Endovascular repair of traumatic aortic isthmic rupture

Traitement endovasculaire des ruptures de l'isthme aortique : Résultats à court et à long termes

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Résumé

Introduction : La réparation ouverte conventionnelle pour traiter une lésion de l'aorte thoracique est liée à une mortalité et une morbidité importantes. La réparation endovasculaire (TEVAR) s'est déjà révélée être une alternative dans la réparation des anévrismes thoraciques, mais elle peut jouer un rôle important dans d'autres pathologies aortiques telles que la rupture isthmique aortique traumatique.

Objectif : Evaluer les résultats à court et à long terme de TEVAR dans la rupture isthmique aortique traumatique.

Méthodes : Nous rapportons une étude prospective menée entre 2010 et 2018 sur des patients admis pour une rupture de l'isthme aortique post traumatique.

Résultats : Trente-six patients consécutifs ont été inclus. Tous les patients avaient subi un violent traumatisme thoracique impliquant une décélération soudaine avec des blessures associées dans divers organes. Le score de gravité des blessures (ISS) était de 40 [14-66]. Tous les patients étaient hémodynamiquement stables. Nous avons déployé une endoprothèse d'un diamètre moyen de 26 mm [18-36]. Le taux de succés technique initial était de 100%. Nous avons rapporté un cas de migration de l'endoprothèse. À un mois, les taux de mortalité et de paraplégie étaient tous deux de 0%. Le taux de morbidité était de 2,7%, y compris un cas d'ischémie aiguë des membres inférieurs. Le suivi moyen était de 40,41 mois [6,5-96]. Les taux de mortalité et de paraplégie étaient de 0%. Le taux de morbidité cumulé était de 5,5% avec un cas de kinking à 6 mois. L'endofuite et les taux de réintervention étaient de 0%.

Conclusion : Bien qu'il ne soit pas complètement exempt de complications, TEVAR est une technique fiable pour le traitement des lésions traumatiques de l'aorte thoracique.

Mots-clés

TEVAR, rupture aortique, résultats

Summary

Introduction: Traumatic thoracic injury of the aortic isthmus is rare but serious. Conventional open repair to treat this lesion is related to significant mortality and morbidity. Thoracic endovascular aortic repair (TEVAR) has already been proven to be an accepted option in thoracic aneurysm repair, but it can play a significant role in other pathologies of the thoracic aorta, such as the traumatic aortic isthmic rupture.

Aim: To evaluate short and long term results of TEVAR in traumatic aortic isthmic rupture.

Methods : We report a prospective study conducted between 2010 and 2018 about patients who were admitted for an acute traumatic aortic isthmic rupture. Patients included were all patients with grade 2 (intramural hematoma), grade 3 (aortic pseudoaneurysm) or grade 4 (free rupture) according to classification severity grade who underwent endovascular repair of aortic rupture.

Results : Thirty six consecutive patients were included. All patients had sustained a violent blunt chest trauma involving sudden deceleration with associated injuries in various organs. The injury severity score (ISS) was 40 [14-66]. All patients were hemodynamically stable. Only one patient was paraplegic due to a cervical spinal lesion. All patients had CT scan. The mean diameter of the thoracic aorta was measured at 24mm [16-34]. The mean delay between trauma and endovascular repair was 2 days [1-9]. We implanted 36 endoprothesis with a mean diameter of 26 mm [18-36]. The length of the endoprothesis was 10 cm in all cases. An over-sizing of 20% was performed. We decided to cover the left subclavian artery in 32 cases because landing zone was <20 mm. We did not perform any revascularization in these cases. We did not report any case of arm ischemia or vertebra-basilar pathology. The initial success rate was 100%. The average length of hospital stay was 6 days [4-10]. We reported one intra-operative complication which was a distal migration of the endoprothesis treated by an implantation of aortic extension graft. At one month, mortality and paraplegia rates were both 0%. Morbidity rate was 2.7% including acute lower limb ischemia occurred for one patient. The mean follow up was 40.41 months [6.5-96]. All patients had a CT scan control at 6, 12 months and then annually. Two patients were lost to follow up. The mortality rate was 0% and the paraplegia rate was 0%. The cumulative morbidity rate was 5.5%. We reported one case of kinking occurred at 6 months with formation of thrombus in both the LSA and the left carotid artery. The endoleak and the re-intervention rates were both 0%.

Conclusion ; Although not completely exempt of complications, TEVAR is safe and provides a reliable method for the treatment of traumatic thoracic aortic injuries. It is associated with satisfactory results in the short and long-term follow-up.

