Review Article
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Treatment Strategy for Blunt Thoracic Aortic Injury in the Thoracic Endovascular Aortic Repair Era

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Abstract

The treatment strategy for blunt traumatic aortic injury (BTAI) has changed dramatically in the last decade. It is reported that outcomes of thoracic endovascular aortic repair (TEVAR) have improved and now the first choice of treatment has completely replaced from surgical treatment to endovascular repair. In patients with co-morbid trauma, TEVAR, which is rapid, less invasive and requires a small amount of anticoagulant, is highly advantageous. Since the commercially available recent stent grafts can be adapted from a diameter of the aorta larger than 16mm, they can be used for most adolescents as well. Based on recent findings, we summarized the latest treatment strategy for aortic injury.

Keywords: Endovascular repair; Thoracic aorta; Trauma; Treatment strategy; Surgical treatment; Pediatric

Abbreviations

BTAI: Blunt Thoracic Aortic Injury; TEVAR: Thoracic Endovascular Aortic Repair; SVS: Society for Vascular Surgery; LSA: Left Subclavian Artery; EVAR: Endovascular Aortic Repair; PWV: Pulse Wave Velocity

Introduction

Blunt thoracic aortic injury (BTAI) remains the second most common cause of mortality after blunt trauma after head injury. The natural history of BTAI is still fatal. BTAI has been treated with open surgery in many decades, which disappointed the surgeons with significant mortality and morbidity. Importantly, pre-hospital mortality is 70-80 % and one third of those reaching medical attention will die without definitive treatment [1-3]. There is less sudden death at the scene of automobile accidents because of improved vehicle designs and safety technology [4]. With the rapid shift from open repair to thoracic endovascular aortic repair (TEVAR) as the primary treatment for most BTAIs, outcomes have improved with significantly reduced mortality and morbidity [5-8].

Mechanism of Injury

Despite decreasing in the incidence of motor vehicle accidents, most trauma centers report an increased number of patients with BTAI [9]. This may be a result of a decrease in prehospital mortality rates from 90% to 63% associated with the implementation of automobile safety measures and improved in-field management and transport.

Blunt aortic injury most often occurs after sudden deceleration, usually in motor vehicle accidents. Other causes include crashes of motorcycles, falls from height, auto–pedestrian collisions, and thoracic crush injuries [10]. The descending aorta is fixed to the chest wall, whereas the heart and great vessels are relatively mobile. Traditional views have held that the proximal descending aorta, where the relatively mobile aortic arch can move against the fixed descending aorta, is at greatest risk from the shearing forces of sudden deceleration [2,11]. However, injury may also occur to the ascending aorta, the distal descending thoracic aorta, or the abdominal aorta [10].

Regarding the mechanism of development of BTAI, several theories have been proposed in addition to the stretching effect from sudden deceleration. Aortic rupture during a sudden increase in intra abdominal pressure may explain the association between blunt aortic injury and diaphragmatic rupture. A "water-hammer" effect, which involves simultaneous occlusion of the aorta and a sudden elevation in blood pressure, and the "osseous pinch" effect from entrapment of the aorta between the anterior chest wall and the vertebral column have also been theorized. Most injuries probably involve a combination of forces [2,12].

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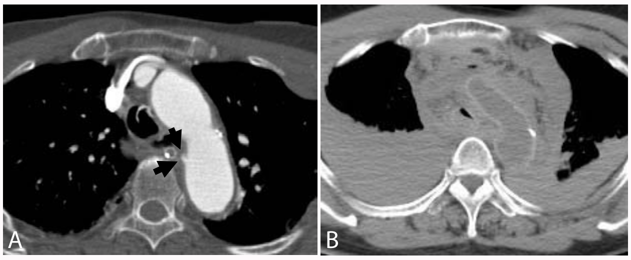

Figure 1: CT image on admission (A) and 2 hours after admission (B). In panel (A), arrow shows a small pseudoaneurysm in the proximal descending thoracic aorta. And panel (B) shows a fatal aortic rupture. D-dimer value was 273μg/ml on admission.

