Endovascular Treatment of Blunt Traumatic Aortic Injury of the Descending Thoracic Aorta; Experience with 14 Cases Over 3 Years

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ABSTRACT

Introduction*: Blunt Thoracic Aortic Injury BTAI is a frequently unrecognized cause of traumatic death. Thoracic Endovascular Aortic Repair (TEVAR) has become the treatment of choice for both elective and emergent conditions involving the descending thoracic aorta. The result has been a decrease in both operative mortality and morbidity as it offers a safer and less invasive therapeutic alternative to open surgery to these high risk surgical patients.****Objectives****: The aim of this study is to describe our last 3 years experience with the endovascular treatment of patients having blunt traumatic rupture of the descending thoracic aorta.****Method****: We prospectively studied patients who had been referred to our hospital after blunt thoracic trauma over the last 3 years with the diagnosis of acute rupture of the descending thoracic aorta. All were managed with endograft coverage of the aortic lesion.Follow up full aortic CTA-scan at 1, 3 and 6, and 12 month.* ***Results****: 14 patients (12 male and 2 female) were enrolled from September 2013 to October 2016. An emergency endovascular procedure was performed in all patients with a median time delay of 10 h (range, 6-24h). The mean age was 45±28years (range, 17-73 years). Mean intensive care unit stay was 5±2 days with mean hospital stay of 20±5 days. No transient or permanent neurologic deficits were reported. No cases of renal failure, cerebrovascular accident, myocardial infarction, cardiac arrhythmias, or congestive heart failure were observed. No supra-aortic revascularization was required in cases mandating LSA coverage. One case of respiratory failure was observed which required prolonged mechanical ventilation, 2 cases of pleural effusion, and 3 cases of vascular access complication due to wound infection. A post-implantation syndrome (PIS) was observed in 5 patients and managed by non-steroidal anti-inflammatory drugs (NSAID) therapy. Overall survival for was 100 % and was maintained at 1-year follow-up. On CT scan surveillance, no stent-graft failure or collapse, no endoleak, or distal migration were detected.* ***Conclusion****: TEVAR for the treatment of acute traumatic rupture of the descending thoracic aorta can be accomplished safely in emergency settings with minimal morbidity and excellent long term results.*
Key words: *Aorta, Trauma, Endovascular*

INTROUDCTION

The incidence of blunt traumatic injury to thoracic aorta has been estimated to be between 1.5 and 2 percent of patients who have blunt thoracic trauma [1-4]. In a study of 274 cases with blunt thoracic aortic injury, 81 % were due to vehicle collisions [5]. Other possible etiologies include aircraft crashes, motor car accidents, falls, and crush injuries [6]. About 70% of victims were male [7], with about 67% of patients described as overweight or obese [8]. Most blunt thoracic aortic injuries occur in the proximal part of the descending aorta; however any portion of the aorta is at risk. The aortic isthmus where the relatively mobile aortic arch can move against the fixed descending aorta (by ligamentum arteriosum), is at greatest risk from the shearing forces of sudden deceleration or compression of aorta between spine and sternum. In order of frequency, trauma usually affects the proximal descending aorta, the ascending aorta, the aortic arch, distal descending aorta, and the abdominal aorta. Patients who survive to reach the hospital usually have small or partial-thickness tears of the aortic wall with pesudoaneurysm formation [9, 10]. Blunt Thoracic Aortic Injury is a frequently unrecognized cause of traumatic death. Seventeen percent of all motor car accidents deaths are due to traumatic aortic rupture [11]. About 85% of people with aortic rupture die immediately, 30% of those who survive initially die within 6 hours, and another

20% die within 24 hours. Untreated, survival more than 4 months is less than 2%. In contrast, survival is reportedly as high as 70% if injuries are diagnosed and treated.[11] Many patients who initially survive aortic injuries have a partial-wall thickness tear with contained hematoma and an intact adventitia, which prevents immediate rupture. That is why persistent or recurrent hypotension is usually not from aortic insults, and other etiologies of hypotension should be suspected [11]. Free rupture may occur, but unlike other causes of bleeding, it is always rapidly and irreversibly fatal. Thus, prompt diagnosis and treatment of aortic thoracic injuries is of paramount importance[12]. The presence of risk factors for blunt aortic injury in the trauma history should raise suspicion for a prompt diagnostic evaluation. The grade of injury together with the patient's associated injuries and medical co-morbidities determine the timing and type of thoracic aortic repair. A new classification system had been created based on the presence or absence of aortic external contour abnormality **(Figure 1)**.