Keywords

TEVAR, aortic rupture, results

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INTRODUCTION

Traumatic thoracic injury of the aortic isthmus is the second most frequent cause of trauma-related mortality [1, 2]. Conventional open repair to treat this lesion is related to significant mortality, morbidity and paraplegia incidence [3,4]. Thoracic endovascular aortic repair (TEVAR) has already been proven to be an accepted option in thoracic aneurysm repair, but it can play a significant role in other pathologies of the thoracic aorta, such as the traumatic aortic isthmic rupture. The aim of this study was to evaluate short and long term results of TEVAR in traumatic aortic isthmic rupture.

METHODS

We report a prospective study conducted between 2010 and 2018 about patients who were admitted to our department for an acute traumatic aortic isthmic rupture. The diagnosis of traumatic rupture of the aorta was established by computed tomography (CT) at the emergency department. Patients included in this study were all patients with grade 2 (intramural hematoma), grade 3 (aortic pseudoaneurysm) or grade 4 (free rupture) according to imaging classification severity grade [5] who underwent endovascular repair of aortic rupture. Patients with grade 1 (intimal tear) who were managed medically and patients with hemodynamic instability who were managed surgically were excluded from this study.

RESULTS

General characteristics of the population

Thirty six consecutive patients were included in our study. The mean age was 22 [16-42]. Thirty three patients were male and 3 patients were female. All patients had sustained a violent blunt chest trauma involving sudden deceleration; road accident was noted in 30 cases and a fall from a great height was noted in 6 cases. All patients had associated injuries in various organs: at least two additional severe lesions, including lung contusion and serial rib fractures with reduced respiratory function, cranio-cerebral lesions, abdominal visceral lacerations, spinal lesion and multiple extremity fractures (Table 1). To define the severity of trauma, an anatomic scoring system, the injury severity score (ISS) was used. The mean ISS was 40 [14-66]. All patients were hemodynamically stable. Only one patient was paraplegic due to a cervical spinal lesion. Four patients were admitted to our institution after emergency surgery for life-threatening non-aortic injury such as head injury in 2 cases and abdominal trauma with spleen rupture in 2 cases.

Table 1: Patient population and associated injuries

Age (mean-range)	22 [16-42]
Gender (M/F)	33/3
Delay between trauma and treatment (Days)	2 [1-9]
ISS score	40 [14-66]
Aorta diameter (mm)	24 [16-34]
Distance to left subclavian artery (mm)	8 [0-24]
Associated injuries :	
- Head	15
- Chest	7
- Face	8
- Abdomen	9
- Extremity	18
Spinal	1

All patients had CT scan. The mean diameter of the thoracic aorta was measured at 24mm [16-34]. The landing zone which was the distance from the aortic rupture to the origin of the left subclavian artery (LSA) was measured at 8 mm [0-24]. Diameters of the ilio-femoral arteries were measured and favorable to a percutaneaous femoral access in all cases. The mean delay between trauma and endovascular repair was 2 days [1-9].

Procedure

Thirty five patients underwent general anesthesia. Only the paraplegic patient underwent local anesthesia. The procedure was performed with a mini surgical incision of the femoral artery and a percutaneous access of the left radial artery. The femoral access was used to implant the endoprothesis and the left radial access to spot the origin of the LSA. Sheaths of the endoprothesis vary from 22 to 24 F. We implanted 36 endoprothesis with a mean diameter of 26 mm [18-36]. The length of the endoprothesis was 10 cm in all cases. Thirty endoprothesis were (Medtronic®) and 6 endoprothesis were (Jiotec ®). An over-sizing of 20% was performed. Endoprothesis were composed of covered stents. Only the first proximal stent was not covered. We decided to cover intentionally the LSA in 32 cases because landing zone was <20 mm. We did not perform any revascularization of the LSA in the cases of its coverage. We did not report any case of arm ischemia or vertebra-basilar pathology. All patients received 50 mg of heparin during the procedure. In post operative, all patients were monitored on the intensive care unit with continuous monitoring of arterial and central venous pressure and renal function. They received preventive anticoagulation during the hospitalization.

Outcomes

The initial success rate was 100%. The average length of hospital stay was 6 days [4-10].