The past decade witnessed dramatic changes in the incidence, diagnosis, and therapy of BTAI [2].With the growing shift from surgical repair to TEVAR as the primary treatment in patients with BTAI, outcomes have improved with significantly reduced mortality and morbidity, including procedure-related paraplegia [5,13-18]. The theoretical sequence of injury involves rupture of the intimal and medial layers. After a period of unpredictable duration, rupture of the external, adventitial aortic wall occurs [19]. Without intervention, the risk of a fatal free rupture of the aorta cannot be ruled out [2,15]. In an *in vitro* study of porcine aortic injury, an intima–media tear occurred before complete disruption of the entire vessel in 93% of specimens. This partial disruption occurred at a mean of 74% of the physical stress required for complete rupture [20].These findings suggest that sufficient residual strength exists after an intima–media injury before complete rupture to allow timely diagnosis and treatment [2]. Because the adventitia remains intact as a barrier to exsanguination in survivors, the most common pathologic findings are tears of the intima and media. Traumatic laceration of the aorta is the most common lesion seen at autopsy, although survival even from this injury has been reported [21].

Treatment Strategy

BTAI was traditionally treated with an open surgical approach. The clamp and sew technique that was used in the past is now preferred very rarely due to the high incidence of paraplegia. Cardiopulmonary bypass is used as a safe method of proper support, which has the advantages of circulatory support, distal perfusion and reduction in paraplegia rates, as well as dealing with unexpected life-threatening bleeding [3,6,22]. Nevertheless, the reported mortality and paraplegia incidence of a group undergoing open surgery were 20.2% and 5.7%, respectively; this is mostly because many of the patients had severe associated injuries, and such injuries serve as an independent mortality factor [23].

TEVAR is now the dominant surgical approach in BTAI, with substantial perioperative morbidity and mortality benefits over open aortic repair [24].Given the multiorgan nature of the injuries in most patients with BTAI, TEVAR has quickly replaced open repair as the treatment of choice for most anatomically suitable patients with BTAI [25]. Overall mortality after admission for BTAI has declined, which is most likely the result of the replacement of open repair by TEVAR as well as the broadened eligibility for operative repair [13,23,24,26].

It appears that patients with minimal aortic injuries (grades I and II) may be managed medically, with the majority resolving within 8 weeks. Minimal aortic injury is associated with low mortality and excellent intermediate-term outcomes [25]. Moderate aortic injury can be managed semi electively with TEVAR, and severe aortic injury requires emergency TEVAR. Several studies demonstrated that high D-dimer levels, which reflect hyperfibrinolysis resulting in clot lysis, were associated with a poor outcome in all trauma patients [27,28]. In moderate aortic injury patients with elevation of D-dimer levels there is a possibility of falling into a sudden free rupture, so emergency TEVAR should be considered (Figure 1). Open surgery is reserved for patients who are not suitable for endovascular repair [29,30].

Medical Treatment

The severity of BTAI is classified into four categories: grade I, intimal tear; grade II, intramural hematoma; grade III, pseudoaneurysm; and grade IV, rupture [31]. SVS guidelines recommend TEVAR for grade II through IV BTAIs, given that grade I injuries typically heal spontaneously.

A recent retrospective review of 41 patients with grade I or II injuries that were conservatively managed demonstrated that at mean follow-up of 86 days, 55% had complete resolution of injury, 40% had no change in aortic injury, and 5% had progression from grade I to grade III injury [32]. When progression did occur, it tended to occur early, at a mean of 16 days from injury. Given the mounting evidence, conservative management of grade I and II injuries is recommended with appropriate observation and follow-up imaging, usually at a short interval (2–7 days) and then at 30 days, 6 months, and 1 year or until the lesion resolves [13,32].

Those without secondary sings of injury (SSI), defined as pseudocoarctation, mediastinal hematoma with mass effect, and large left hemothorax, may undergo delayed repair after initial medical management. The majority of these injuries healed or remained unchanged on repeat imaging and nonoperative management did not result in aortic-related death or require intervention [32,33].