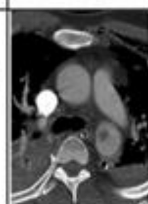
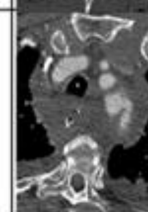
Absent External Contour Abnormality			Present External Contour Abnormality		
Type of Aortic Injury	*Definition*	*Example*	*Type of Aortic Injury*	*Definition*	*Example*
Intimal Tear	No aortic external contour abnormality: tear and/or associated thrombus is <10mm		**Pseudoaneurysm**	Aortic external contour abnormality: contained	
Large Intimal Flap	No aortic external contour abnormality: tear and/or associated thrombus is >10mm		**Rupture**	Aortic external contour abnormality: not contained, free rupture	

Fig. 1: classification of traumatic aortic dissection based upon findings from cross sectional images (Quoted from Benjamin et al.)[13]

Only 20% of free rupture may survive for a limited period after trauma long enough to reach the hospital to be managed [14].

Aim:

Is to report our experience with the endovascular treatment of blunt traumatic rupture of the descending thoracic aorta over 3 years.

PATIENTS AND METHOD

All victims who were referred to our hospital following road traffic accidents and were discovered after routine polytrauma work-up to have a diagnosis of acute rupture of the descending thoracic aorta were offered endovascular stent graft treatment according to our institutional standardized protocol and were followed prospectively thereafter.

On admission, patients with trauma history suggestive of possible blunt thoracic injuries e.g. vehicle collision, motor car accident with death of other victims, or severe fall or crash, an initial preferably sitting plain chest radiograph in anteroposterior projection was ordered. Abnormal radiographic findings or presence of unexplained hypotension, unequal pulse/pressure in both upper limbs or unexplained neurological deficit were our indications for initial high resolution non contrast chest CT. Abnormal mediastinal findings with abnormal aortic contour was our indication for chest and abdomen high-resolution multidetector computed tomography angiography (MD-CTA).

Hemodynamically victims with blunt thoracic trauma and potential aortic injury are either stable or unstable.

Hemodynamic instability in absence of free aortic rupture on MD-CTA calls for rapid identification and control of on-going hemorrhage from other sites, and to avoid over-resuscitation. Sites of concealed hemorrhage were identified with Chest and Pelvis radiographs and FAST (Focal Abdominal Sonar of Trauma) ultrasound.

Prioritization of management towards treatment of acute life threatening conditions including cases with free aortic rupture (type IV) to be followed by management of less fatal aortic injuries

To proceed with the endovascular intervention, only types II,III and IV blunt aortic injury BAI are offered the treatment and the victims should fulfill the following hemodynamic criteria:systolic blood pressure ≥ 90 mm Hg, heart rate less than 110, central venous pressure 7 to 14 cm H_2O, and hemoglobin level≥ 10 g/dL.

Determining the feasibility of stent graft therapy was based image's analysis of the CT angiography done during the initial survey using Osirix MD viewer for Mac. Measurements collected included the diameter of the proximal aortic lumen at least 20mm proximal to the injury and aortic lumen at least 30 mm distally. The diameters should be within 18 to 44 mm to follow the manufacturer IFU. Measurements also included the estimated length of coverage and the difference between the two obtained diameters. Our stent graft selection criteria were based upon availability, considering the proximal and distal landing with max 10 to 15% oversizing. Furthermore the thrombus load should not exceed 50% of aortic circumference and adequacy of the access vessels for device delivery.

Vertebral arteries flow was assessed by duplex scanning pre-intervention and cases with abnormal flow would necessitate LSA revascularization in cases where its coverage is mandatory for optimum proximal landing. [15, 16]

Stent grafts either were available on shelf or were delivered within 6-12 hours on request. All patients were kept under monitoring in the intensive or intermediate care units to stabilize their hemodynamic condition and allow planning of an endovascular or surgical procedure. A cerebrospinal fluid (CSF) catheter was inserted before the operation and the CSF pressure was maintained at 10 mm Hg or below and at the same time, the mean arterial pressure was maintained between 90 and 120 mmHg for the first 72 h to keep adequate spinal cord perfusion pressure [17].

In all cases the procedure was done under general anesthesia with endotracheal intubation.Two different commercially available thoracic stent-graft systems were used, *Valiant Captivia* (Medtronic World Medical, Sunrise, Fla) and Zenith TX2(*Cook Medical*, Bloomington, Indiana), the choice between both was determined mainly by the availability of the suitable sizes and length for each case.