We reported one intra-operative complication which was a distal migration of the endoprothesis treated by an implantation of aortic extension graft (Figure 1). At one month, mortality and paraplegia rates were both 0%. Morbidity rate was 2.7% including acute lower limb ischemia occurred for one patient due to the percutaneous femoral access. We performed an embolectomy with a fogarty catheter with a satisfactory result. The mean follow up was 40.41 months [6.5-96]. All patients had a CT scan control at 6, 12 months and then annually. Two patients were lost to follow up. The mortality rate was 0% and the paraplegia rate was 0%. The cumulative morbidity rate was 5.5%. We reported one case of kinking occurred at 6 months with formation of thrombus in both the LSA and the left carotid artery (Figure 2). Because he was asymptomatic, we decided for a conservative treatment for this patient who received double antiplatelet therapy and curative anticoagulation. Evolution was favorable after 12 months of follow up because patient remains asymptomatic. However, thrombus and kinking persisted. The endoleak and the re-intervention rates were both 0% (Table 2).

Table 2: Early and long term outcomes

Length of hospital stay (days)	**6 [4-10]**
Early outcomes (< 1month)	
- Mortality rate	0 %
- Paraplegia rate	0 %
- Complications :	
• Intra-operative	1 case : distal migration
• Post operative	1 case : acute lower limb ischemia
Long term outcomes (> 1 month)	
- Mortality rate	0 %
- Paraplegia rate	0%
- Complications :	
• Kinking + thrombus formation	1 case
- Re-intervention rate	0 %
- Endoleak rate	0 %

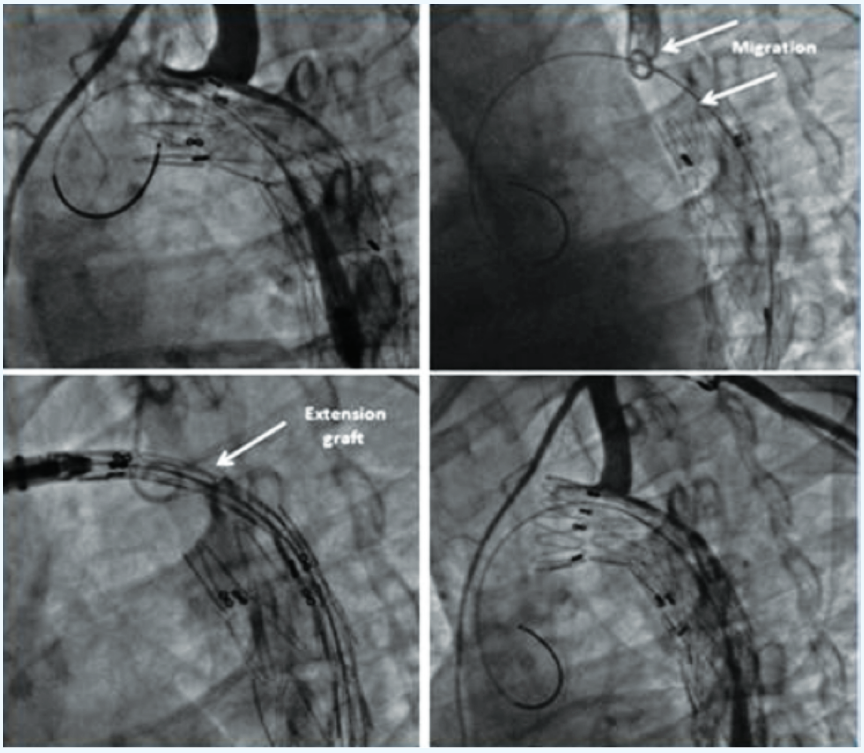

Figure 1: Intra-operative distal migration of the endoprothesis

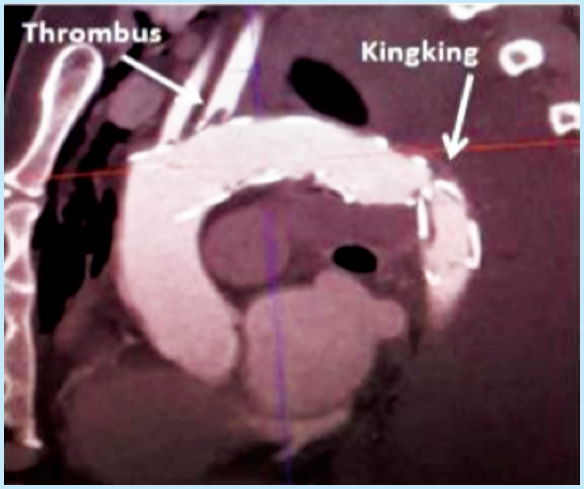

Figure 2: Kinking of the endoprothesis with thrombus formation

DISCUSSION

Our study showed that TEVAR in traumatic aortic rupture is associated with satisfactory early and long term results. Complications which occurred in our study such as distal migration of the endoprothesis and kinking with thrombus formation in the supra-aortic trunks are rare. To our knowledge, these complications had never been reported in literature.

