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Original Article

Emergency percutaneous thoracic endovascular aortic repair for patients with traumatic thoracic aortic blunt injury: A single center experience

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ABSTRACT

Purpose: To analyze the efficacy and outcome of percutaneous thoracic endovascular aortic repair (TEVAR) in patients with traumatic blunt aortic injury in our single-center.

Methods: From January 2014 to December 2018, a total of 89 patients with traumatic blunt aortic injuries were treated with emergency TEVAR in our center. Their clinical data such as demographics, operative details and postprocedure outcomes were analyzed retrospectively in this study using SPSS 20 software. Continuous variables were expressed as mean and standard deviation or median and interquartile range. Categorical variables are expressed as the numbers and percentages of patients.

Results: The median age of the patients was 37 years, and 76 (85.4%) were males. All the patients were involved in violent accidents and combined with associated injuries. Two patients died while awaiting the operations and 87 patients underwent emergency percutaneous TEVAR, with a 100% technique success. The mean time interval from admission to operating room was (90.1 ± 18.7) min, and the mean procedure time was (54.6 ± 11.9) min. Eighty (92.0%) patients were operated on under local anesthesia, while other 7 (8.0%) patients were under general anesthesia. Two cases underwent open repair of the femoral arteries because of the pseudoaneurysm formation of the access vessels. A total of 98 aortic covered stent grafts were deployed, of which 11 patients used two stent grafts (all in dissection cases). The length of the stent was (177.5 ± 24.6) mm. The horizontal diameter of aorta arch at the proximal left subclavian artery ostium was (24.9 ± 2.4) mm, the proximal diameter of the covered stent was (30.5 ± 2.6) mm, and the oversize rate of proximal site was (22.7 ± 4.0)%. The proximal landing zone length was (14.1 ± 5.5) mm. The left subclavian artery ostium was completely covered in 5 patients and partially covered in 32 patients. No blood flow reconstruction was performed. The overall aortic-related mortality was 2.25% (2/89). Among 87 patients, the median follow-up time was 24 months. Postoperative computed tomography angiography scans demonstrated no residual pseudoaneurysm, hematoma or endoleak. One patient complained of mild left upper limb weakness during follow-up due to left subclavian artery occlusion. Neither late death, nor neurological or other complications occurred.

Conclusion: Emergency percutaneous endovascular repair is a less invasive and effective approach for the treatment of traumatic blunt aortic injuries. Long-term results remain to be further followed.

Introduction

Traumatic aortic disease is a relatively rare but fatal injury, with an extremely high mortality rate. Thoracic aortic injury is the second most common cause of death in trauma patients, exceeded only by intracranial hemorrhage.[1] According to the data of US National Trauma Data Bank (NTDB) from the year 2000–2005, among 3114 patients with traumatic blunt aortic injury, 24% were either dead on arrival or die during triage, of whom surviving triage but unable to undergo aortic repair, up to 68% died.[2] Traumatic blunt aortic injury is most common in traffic accidents, followed by sudden deceleration and external crush injuries. In blunt aortic injuries, the arterial wall is damaged from inside to outside, from the intima towards the adventitia. Patients are often died from massive blood loss, shock and refractory hypoxemia.

With the advent of thoracic endovascular aortic repair (TEVAR), the management of the traumatic blunt aortic injury has changed dramatically during the last decade. The aim of present study was to analyze the efficacy and outcome of TEVAR in patients with traumatic blunt aortic injury in our single-center.

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Methods

Patients

A retrospective analysis was performed using a database of thoracic aortic endovascular repair procedures at our institution from January 2014 to December 2018. The Institutional Review Board approved this study. A total of 89 patients with traumatic blunt thoracic aortic injuries were admitted to our center and the clinical data such as demographics, operative details, post-procedure outcomes were analyzed. All patients underwent emergency total body computed tomography angiography (CTA) to identify concomitant vascular, cerebral, or thoracoabdominal visceral injuries. After diagnosis was established, the emergency TEVAR procedure was prepared.

Percutaneous TEVAR

All patients underwent percutaneous TEVAR under either local anesthesia or general anesthesia.