Femoral artery cut down was carried out with broad-spectrum antibiotic prophylaxis was given just before the skin incision. Then 6 or 7 F regular sheath was inserted and then a vertebral catheter was positioned in the ascending thoracic aorta over a soft angled hydrophilic 0.035 guidewire (Terumo, Tokyo, Japan). The guidewire was then exchanged to a 0.035 J-tip super-stiff guidewire (260 cm long) for stent-graft insertion. An initial digital subtraction angiography of the thoracic aorta was performed via a pigtail catheter from the contra lateral percutaneous femoral access or from the left brachial access, with 30 mL contrast material at a flow rate of (15 mL/s) and pressure (800 mm Hg). The stent-graft system was then trailed to the planned position, and correct location was confirmed by an additional digital subtraction angiography immediately before stent-graft deployment. To avoid downstream migration of the device during deployment, systolic arterial blood pressure was lowered to 70 mm Hg with sodium nitroprusside just before device release or short cardiac arrest was achieved by intravenous injection of adenosine (6-12 mg) to ease device deployment and to allow exact device positioning. In all cases, a final digital subtraction angiography (with or without transesophageal echocardiography) was performed to confirm the correct stent-graft location and to demonstrate free flow to the supra-aortic arteries as well as the stent graft.

At the end of the procedure, the arteriotomy was closed with a continuous 5.0 Prolene suture. All patients were kept in the intensive care unit for postoperative care for at least 72 hours to allow monitoring of cerebrospinal pressure.

Follow-up examinations were performed with multidetector computed tomography angiography (MD-CTA) scans before discharge and at 3, 6, and 12 months after the intervention. Technical success of the procedure was defined as: the correct placement of patent endograft, exclusion of the aortic lesion and absence of endoleaks (type I or III)[18].

Follow up

Follow-up data consisted of a clinical examination and a full aortic MD-CTA-scan at 1, 3 and 6 months, and yearly thereafter. Data from early postoperative complications especially paraplegia (or paraparesis), renal and respiratory failure were also collected. A complete clinical and duplex ultrasound evaluation of the left arm was performed in cases with intended LSA coverage immediately after the procedure and then at 3, 6 and12 months postoperatively and yearly thereafter to evaluate left arm perfusion and function.

RESULTS

From September 2013 to October 2016, 14 patients (12 male and 2 female) were referred to our hospital after road traffic accidents and were diagnosed to have BTAI due to their abnormal chest x ray findings and further documented by non-contrast high resolution CT. Six victims had hypotension on admission due to rupture spleen (3 cases), intestinal injuries (1 case) and one case due to massive heamothorax and multiple rib fractures with type IV BTAI. Urgent laparotomy was carried out prior to thoracic aortic endograft repair for splenectomy and intestinal resection anastomosis repair in 4 cases. Injuries characteristics were outlined in **table 1**.

Table 1: Injuries characteristics

Characteristic	
Mechanism of blunt aortic injury	
Vehicle accidents	12 (85.7%)
Pedestrian hit by motor vehicles	2 (14.2%)
Extent of aortic injury	
Grade I: intimal tear	0 (0 %)
Grade II: intramural hematoma	1 (7.14%)
Grade III: aortic pseudoaneurysm	12 (85.7%)
Grade IV: free (impending) rupture	1 (7.14%)
Location of aortic injury	
Isthmus (area distal to the left Subclavian artery extending to the third intercostal artery)	14 (100 %)
Associated chest injuries	
Lung injury (hemo-pneumothorax)	1 (7.14%)
Unstable fracture of limbs	1 (7.14%)
Rib fracture	1 (7.14%)
Associated extrathoracic injuries	
Spleen rupture	3 (21.4%)
Intestinal injury	1 (7.14%)

Following the initial stabilization and according to the preseated criteria of hemodynamic stability all of our 14 victims were offered the intended endovascular procedure with a median time from trauma of 10 h (range, 6-24h). The mean age was 45±28years (range, 17-73 years), five victims were diabetic and one was hypertensive. Luckily no one had renal impairment.

Most of our procedures could be performed through a femoral access by a cut down at the groin. In two cases (14.2%), the diameter of the common femoral artery (CFA) was considered too small by the operator, and the endograft was introduced through the external iliac artery, exposed by retroperitoneal access.

