Chapter

Blunt Traumatic Aortic Injury

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Abstract

Traumatic aortic injuries represent a leading cause of death following motor-vehicular accidents. These injuries curry a very high mortality rate even though a significant number of patients reaches the hospital alive. These injuries are identified in the contest of a polytrauma work up and are almost always associated with multiple other severe traumatic injuries which makes the management of these patients very challenging. The technology advancements seen in recent years with radiologic imaging and the progress of the therapeutic options brought up by the uprise of endovascular therapy, along with the sophistication of the techniques of trauma resuscitation and intensive care management, have improved significantly the overall prognosis of these patients. Although traumatic aortic injuries need to be generally considered a life-threatening condition, their degree of severity may differ significantly from case to case requiring immediate repair in some patients, whereas their repair can be delayed in cases when the severity of the aortic injury does not represent an immediate threat to the patient life. Therefore, the challenge of treatment of the polytrauma patients with an aortic injury is to identify the best strategy of therapy able to prioritize the treatment of the injuries based on their lethal potential. In this contest, the ability of properly defining the severity of the aortic injury is the key-factor to allow the appropriate definition of a treatment strategy able to identify treatment priorities. In our experience, radiologic assessment of the aortic injury in correlation with the evaluation of clinical parameters and a comprehensive polytrauma assessment allows to optimize the ability of the trauma team to establish the most appropriate strategy for the care of this complex patients' group.

Keywords: polytrauma assessment, traumatic aortic injury, thoracic endovascular aortic repair, radiologic assessment

1. Introduction

Traumatic aortic injuries (TAI) represent the second leading cause of death from motor vehicle crashes, accounting for 15% of all motor vehicle accident associated deaths [1–3]. According to a historical case series, death occurs at the scene of the accident in 70 to 90% of these cases [1, 3–7], and of the patients (75%) who arrive to the hospital alive, although hemodynamically stable, only 10% survives more than 6 hours [1, 3]. Patients with TAI surviving at the scene who arrive to the hospital alive most frequently present with an injury at the aortic isthmus, since periadventitial tissue in this location seems to provide some degree of protection against free rupture, allowing the necessary time to transfer the patient from the trauma scene to the hospital [8–10]. The majority of patients with BAI have an

