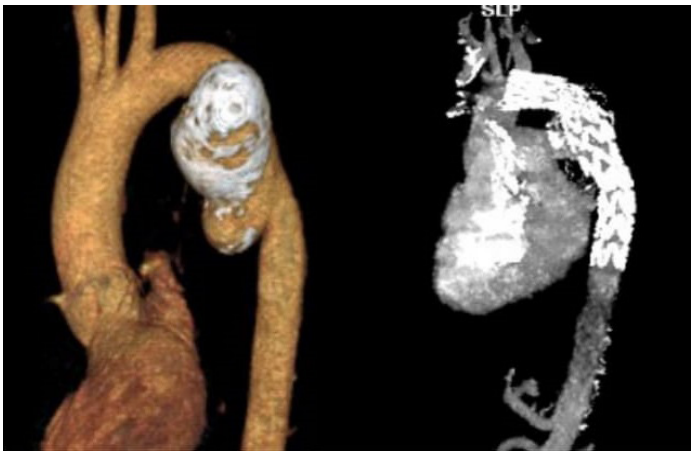

Figure 1-A and 1-B. *Chronic BTTAI before and after*

SVS classification was used to rate the severity of aortic damage. When performing endovascular treatment of BTTAI in an emergency, it was preferred to treat grade II BTTAI with semi-elective procedures. Surveillance imaging about the clinical conditions was performed on grade I patients. Prior to any intervention, a personalized treatment plan with multidisciplinary consensus was decided in our hospital for polytraumatized patients. The grading of the aortic damage in our patients is shown in Table 1. Primary outcomes were a technical success defined as complete sealing of the BTTAI without any endoleak and early (30-day) mortality. Secondary outcomes were aneurysm-related morbidity, mortality, and re-interventions in the follow-up period.

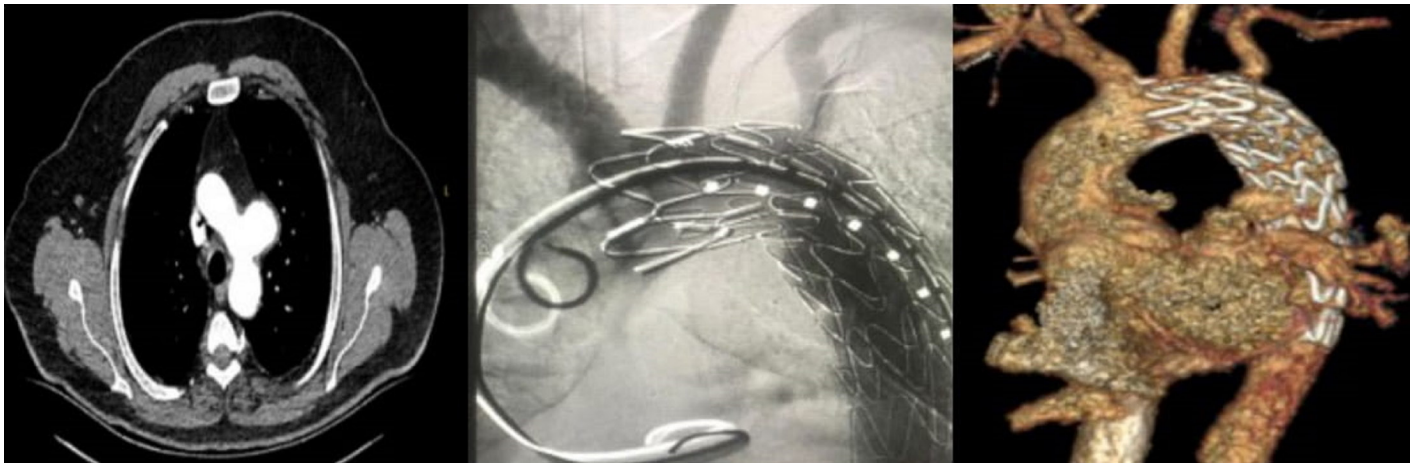

Figure 2-A, 2-B and 2-C. *Grade III aortic injury and treated by SMFSG*

Operative technique

Almost always right femoral artery was prepared surgically and a sheath insertion to the other side for pigtail catheterization. For BTTAI, the use and dose of Unfractionated Heparin (UFH) were left to the endovascular team in an individualized manner, considering the severity of all associated injuries. Half dose or full dose of UFH was administered. In general, the application of 5000 IU (100 IU/kg body weight) of UFH and an ACT of around 200-250 seconds was achieved. Half-dose UFH was administered only to patients with intracranial hemorrhage (ICH). An angiography pigtail catheter was inserted into the aortic arch from the contralateral groin or the brachial access. Medtronic Valiant (Medtronic, Santa Rosa, CA, USA) or Life-tech Ankura thoracic endografts (Lifetech scientific, Shenzen, China) were used. Oversizing was aimed at around 10% and always less than 20%. In the case of intentional left subclavian artery (LSA) coverage, selective revascularization was the treatment of choice. For all patient's completion angiography was made. After July 2020 we began to perform the surgeon modified fenestrated stent graft (SMFSG) technique in our clinic [16]. Eight patients had LSA revascularization in this way. We also implanted a balloon expandable covered stent Bard lifestream 9x58 mm at LSA from the brachial access in one.