Technical success, as defined by total injury coverage and absence of endoleaks or migration was documented in all of our victims **(figure 2&3).** Coverage of the LSA ostium was mandatory in 3 cases in order to gain optimal proximal landing zone. The stent graft used included 9 Valiant Captivia® (Medtronic) and 5 Zenith TX2® (Cook Medical).

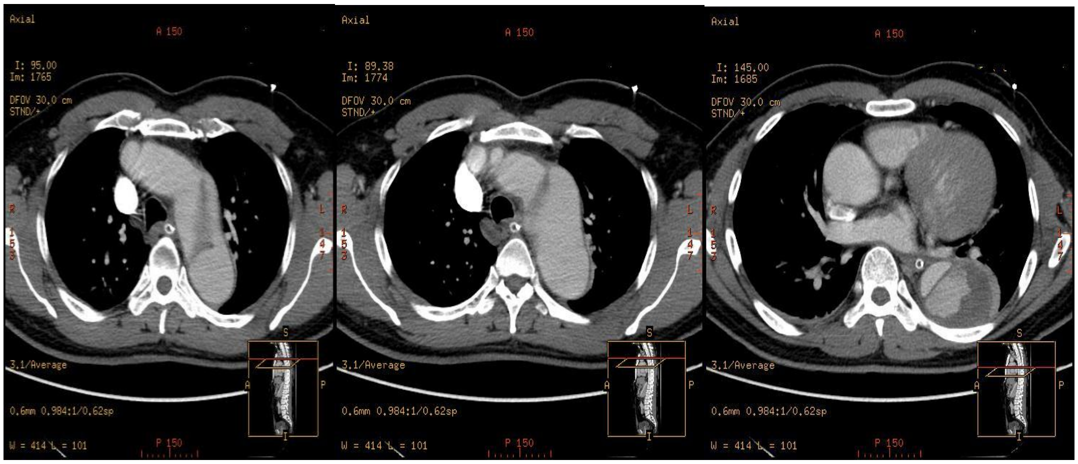


Fig. 2: Traumatic thoracic aortic dissection with aneurismal dilation of the false lumen reaching up to 6.5 cm in its maxim transverse diameter

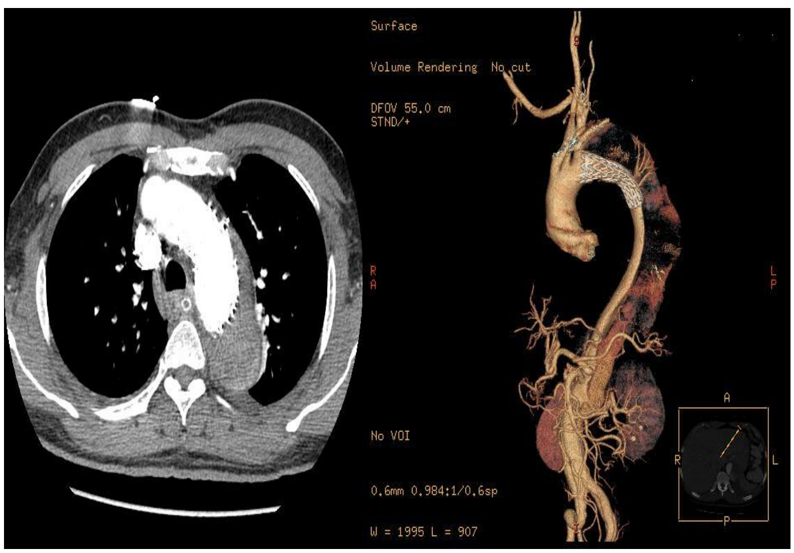


Fig. 3: Follow –up CT of the same case done after 3months of endograft management with adequate sealing of the aortic tear and absence of endoleak or graft migration

Early outcomes

The early mortality defined as either in-hospital or within 30 days was 0/14 (0 %). After intervention, all patients were admitted to the intensive care unit, where mean stay was 5±2 days. The mean hospital stay was 20±5 days; during this time, no transient or permanent neurologic deficits were reported. No renal failure, cerebrovascular accident, myocardial infarction, cardiac arrhythmias, and congestive heart failure were observed. No supra-aortic revascularization was required. One case of respiratory failure was observed which required prolonged intubation, 2 cases of pleural effusion, and 3 cases of vascular access complication due to wound dehiscence and/or infection. Post-implantation syndrome (PIS) was observed in 5 patients and was managed by non-steroidal anti-inflammatory drugs (NSAID) therapy. **(Table 2).**