Aortic endoprothesis migration was reported especially in endovascular repair of aortic aneurysm [6]. Such complication, in case of abdominal aneurysm can be explained by the diameter increase of the proximal neck of the aneurysm which can be caused by an enlargement of the degenerative sac [7]. The migration occurred in our study can be explained by an under-sizing of the endoprothesis or by an increase in blood pressure.

Unlike aneurysm, aortic dilatation following TEVAR for blunt trauma is minimal during follow-up. For this reason, stent-graft migration is rare. Fontana F et al [8] evaluated retrospectively 23 patients who underwent TEVAR for aortic rupture. They reported an increase in aortic diameter either proximal or distal to the stent-graft (mean value 0.7 and 0.5 mm, respectively).

We don't have an explication for the kinking of the endoprothesis occurred after 6 months. Aortic arch angulation was not significantly acute in this case. However, an endoprothesis factory defect or stent attachment cannot be eliminated. This result raises concern about the durability of the devices. In fact, stent fractures and fabric fatigue may occur during the 10-year follow-up period. Thrombus formation in the LSA may be due to its coverage despite the administration of heparin but the thrombus in the left carotid artery is still not explained because in the origin of this artery was deployed the non-covered proximal stent of the endoprothesis.

TEVAR Complications are rare bur reported in all studies. Fernandez V et al [9] in a retrospective study of 20 patients reported 4 postoperative complications (20%) after a mean follow up of 43.53 months. Two revascularizations of the LSA and 2 aortic reinterventions (endovascular treatment of a collapsed stent graft and open repair after thrombosis of another stent graft). In this study, all complications were successfully treated. Intra-graft mural thrombus formation was reported at 6 months in 7 patients but no thrombus in supra-aortic truncks. An asymptomatic fracture of the longitudinal reinforcing bar of the stent graft was reported 4 years later in 1 patient.

The American society of the surgery of trauma reported a prospective multicentric study in 2008 [10] which compared TEVAR to open repair for patients with traumatic aortic rupture. In this study authors found that TEVAR was associated with significantly lower mortality and fewer blood transfusions, but there was a considerable risk of serious device-related complications. Twenty (20%) of patients included in the endovascular group developed device related complications among them 18 endoleaks were reported. At this time, TEVAR long term results for aortic rupture were unknown. Initial experiences were not sufficient and trials with long follow up which reported long term results were inexistent. Actually, some new-generation devices, with smaller diameters, are appearing to try to improve the results of TEVAR in treating traumatic aortic injury. In fact, some informations are now available for long term outcomes of TEVAR in aortic rupture. Martin C et al in 2017 [11] reported a study of 60 patients with a mean follow-up of 5 years and a maximum of 14 years. Endovascular repair was successful in all cases with no cerebrovascular or paraplegia events after treatment. There was no repeat surgery related to the aorta during follow-up. No stent graft failure, neurological or ischaemic event related to the stent graft was noted. One patient had a type 1 endoleak without any reintervention. The survival rate was 86.5% in 1 year, 81.6% in 5 years and 75.3% in 10 years. In 2019, Agostinelli A et al [12] reported results after 20 years of follow up for 35 patients with traumatic aortic rupture treated with TEVAR. In this study, two patients died perioperatively (5.7%). The estimated survival was 92% and 87% at 5 and 10 years, respectively, with no aorta-related deaths. The estimated freedom from aortic redo was 96% and 91% at 5 and 10 years, respectively.

Our study confirms the good long term results of TEVAR with a mortality rate of 0% and a paraplegia rate of 0% after a mean follow up of 40.41 months.

The ideal strategy for long-term follow-up of patients with traumatic aortic rupture after TEVAR is still in

evolution. Annually performed CTA control for life is considered the best method for elective TEVAR surveillance, but this strategy might not suit patients who underwent TEVAR for aortic rupture. Opposite to the nature of degenerative thoracic aortic aneurysms, traumatic aortic rupture is not an evolving aortic disease process, but rather a stable injury as a direct result of trauma. Despite current guidelines suggesting the contrary, annual CTA might not be mandatory if TEVAR in aortic rupture cases is successfully completed and no complications occurred in the short- and midterm follow-up periods [13]. The RESCUE trial results suggest that annual follow-up is mandatory only for a period of 5 years [14]. This becomes more important given, the younger age of these patients, and the concerns of cumulative radiation and iodinated contrast exposure [15,16]. Actually, other alternative follow-up strategies are suggested, such as the combination of plain X-ray and MRA that could be of benefit for the long-term surveillance of these patients [13].