Statistical analysis

All BTTAI patients enrolled to the study. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk test) to determine the normality of their distribution. Normally distributed continuous variables were expressed as mean ± standard deviation (SD), or median values with an interquartile range if not normally distributed. Categorical variables were expressed as numbers and percentages. Demographic characteristics, perioperative variables, and calculated values were compared using the independent Samples t-test or the Mann-Whitney U-test for continuous variables, and the Chi-Square test or Fisher's Exact Test for categorical variables. Statistical analyses were performed using the SPSS for Windows version 15.0 statistical software program (SPSS Inc., Chicago, IL, USA).

RESULTS

The mean age of the patients was 41.7±12.5 years (26-70). Technical success was 100%. Early mortality was 7.9%. In the hospital, mortality was not related to the aortic injury. One of the mortalities was due to multiorgan failure and pneumonia on the 28th day, and the other one who had a brain injury and cerebrovascular event (CVE), died because of sepsis on the post-procedural 10th day. The last one also with CVE and brain injury died on the post-procedural 12th day. There was no aortic aneurysm-related mortality. 5 patients had grade IV, and 21 patients had grade III aortic injuries (Table 1). Six of the patients were operated on many years after the car accidents as there was pseudoaneurysm formation at the aortic isthmic area.

Table 1. The grading of our patients' aortic injuries

Grade 1 Intimal Tear	Grade 2 Intramural hematoma	Grade 3 Pseudoaneurysm	Grade 4 Rupture
0	12	21	5

There were 25 patients with zone 2 landing; 8 SMFSG-TEVAR, 3 Chimney-TEVAR, 5 Caroticosubclavian bypass-TEVAR, and two partial and 7 intentional coverage of LSA and TEVAR. During the follow-up, one left arm ischemia, and one subclavian steal syndrome was experienced in the patients who had intentional LSA coverage and TEVAR. CSB was postoperatively performed for both. The other TEVAR-related complication was the type 1a endoleak which developed at the post-procedural 3rd month in a patient who had undergone a chimney TEVAR. 13 patients had zone 3 landing TEVAR with no complication. There were no thromboembolic or bleeding complications in the postoperative period due to heparin administration.

Patients were severely injured having an ISS average of 35 (16-48). All six chronic patients were in ASA II status. No stroke or paraplegia was seen. No aortic-related re-intervention or mortality was recorded. Additional surgeries consisted of 14 laparotomies for solid organ packing due to laceration and splenectomy, 5 patients had craniofacial surgery, and 24 patients experienced extremity and/or pelvic fractures requiring surgical fixation. Twelve patients had left chest tube drainages after the procedure. On presentation 5 patient (13.2%) was hypotensive and had a Glasgow coma score of <8. Access was obtained through the femoral route in all cases. For SMFSG Lifetech Ankura thoracic endograft was chosen. For the rest, Medtronic valiant and life tech Ankura thoracic endografts were used. The length of the endograft was 14.57 (10-20) cm. The graft oversizing was approximately between 10-20%.

The mean duration of the procedures was 67±18.5 minutes including the anesthesia period and the mean fluoroscopy period was 4.2±1.3 minutes. The intensive care unit (ICU) period was different for each patient because of the associated injuries, however, after the endovascular procedure, all patients stayed for at least one day in the cardiovascular ICU and then transferred to the general ICU for the other injuries. The mean ICU period was 6.8 (2-20) days. The mean length of stay was 17.8 (3-90) days. All perioperative variables are given in Table 2.

Table 2. The perioperative results	
Mean follow up period	49.7 ± 18.3 months
Mean duration of the prosedure	67 ± 18.5 minutes
Mean flouroscopy period	4.2 ± 1.3 minutes
Early mortality	% 7.9
Technical success	% 100
Mean ICU period	6.8 (2-20) days
Mean length of stay	17.8 (3-90) days

All survived patients were compatible with surveillance protocols. The mean follow-up period was 49.7±18.3 months. There was no TEVAR-related complication like endoleak or migration except for one chimney TEVAR patient.

DISCUSSION

TEVAR was found to be the best therapy option for BTTAI as a less intrusive therapeutic alternative to conventional open surgical methods. In this group of poly-traumatic fragile patients, TEVAR not only improves early mortality statistics but also promotes earlier ambulation and reduces hospital stay. In comparison to open surgery, TEVAR patients experienced lower early mortality and paraplegia [17], according to meta-analysis of retrospective cohort studies. Predictors of mortality included age, renal impairment, male gender, increased İSS, and LSA involvement [18]. In our series, we did not observe any endovascular complications in the early or long-term follow-up period with satisfactory early mortality results. There was no aorta-related mortality.