Long-term outcomes

Overall survival for the entire group was 100 % at 1-year follow-up. At follow-up CT scan surveillance, no stent-graft failure or collapse, leak, or distal migration was detected. **(Table 2).**

Table 2: Early and long term complications

Complication	*Early complications*	*Long term complications*
No of patients	14	
Paraplegia/paraparesis	0 (0)	-
Renal failure	0 (0)	-
Respiratory failure	1 (7.14%)	-
Cardiac arrhythmias	0 (0)	-
Cerebrovascular accident	0 (0)	-
Pleural effusion	2 (14.2%)	-
Re-intervention	0 (0)	-
Vascular access-related complications	3 (21.4%)	-
Left Arm Claudication (clinical or instrumental)	1(7.14%)	-

DISCUSSION

The emergency treatment of traumatic transections of the descending thoracic aorta remains a great challenge. The success of the conventional open surgical treatment is still plagued by the high perioperative morbidity and mortality despite widespread adaption of standardized treatment protocols [19,20]. Associated severe co-morbidity is common in this group of patients and significantly influences the early outcome. This is illustrated by Crawford and colleagues who reported 12% 30 day- mortality due to ruptured descending thoracic aneurysms in low risk patients group while reaching up to 44% in high-risk patients who have associated medical co-morbidities [21]. Catastrophic postoperative complications (e.g.: paraplegia) continues to occur at a rate of 2.9% after emergency surgical repair of transected thoracic aorta[22, 23]. Also, high rates of respiratory failure, renal insufficiency, and/or the need for re-intervention for bleeding are common after the conventional surgical repair [24, 25]. Thoracic EndoVascular Aneurysm Repair (TEVAR) was first introduced in the early 1990s in an effort to overcome the postoperative complications commonly encountered in surgical repair [26, 27]. The short term results of TEVAR in both elective and emergency cases showed its safety and feasibility [28-30]. However, few midterm and long-term follow up data are available.The first report of patients with 7-yearfollow-up was published by Alric and colleagueswho found that despite acceptable short-term results in aortic aneurysm repair, stent grafts failed to protect patients from aneurysm–related deaths. Additionally, they found a significantly high rate of late complications, with about 49% of the patients having endoleaks and proximal stent migration occurred in 56.5% of cases. These findings raise the alarm whether long-term protection from procedure-related death is provided by TEVAR procedures [31].

Compared with other etiologies that are treated with thoracic endovascular stenting, such as thoracic aneurysm, patients with blunt thoracic aortic injuries are usually of young ages with special aortic anatomic characteristics that can present challenges for the placement of stent-graft devices, which were not designed for such indication. Endogarft repair after blunt injuries of thoracic aorta is indicated for injuries Grades II, III, and IV. Treatment should be offered to grade I only whenever progression to a higher grade become evident on subsequent scans. Aortic repair may be delayed in high surgical risk patients from associated co-morbidities, challenging aortic anatomy, or coexistent injuries [32]. Based upon observational data that demonstrate improved perioperative outcomes [33-42], we agree with recommendations of major trauma society and the vascular society guidelines that recommend stent-graft repair rather than direct open surgical repair for thoracic aortic injuries so long as the patient indication and the aortic anatomy are suitable for endogafting [43,44]. This therapeutic strategy depends upon the aim of preventing perioperative mortality and morbidity such as paraplegia, in comparison with endograft complications that lead to higher rates of re-intervention and uncertain long-term outcomes. It is important to keep in mind, though, that patients with blunt aortic injury may be more suited for one approach or another depending on local institutional resources and other issues such as the presence, location, and type of associated injuries, the anatomical site of the aortic traumatic rupture and diameter of the injured aorta, the patient's life expectancy, and possibility of compliance with long-term follow-up in the event of endovascular repair. Retrospective reviews and analysis of pooled data from various studies comparing the rates of major perioperative morbidity and mortality are in favor for endovascular repair [33-42, 45, 46]. So, Thoracic Endovascular Aortic Repair (TEVAR) has become the treatment of choice for all conditions, both elective and emergent, involving the descending thoracic aorta [47, 48]. The result has been a decrease in both operative mortality and morbidity for patients with these conditions and it has offered a safer and less invasive therapeutic alternative to open surgery in such group of high risk surgical patients [47-48].