Preclose technique

The common femoral artery was accessed percutaneously using Seldinger method. It is important to make sure to puncture the common femoral artery along its anterior aspect at least 1 cm proximal to the bifurcation (which is crucial for accurate hemostasis). Then a 0.035-inch guide wire was inserted into the aorta and the puncture site was dilated with a 6F dilator. Then the first Perclose Proglide Vascular Suture System (Abbott Vascular, USA) was inserted over the guide wire, rotated medially approximately 30° and deployed, but the strands were left out extracorporeally and tagged with a small clamp. Guidewire access was maintained, and a second Proglide device was inserted, rotated laterally 30° (the angle between the two systems >60°), and deployed. After this device was removed, hemostasis was maintained by reinserting a 9F sheath.

TEVAR

Considering that all the patients suffered concomitant injuries, only 2000 U intravenous heparinization was used instead of standard heparinization during the procedure. All devices were flushed with heparin solution (10 U/mL) to prevent clot formation. A diagnostic angiography of the entire aorta was performed, including abdominal, thoracic as well as ascending aorta. The aortic injuries, the landing zone status and the relation to the side branches were analyzed. Thoracic stent grafts were loaded on the Lunderquist extra-stiff guide wire (Cook Medical, USA), and were delivered to the aortic arch under fluoroscopy. Then the stent grafts were deployed at the exact location as planned pre-operatively. The left subclavian artery ostium was partially or totally covered if proximal landing zone was insufficient. The post-operative angiogram was performed again to confirm fully exclusion of the lesion.

Upon completion of the procedure, the preformed knots were lubricated with saline and gradually tightened. First, the knots were tied with the guide wire in place to assess accurate hemostasis while maintaining access. If adequate hemostasis was achieved immediately, further tightening of the knots was performed upon guide wire removal. Compress the access site for 5–10 min and the patient kept at bedrest for 12 h.

Follow-up

The clinical and CTA follow-up were performed at 1, 6, and 12 months after the intervention, and annually thereafter.

Statistical analysis

Statistical analysis was computed using SPSS 20 software version (IBM, Armonk, NY). Continuous variables were expressed as mean and standard deviation when parametric, and as median and interquartile range when nonparametric. Categorical variables are expressed as the numbers and percentages of patients.

Results

Patient characteristics

The median age of enrolled patients was 37 years, range (24–58) years, and 76 (85.4%) were males. All patients were involved in violent accidents, including vehicle collision ($n = 73$, 82.0%), fall from heights ($n = 16$, 18%). The aortic injuries were located at the aortic isthmus in 98.9% cases. No ascending or transverse arch injuries were observed. The injuries characteristics were summarized in Table 1.

Procedure

The median time interval from suffering the accidents to arriving at our center was 24 h, range 5–135 h 80 patients (89.89%) were transferred from other institutions. All patients were prepared for the emergency TEVAR as soon as diagnosed. Unfortunately, 2 patients were dead because of aortic rupture before the operation. Among them, one patient (a 25 year old male patient) died soon after the CTA scan was done; the other (a 35 year old male patient) died on his way to the operating room. Both 2 patients were diagnosed Grade IV aortic injuries by CTA. The remaining 87 patients underwent emergency percutaneous TEVAR procedure successfully (Figs. 1 and 2). The mean time interval from admission to operating room was (90.1 ± 18.7) min, and the mean procedure time was (54.6 ± 11.9) min.

Vessel access

All patients underwent TEVAR percutaneously. A total of 174 Proglide devices were used to 87 access sites. The right femoral artery was punctured in 75 patients (86.2%) and the left femoral artery in 12 patients (13.8%) for stent delivery. And because of associated injuries of the left arm, the left radial artery could not successfully punctured and inserted sheath in 2 patients, so the contralateral side of femoral artery was punctured instead. 2 cases underwent open repair because of the pseudoaneurysm formation 2 and 3 days after the initial procedures, respectively. There were no hematomas, pseudoaneurysms, or other access-related complications that required additional surgical or endovascular interventions.

Table 1
Injury characteristics.