Although there is no Level I evidence, TEVAR is gradually gaining ground in treatment of traumatic aortic rupture cases, as the advantages of this procedure in terms of operative complexity when compared to open surgical repair are clear. Open repair usually requires left thoracotomy, single lung ventilation, and aortic cross-clamping with complex cardiorespiratory support. However, in most cases, multi-trauma patients may not tolerate most of the necessary surgical or anesthesiologic periprocedural manipulation, while cervical instability and synchronous presence of multiple fractures could make positioning for left thoracotomy on the surgical table problematic or even impossible [17]. Grave concomitant injuries and increased bleeding risk may also render up the use of heparin.

Open repair of aortic rupture with cardiopulmonary bypass requires a large dose of systemic heparin to perform; a disadvantage that TEVAR does not have. Published data partially support performing TEVAR without the use of heparin in cases with presence of grave concomitant injuries and high risk for bleeding [18-19]. But, on the other hand, the majority of currently available sheaths is superior to 20 F in diameter and occludes the blood flow at the access vessel. For this reason, we decided to administrate 50 mg of heparin during the procedure. Despite this preventive measure, we reported a case of lower limb ischemia in our series.

As previously mentioned during the TEVAR versus open repair comparisons, patients receiving TEVAR have better outcomes. Mousa et al [20] reported a total hospital mortality rate after surgical intervention of 10.8%; but there were significant differences when open surgery was compared with TEVAR, which supports more utilization of TEVAR in blunt trauma (14.61% vs. 7.43%; p = 0.009). In the same study, a logistic regression analysis after adjustment by age, sex, and comorbidities indicated that patients were significantly more likely to die after open surgery than after TEVAR (OR, 8.3; 95% CI, 3.04Y22.48). The patients in the open surgery cohort had more complications, such as stroke, cardiac and renal failure and were also associated with increased mortality. In a comprehensive meta-analysis review of 7,768 patients, Murad NH et al [21] reported the mortality rates of patients who were treated with TEVAR, open repair, and non operative medical management to be 9%, 19%, and 46%, respectively (p G 0.01). In addition, they reported that the risk of spinal cord ischemia and end-stage renal disease was higher for patients who received open repair. The findings and clinical implications from this review were used by the Committee on Thoracic Aortic Disease from the Society for Vascular Surgery (SVS) to aid in the development of suggestions and clinical practice guidelines for the use of TEVAR while treating patients with blunt trauma, as mentioned below.

The American Society of Vascular surgery [22] reported a systematic review which included 7768 patients from 139 studies. The mortality rate was significantly lower in patients who underwent endovascular repair, followed by open repair, and nonoperative management (9%, 19%, and 46%, respectively, $P < .01$). Based on the overall very low quality of evidence, the committee suggests that endovascular repair of thoracic aortic transection is associated with better survival and decreased risk of spinal cord ischemia, renal injury, graft, and systemic infections compared with open repair or nonoperative management (Grade 2, Level C).

In our study, we covered the LSA in 32 patients. Dealing with LSA coverage is challenging in TEVAR for traumatic aortic rupture. To date, no clear consensus regarding preoperative LSA revascularization has been reached and published data are controversial. Some authors suggest LSA coverage when necessary and expectant strategy, and others suggesting the opposite [23-25]. Suggested indications include patent left internal mammary artery to left anterior descending coronary artery bypass or any anatomic variation that renders a patent left vertebral artery necessary. Decision can be made on an individual basis and take into account the level of expertise in either open or endovascular technique, the patient's general condition, and the presence of concomitant injuries [26,27]. The landing zone requirements for TEVAR are different to that of thoracic aneurysmal disease. In our study, we decided to cover the LSA in the case of landing zone <20 mm in order to have a better anchorage and proximal fixation of the stent graft. Beyond 20 mm, we think that endoprothesis is sufficient to cover the aortic rupture and there is no need to cover the LSA. We did not perform any LSA revascularization in our study and results were satisfactory because we did not report any arm ischemia or vertebra-basilar pathology.

In our series, we did not perform cerebrospinal fluid drainage because spinal cord ischemia occurs rarely (3%) after TEVAR for traumatic aortic rupture, significantly lower than open thoracic aortic repair [21,28] . To our opinion, routine cerebrospinal fluid drainage is not justified by a number of characteristics of TEVAR for aortic rupture, such as the limited length of the covered thoracic aorta (<10 cm) and the substantial risk of epidural bleeding in the multi-trauma patient, who can presents with synchronous coagulopathy.

CONCLUSION

Although not completely exempt of complications, TEVAR is safe and provides a reliable method for the treatment of traumatic thoracic aortic injuries. It is associated with satisfactory results in the short and long-term follow-up.

Conflict of interest: None

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