In our study, with a median follow up of 1 year, among the early complications there was no mortality or major neurological complications especially no paraplegia/paraparesis events. Minimal cardiovascular, respiratory and bleeding complications were recorded in the early post operative periods (as shown in table 3) with no long –term complications reported. All procedures showed technical success rate of 100%. Being small sized non-randomized study; no solid conclusions could be made and several studies have shown that long-term follow-up data are significantly important to assess the durability of TEVAR in younger population. Stent fractures and/or migration may become more evident during longer periods of follow-up. Because the aorta tends to dilate with age, small-sized devices found appropriate at the time of procedure need assessment of its long-term performance. A recently published 10-years follow-up data in TEVAR patients by Canaud et al. demonstrated that the reduction in the rate of operative mortality of TEVAR, compared with that of surgical repair, lasts over time, without any device-related failures. The endoleaks are more frequent in patients with aneurysaml aorta treated with TEVAR procedures than patients with aortic transection; these findings confirm the observation that aortic dilation seems to be related to the natural history of the thoracic aorta than to any stent graft effect [49].

Most of our procedures could be performed through a femoral access by a cut down at the groin. In two cases (14.2%), the diameter of the common femoral artery (CFA) was considered too small by the operator, and the endograft was introduced through the external iliac artery, exposed by retroperitoneal access. We have chosen iliac access less frequently than other authors [50, 51] in order to prevent the added morbidity of retroperitoneal exposure, which may have major consequences in those trauma patients [52]. Some minor complications of surgical access were seen in this series in 3 cases (21.4%). Another important prerequisite for TEVAR is to assure a sufficient proximal sealing zone for the stent graft to avoid type Ia endoleak. A minimum length of 20 mm of proximal landing zone was provided in all cases without any endoleak recorded in the follow-up. This approach may have led to coverage of the LSA ostium in some cases (3patients, 21.4%) compared with the range of 23% to 32% described in the literature[50,51]. In those patients, the landing zone between the LSA ostium and the target aortic tear was < 20mm and considered insufficient to assure proximal sealing. Most authors agree that LSA should not be systematically revascularized, except in cases of an ipsilateral large dominant vertebral artery or of coronary bypass from the left internal mammary artery. However, one case of vertebral artery fatal embolic cerebral ischemia has been described by Buz et al,due to mobile thrombus developed on a partially occluded LSA after TEVAR[53]. In our series, only one case out of 3 covered LSA (7.14%), presented with a delayed ischemic arm claudication 2 weeks after the procedure, which has been managed conservatively. Rates of LSA revascularization after coverage of the LSA ostium by an endograft are published in the literature ranging from 0% to25%,[54,47]. LSA revascularization appears also important in cases of stent grafting of an extensive segment of the descending thoracic aorta, inorder to increase spinal cord collateral blood supply[54]. However, endovascular repair of traumatic dissection in descending thoracic aorta usually requires only a discrete length of stent grafting, resulting in a minimal risk of spinal cord ischemia. Despite the big body of available data on the short- and midterm outcomes, the long-term results of endogarft repair for traumatic aortic dissection remain a major issue in relatively young patients. In our study we aimed to know the long term consequences in regards to the stent graft material which is exposed to continuous pulsatile shear stress forces and the long –term results of placing a covered stent in the curvature of the distal aortic arch that might impair the early promising short and midterm results. Based upon our experience with such aortic lesions we can highlight that, the development of an ideal covered stent device for traumatic aortic rupture is important;it should be suitable to the anatomic tight curvature of the distal aortic arch of those young patients, correctly oversized of 15%to 20%, short enough to avoid extensive coverage of intercostals arteries and subsequent spinal cord ischemia, of easy precise deployment with a stable and flexible low profile delivery system, and durably anchored to prevent late migration. Proximal apposition is also an important issue for long-term durability, since individual case reports of stent graft collapse resulting in major morbidity and mortality and the need for re-intervention have been reported with several different devices [55,56]. Another critical issue is the need for devices with smaller diameter suitable for those younger patients with small aortas. We often found problems related to the size miss match between the small aortic diameter and the smallest stent graft diameter available for emergency use.The range of stent graft diameters available for us was 24 to 40mm during the study period. Recently, a lot of stent graft manufacturers have provided commercially available devices with a smallest diameter of 22 mm. It is for that reason; trauma centers who manage such traumatic lesions should therefore be equipped of short stent grafts(≤ 150 mm) with small diameters (20 to 30 mm).

CONCLUSION

According to our experience, and considering also the aforementioned limitations, we can consider that TEVAR for the treatment of acute traumatic dissections of the descending thoracic aorta can be safely and successfully carried out in emergency settings with minimal morbidity and excellent long term results. However, further studies with a higher number of patients are required to confirm our long term results.

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