Injury characteristics	*n* (%)
Lesion location	
Aortic isthmus	88 (98.9)
Descending aorta	1 (1.1)
Lesion severity	
Grade I intimal tear	0 (0)
Grade II intramural hematoma and hemothorax	14 (15.7)
Grade III pseudoaneurysm/dissection	64 (71.9)
Grade IV transection/rupture	11 (12.3)
Associated injuries	
Head	12 (13.5)
Lung	46 (51.7)
Bones	81 (91.0)
Visceral organs	10 (11.2)
Multiple lesions	58 (65.2)

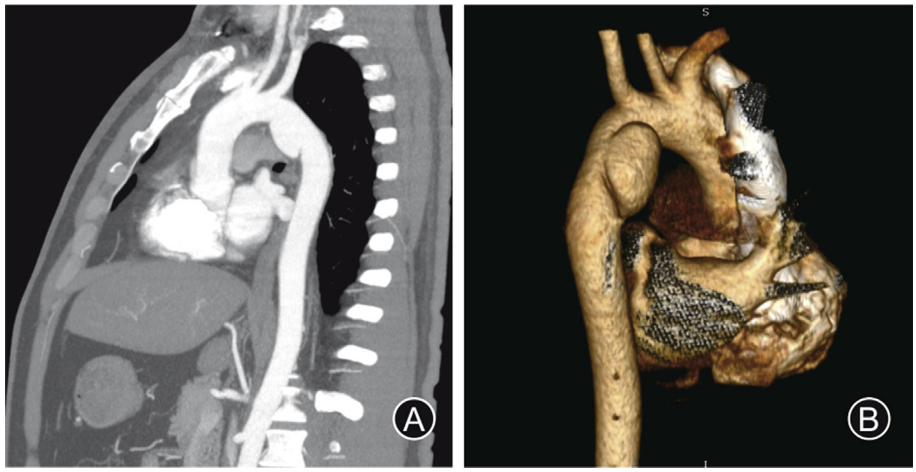

Fig. 1. Images of preoperative aorta CTA and emergency endovascular repair for patients with traumatic blunt aortic injury. (A): CTA multiplanar reconstruction; (B): CTA volume reconstruction, both showing pseudoaneurysm formation in aortic isthmus.

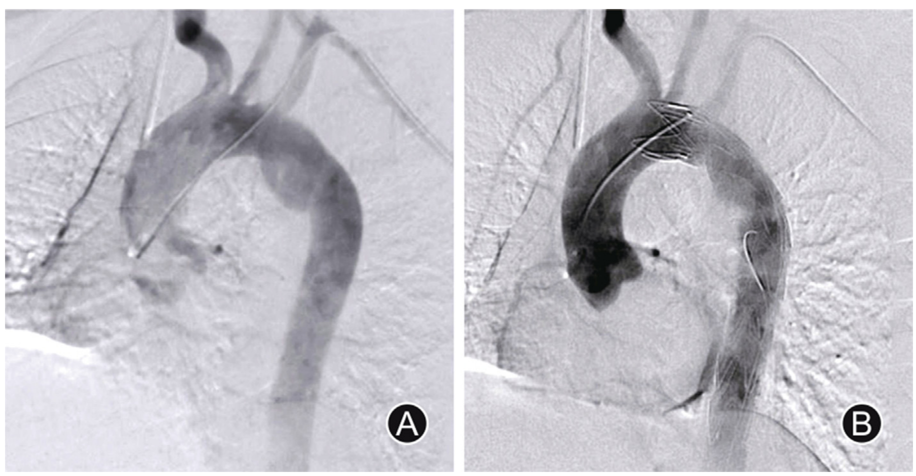

Fig. 2. (A): Preoperative angiography during emergency TEVAR is similar to CT angiography, but the lesion extent is smaller; (B): Postoperative angiography showing the pseudoaneurysm is completely resected.

Endovascular repair

Eighty (92.0%) patients were operated under local anesthesia, while the other 7 (8.0%) patients were operated under general anesthesia because of their unstable hemodynamic or lost conscious. A total of 98 covered aortic stent grafts were deployed, in which 2 stent grafts were deployed in 11 patients (all in dissection cases). The length of the stent was (177.5 ± 24.6) mm. The horizontal diameter of the aortic arch at the level of proximal left subclavian artery ostium was (24.9 ± 2.4) mm, the proximal diameter of the covered stent was (30.5 ± 2.6) mm, and the oversize rate of proximal site was (22.7 ± 4.0) %. The proximal landing zone length was (14.1 ± 5.5) mm. The left subclavian artery ostium was completely covered in 5 patients, partially covered in 32 patients. No blood flow reconstruction was performed.