Based on CT scan analysis, a non-operative management strategy remains an option for selected patients with grade I Injury, who should harmoniously obey surveillance controls [19]. Delayed repair for grade II and III aortic injury may be acceptable if associated life-threatening traumatic injuries need to be addressed first. In our clinic, we prefer semi-urgent TEVAR for grade II aortic injuries and urgent TEVAR for grade III and IV aortic injuries with successful early outcomes. After discharge, the follow-up period was uneventful. In our series, we have six patients who had BTTAI (6-20 years ago) before and had TEVAR after visiting our outpatient clinic with symptomatic pseudoaneurysm formation at the aortic isthmus. Unfortunately, prior tomographic evaluations could not be found and documented. Patients with BTTAI have numerous concomitant injuries like intracranial hemorrhage, pulmonary contusion, intraabdominal solid organ injuries, and fractures that lead to prioritization of repair. Delayed intervention, particularly in the case of high-grade injuries, may allow for initial patient stabilization and improved outcomes [20-22], or these better outcomes may be possible just because the patient is more stable and can wait as the ISS was low.

Accurate measurements of true luminal diameter are especially important in the setting of a young trauma patient. Wallace et al suggested IVUS at the time of TEVAR provides a more accurate measurement of the aortic lumen diameter (ALD) and speculated that measurement by computerized tomographic angiography (CTA) may result in undersized endograft [23], which may be due to hypovolemic shock or resuscitation. In our center, measurements were calculated by CTA. The optimal target level of oversizing in non-atherosclerotic aortas is a matter of debate. The society of vascular surgery expert panel was unable to reach a consensus on a recommendation for optimal oversizing. An international consensus suggests oversizing is less than 20% [24]. We performed 10-20% oversizing in our patients. Available endograft sizes also carry an important role in this choice in urgent cases.

In literature controversy still exists on the use of UFH for BTTAI and remains at the surgeon's discretion. Series without the use of UFH reported no thromboembolic vascular events [25-26] on the contrary after the use of UFH during TEVAR, there were no reported adverse effects [27-28]. Kennel-Pierre et al reported their study with three different doses of UFH and found no difference in outcomes unless the non-heparinized group had shorter intensive care unit stays with prompt treatment [29]. In poly traumatized patients, hemorrhagic complications are of great concern, therefore we administer the dose of UFH achieving an ACT of 200 seconds and the soonest possible period of exposure of the sheaths, guidewires, and endograft systems in the body. There were no thromboembolic or bleeding complications in our patient cohort. Regarding patients with intracranial hemorrhage (ICH) and solid organ injuries (SOI), we gave special attention to the administration of UFH almost always the half dose.

The multicenter RESCUE study reveals excellent midterm results with the Valiant Captiva thoracic stent graft system in the treatment of BTTAI [30]. The late risk for aortic-related complications, treatment or device failure, and mortality was relatively low. We deployed Medtronic Valiant Captiva (Medtronic, Santa Rosa, CA, USA), Jotec (Jotec GmbH, Hechingen, Germany), and Lifetech Ankura thoracic endograft. For SMFSG all brands may be used however we preferred Lifetech Ankura endograft as it was easier and faster in such an emergent case necessitating no additional procedure.

Aortic dilatation is a common benign finding after TEVAR for BTTAI and is most pronounced at the distal end of the stent graft. This was thought to be due to the straight endograft where the distal end seems to be oversized. However, in the late-term follow-up, there are no known associated complications [31]. Depending on graft size availability, oversizing for BTTAI

varies between 5-20% however for successful wall apposition and sealing without excessive radial force. In our series, we did not experience any endovascular complications like endoleak or migration. We also used tapered and/or double tapered thoracic endograft according to distal aortic diameter to avoid excessive oversizing.

LSA revascularization increased the utility of TEVAR by advancing the seal to zone 2 in the aortic arch. In our patient cohort, 65.8% had involvement of LSA at the injury site. Most will agree that the LSA can be selectively covered but revascularization is preferred to reduce the risk of neurologic or ischemic complications. Among the wide variety of revascularization for LSA (carotid-subclavian bypass, custom-made fenestrated or branched endografts, chimney, insitu laser or balloon fenestrations, and SMFSG), SMFSG seems to be the most economic and faster way to revascularize LSA. No extra surgical fields, no sophisticated instruments needed, except a sterile ruler, cauter, and a scalpel. All these alternative techniques have their strengths and limitations. The limitations for back table fenestration are the possibility of spoiling the endograft integrity and therefore durability concerns. Left brachial access for a bailout Chimney or stenting or surgical bypass may be performed. These advanced skilled endovascular procedures should be limited to experienced aortic centers.

TEVAR is the most suitable treatment for BTTAI in the modern era, especially for polytraumatized patients with successful early and long-term results. Saccular aneurysms at the isthmic aortic region may be due to previous BTTAI, for etiologic evaluation it should be kept in mind. Non-operative management may be acceptable for patients with Grade I aortic injury and who may obey surveillance. Heparin is reported to be safe during TEVAR for BTTAI and should be administered when no specific contraindication exists. LSA intentional coverage may be performed however SMFSG is an effective, economic, fast, and readily available technique for endovascular LSA revascularization.

Ethics Committee Approval: The study protocol was approved by the ANKARA CİTY HOSPİTAL Clinical Research Ethics Committee (date/no: E.Kurul- E1-21-1576 / 03.03.2021). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Individual informed consent was waived due to retrospective design.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors contributed equally to the article.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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