Endovascular Treatment

Current trends

Developments in diagnosis and treatment have transformed the management of BTAI. For patients in stable condition, treatment practice has shifted from early open repair to nonoperative management for low-grade lesions and routine delayed endovascular repair for more significant injuries. However, effective therapy depends on accurate staging of injury grade and stability to select patients for appropriate management [34]. Computed tomography of the chest with intravenous contrast is strongly recommended to diagnose clinically significant BTAI.

Ghazy et al. report that with an overall mortality of 18%, no early device related complications, and two re-operations during the follow-up, the results of the study are similar to those of the Seattle group, who reported an all-cause in hospital mortality of 15%, with 6% BTAI related mortality in their latest series [18,29].

A number of specific management details remain somewhat controversial, or at least surgeon or institution specific. These issues include management of revascularization for left subclavian artery (LSA) coverage, intraprocedural systemic heparinization, routine placement of spinal drainage, and choice of open or percutaneous access. Adams et al. report, as their experience with TEVAR for BTAI has grown, the frequency with which they have needed to cover the LSA has steadily decreased due to their acceptance of a shorter proximal landing zone in nonaneurysmal traumatic aortic pathology [13].

Indications for endovascular treatment

Endovascular repair is strongly recommended for patients without contraindications [18,35]. However, minimal aortic injury can be successfully managed nonoperatively with optional follow-up imaging and antiplatelet therapy.

With the advent of CT scans with improved resolution, and the ensuing detection of aortic injuries that would previously have been undetected, it has also been suggested that some patients with type I and type II injuries could be managed medically, with no need for subsequent repair [33,36]. Furthermore, as patients with traumatic aortic injury commonly have other, potentially life threatening injuries, the timing of TEVAR must be chosen taking all the injuries into consideration [2]. On the other hand, in hybrid operating theatres there is now a chance to treat multiple injuries in the same environment, making the need to prioritize among injuries less crucial [37].

A case of an 8-year-old girl was reported to have undergone successful endovascular repair of a traumatic thoracic aortic injury using a Zenith Alpha thoracic endograft (Cook Medical, Bloomington, IN) [38]. Although open surgical repair is the gold standard for repair of traumatic aortic injuries in the pediatric population, new endovascular stent grafts with smaller delivery systems offer a viable alternative in carefully selected patients mainly those with concomitant injuries putting them at a prohibitive risk for open repair [38-40].

Complications of endovascular treatment

Brain injury after TEVAR is a major complication and most often associated with the underlying pathology or excessive device manipulation within the arch [41]. Spinal cord injury can occur immediately after TEVAR or be delayed, requiring clinical and neurological surveillance [42,43]. Retrograde aortic dissection may also occur.

Endovascular aortic repair (EVAR) and TEVAR have been widely incorporated into clinical practice, but changes in arterial stiffness after aortic endografting and postimplantation syndrome remain important concerns to be investigated. Currently used stent grafts have biomechanical properties with stiffness not comparable with that of the native aorta. Also, it can be assumed that the alterations of aortic mechanical properties can have a direct impact on heart output. The biomechanics of the thoracic aorta play an essential role in the endovascular treatment of the descending thoracic aorta and its side branches. The pulsatility of the aorta and its side branches during the cardiac cycle and other morphologic factors might all be of influence on the endovascular treatment for thoracic aortic pathology [44]. Tzilalis et al. studying a series of young patients treated with TEVAR for thoracic aortic transection concluded that aortic endografts could produce a discontinuation of the pulsatile waves with a subsequent increase of aortic pulse wave velocity (PWV) and systolic blood pressure [45]. Increased PWV is an important risk factor for future cardiovascular events and should be evaluated in all patients after TEVAR.

Stent graft collapse, endoleaks, and stent migrations are all known complications of TEVAR [46]. Recently, cases presenting thrombosis after stent grafting for BTAI and treated in different ways have been discussed [42,43,47]. Although TEVARs performed for BTAI develop small mural thrombi at a greater rate than TEVARs for aneurysmal disease, likely as a consequence of aggressive oversizing leading to endograft infolding in BTAI, the incidence of intragraft thrombosis remains low [43]. The aortic diameter decreases dramatically in trauma patients with hypovolemic shock. This decrease in aortic diameter could lead to inadequate aortic measurements and undersizing of the endograft in hemodynamically unstable BTAI patients requiring TEVAR [48]. In a 19-year-old male of a motorcycle accident with hypovolemic shock, the average thoracic aortic diameter on the CT at admission was 18% smaller compared with that at the time of discharge (Figure 2).