Follow-up results

The overall aortic-related mortality was 2.25% (2/89). Among 87 patients who underwent operation successfully, the median follow-up time was 24 months. During the follow-up, no late death occurred and postoperative CTA scans demonstrated that no residual pseudoaneurysm, hematoma, or endoleak was revealed. Only one patient complained of mild left upper limb weakness due to TEVAR with intentional closure of the left subclavian artery, but no neurological symptoms such as cerebral infarction or dizziness were found. Thus no left subclavian artery revascularization was performed. Complete aortic remodeling was observed in 23 cases (all intramural hematomas and transections) (Fig. 3); totally thrombalization was observed in 42 cases (all pseudoaneurysms). Complete aortic remodeling was observed in 16 cases of dissections. Totally thrombalizations at stent graft segments were observed in the other 6 dissection cases, while persistent dissections in abdominal aorta were observed because of the multiple distal re-entries.

Discussion

Traumatic blunt aortic injury is associated with an extremely high mortality and represents the second most common cause of death in trauma patients.[1] Traumatic blunt aortic injury is frequently related to a sudden deceleration, most commonly in automobile crashes. Other causes include crashes of motorcycles, auto-pedestrian collisions, falls, and crush injuries.[3] The

Fig. 3. Aortic CTA in 12 months postoperative follow-up. (A): multiplanar reconstruction; (B): volume reconstruction showing completely aortic remodeling.

mechanism of the injury is most likely to the result of simultaneously multiple forces acting on the aorta suddenly, including movement of the sternum posteriorly with compression of the aorta onto the spine, a sudden increase in hydrostatic forces within the aorta, and the deceleration stress on the aorta with shearing and torsion of the descending aorta, which remains focally fixed by the ligamentum arteriosum.[4] Of the 89 patients in this study, injuries caused by traffic accidents accounted for 82.02% (73 cases), and falling injuries accounted for 17.98% (16 cases). Most of the injuries are located at the aortic isthmus. In our study, 98.9% were involved in the aortic isthmus, only 1 case involved in the descending aorta.

Based on the severity, traumatic blunt aortic injury is classified into four grades: grade I, intimal tear, with no involvement of the media and no contour abnormalities to the outside surface of the aorta; grade II, injury extends to the media, such as an intramural hematoma or dissection, with the presence of an external contour abnormality; grade III, pseudoaneurysm; and grade IV, rupture.[5] According to 2011 Guidelines by SVS, Grade I injury may be managed nonoperatively, Grade II, III, and IV injuries should be repaired. Despite the recommendations, the management of intramural hematoma (grade II) remains controversial. Recently several retrospective literatures reported that medication therapy may be safe in selected cases of grade II injuries.[5–7] Rabin et al.[8] also suggested that secondary signs of injury, such as pseudocoarctation, mediastinal hematoma with mass effect, and severe left hemothorax, are important indicators of a high risk of rupture. In our data, 14 patients were diagnosed with intramural hematoma (grade II injuries), and all of them were combined with middle to severe left hemothorax, which was an indicator of high risk. Thus, they underwent emergency TEVAR in our center.

Aortic CTA is a fast, non-invasive, effective method and it has been widely used in clinic. Demetriades et al.[9] reported that current CT scanners have been shown to achieve 100% sensitivity and specificity for traumatic blunt aortic injury. Total aorta CTA can fully assess the severity of the aortic injury, as well as identification of associated injuries that are commonly present. What is more, precise information needed for planning the operation can be achieved by the CTA reconstruction data. In our institution, the emergency aortic CTA is available in 24 h, which ensures that each trauma patient can finish CTA scan in a short time. The emergency aortic CTA scanning protocol is a standard non-ECG-gated aortic CTA. We recommend that an emergency aortic CTA should be present when a patient injured in a high-energy mechanism and a traumatic blunt aortic injury is suspected.

In 1997, Semba et al.[10] reported the first success of covered stent graft to repair a traumatic blunt aortic injury using endovascular technique. Then, several studies have confirmed the efficacy of TEVAR in the treatment of traumatic aortic injuries.[10,11] Endovascular repair has now replaced open repair as the primary treatment choice for most anatomically suitable patient with traumatic blunt aortic injuries.[12] First, in traditional dissection, proximal landing zone is not absolute normal aortic wall sometimes (hematoma or atherosclerotic changes, etc.), and the distal landing zone is at least partial intimal tear. But for blunt injury, the lesion is frequently localized, with relatively normal proximal and distal segment of the aorta wall, thus providing excellent landing zones for the stent graft. Second, the aortic injury most commonly occurs at the isthmus, which is approximately 10–20 mm distal from the LSA ostium, sometimes causing insufficient proximal landing zone. But in our experience, less than 15 mm is not an exact contraindication for TEVAR. Recent case reports and presentations also mentioned the similar opinion, that blunt injury can be treated with shorter landing zones.[13] In this study, the proximal landing zone length was (14.1 $\pm$ 5.5) mm. The left subclavian artery was completely covered in 5 patients and partially covered in 32 patients. No blood flow reconstruction was performed. Only 1 patient complained of left arm weakened. Third, it is important to note that the injury involved length in angiography during the procedure is frequently shorter than it showed in CTA. The difference is due to the periaortic hematoma or hemorrhage that is hardly detected in angiography. Thus, the length of the stent graft should be longer to make sure that it covered all involved segment. In this study, the length of involved segment was (44.5 $\pm$ 7.4) mm, and the length of the covered stent graft was (164.3 $\pm$ 15.2) mm. In addition, in order to achieve a completely exclusion of the lesion, our experience is that a 20%–25% oversize of the diameter should be considered.

Percutaneous access during endovascular aortic repairs is difficult because of the large size of delivery systems. Avoidance of surgical femoral exposure may result in shorter procedure time, fewer wound complications, and less patient discomfort. The Perclose Proglide vascular suture system using “Preclose Technique” offers the advantages of a permanent suture, the least amount of intravascular and extravascular foreign material, and similarity with conventional arterial repair. Several articles have described the noninferiority of the Preclose Technique over the classic femoral cutdown for endovascular aortic repair.[14,15] Lee et al.[15] retrospectively examined 279 femoral accesses of percutaneous closure of femoral arteries using Preclose Technique, the overall successful rate was over 94%, and the incidence of access-related complications were comparable to a surgical exposure group. In our study, the successful rate was 97.7%. We believe that there are several advantages of Preclose Technique applied in the emergency TEVAR for traumatic blunt aortic injury. First, it can significantly shorten the procedure time. In our study, the mean procedure time of percutaneous TEVAR was only 54.6 min. It is very important for our patients because their aortic injuries should be repaired in less than 1 h. Second, in majority cases, the procedure can be performed under local anesthesia. It offers neurologic monitoring for intraoperative cerebrovascular accidents or spinal cord ischemia. It can further shorten the hospital-stay compared with those operated under general anesthesia. Third, despite accurate and fast hemostasis, the access artery can be used for puncture again, which is helpful for further treatment of other associated injuries. There are some limitations for Preclose Technique. First, it takes a certain learning curve associated with the use of the device. In our series, pseudoaneurysm formation at access sites occurred in 2 cases, which both occurred at the beginning of the series. Second, there are some contraindications for this procedure, such as obesity patient, severely scarred groin, and heavy calcific vessel, etc.

In conclusion, emergency percutaneous endovascular repair is a less invasive and effective approach for the treatment of traumatic blunt aortic injuries. This percutaneous TEVAR procedure can significantly shorten the procedure time, which can be performed soon after the establishment of diagnosis prior to management of other concomitant injuries. Since trauma patients are relatively young, the long-term result remains unclear, so further follow-up is necessary. The morphologic changes of the aorta that come with age may still occur and lead to stent graft-related complications.

Funding

Nil.

Ethical Statement

The study was performed in accordance with the Declaration of Helsinki and approved by the institutional committee on research ethics.

Declaration of Competing Interest

Authors declare no conflicts of interest.

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