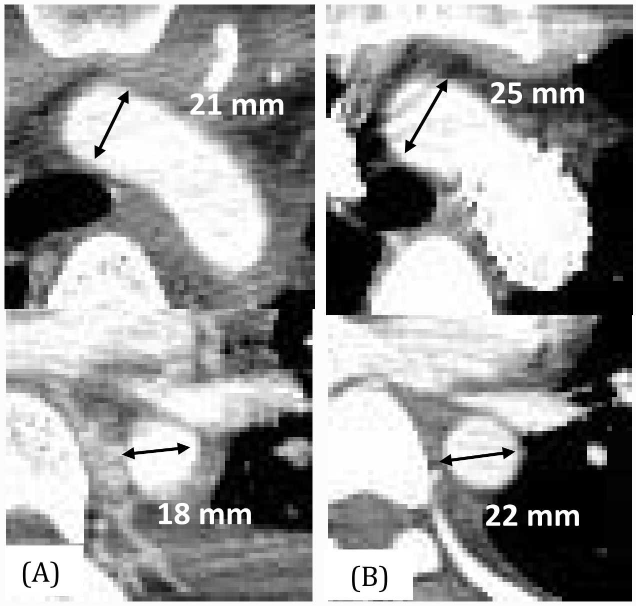

Figure 2: A 19-year-old male of a motorcycle accident, treated with TEVAR. CT axial views demonstrate that the average thoracic aortic diameter on admission (A) is smaller than that at the time of discharge (B). Upper views: aortic arch, lower views: descending thoracic aorta.

Surgical Treatment

In recent years there has been a paradigm shift from open repair to TEVAR as the preferred treatment for patients with blunt traumatic thoracic aortic injury, regardless of patient age. This is supported by several studies demonstrating lower mortality than after open repair [2,5,17,49].

Various operative techniques may be used in an open repair such as direct suture, resection and direct anastomosis, and insertion of an inter-position graft, and these depend on the nature and extent of the injury [50-52]. Cardiopulmonary bypass is used as a safe method of proper circulatory support, as well as dealing with unexpected life-threatening bleeding during the operation with the use of an integral pump sucker. Early studies assessing perioperative outcome after open repair showed poor results, with high surgical mortality and morbidity, of which a high paraplegia rate was most notable [23,50-52].

Treatment of Pediatric Patients

Traumatic aortic injuries are an uncommon injury in children and can result from motor vehicle collisions or other sudden deceleration mechanisms. However, TEVAR still offers significant benefits over open repair for patients with suitable aortic anatomy [13]. Currently, the conformable Gore TAG thoracic endoprosthesis (CTAG) device (W. L. Gore and Associates, Flagstaff, AZ) and the Valiant Thoracic Stent Graft System (Medtronic Vascular, Santa Rosa, CA) are available in 21- and 22-mm configurations and are indicated to treat down to 16- and 18-mm-diameter aortas, respectively. Considerations for treating BTAI in young patients must also take into account allowance for continued somatic growth. For these reasons, some centers advocate the use of covered balloon-expandable stents because they are shorter in length and can be further dilated in the future as the patient's aorta grows [46,53]. Lengthy follow-up care is recommended in children treated with an endovascular device to monitor for endoleaks and device complications [40].

Conclusions

The use of TEVAR of the traumatically injured aorta continues to evolve, and TEVAR has established itself as an alternative strategy to surgical intervention for the management of BTAIs. TEVAR is a rapid, safe, and effective therapy in patients with BTAI. In moderate aortic injury patients with elevation of D-dimer levels there is a possibility of falling into a sudden free rupture, so emergency TEVAR should be considered. Optimal treatment of children with BTAI remains an area of uncertainty given the rarity of this injury and limited long-term data on the outcomes with the endovascular technique. Although long-term device related adverse events seem to be rare, little is still known about aortic remodeling of the affected segment over decades. Careful consideration must continue to be repeated on this fairly novel and effective treatment.

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