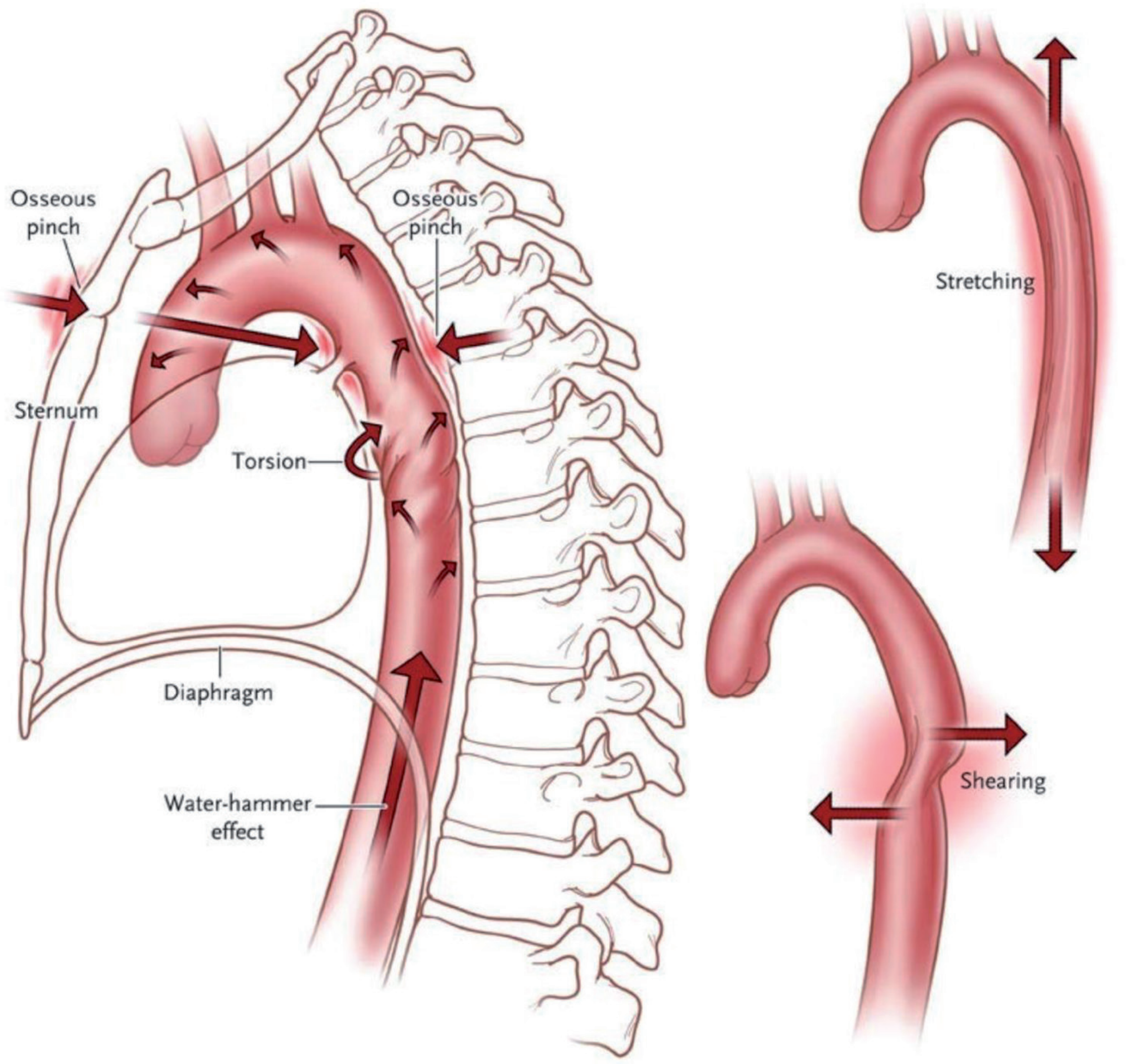

Figure 1.
Theories of blunt aortic injury. Blunt aortic injuries involve a combination of forces, including stretching, shearing, torsion, a "water-hammer" effect (which involves simultaneous occlusion of the aorta and a sudden elevation in blood pressure), and the "osseous pinch" effect from entrapment of the aorta between the anterior chest wall and the vertebral column (modified with permission) [11].

associated closed head injury (51%), multiple rib fractures (46%), lung contusions (38%), or orthopedic injuries (20–35%) [1].

2. Pathophysiology

Blunt traumatic aortic injuries can involve any thoracic aortic segment, including occasionally even the abdominal aorta. The aortic isthmus is by far the most common location, followed by the ascending aorta (10–25%), the aortic arch (10–20%) and the abdominal aorta (5–10%). The theory is that a combination of sudden deceleration, associated to torsion, stretching and sharing forces, and thoracic compression, would cause the aortic injury (**Figure 1**) [11].

3. Clinical management

Diagnosis is made in the contest of the trauma work up as defined by the Advanced Trauma Life Support (ATLS) guidelines. Computed tomography (CT) scan is by far the test of choice to diagnose TAI with a sensitivity and negative predictive value close to 100%. In the very unusual circumstance that CT scan does not provide a definite answer and some doubt on the presence of a TAI remains, which would only occur in the case of a minimal injury, aortic angiogram, eventually with intravascular ultrasound (IVUS), represents the gold-standard to reach a definitive diagnosis. Once diagnosis is made, the severity of the injury assessed by imaging studies and the polytrauma assessment will dictate the treatment strategy [12].

Based on the application of ATLS protocols, treatment of the different trauma injuries will be prioritized based on their acute lethal potential [10]. Exsanguinating hemorrhages from any location and intracranial injury with mass effect take priority of treatment, unless hemodynamic instability obviously related to the imaging finding of an extremely unstable aortic injury would suggest to proceed with immediate endovascular aortic repair. In general, clinical management of the trauma patient arriving to the hospital requires the application of standard measures of trauma resuscitation aiming at establishing the best possible hemodynamic conditions. Once a TAI is diagnosed, anti-impulsive therapy with short-acting beta-blockers should be instituted, if allowed by hemodynamic conditions, to reduce aortic wall-stress. At that point the timing of the aortic repair should be decided based on the radiologic assessment of the aortic injury, the patient's general conditions, accounting in the decision-making process a polytrauma assessment which will allow to determine the sequence of therapeutic interventions offering the best chance of a positive clinical outcome [10].

In fact, although the vast majority of aortic injuries, based on a traditional 'old-school' approach, would represent an indication for therapeutic intervention, there has been more recently a strong school of thoughts proposing a conservative type of management for the type of injuries with a low lethal potential. In these cases, the therapeutic intervention can be delayed or completely aborted, selecting a strategy of radiologic monitoring which would allow to indicate a need for intervention only in cases showing evolution of the aortic injury in a growing pseudo-aneurysm [13–18].

The Society for Vascular Surgery (SVS) has proposed a grading system for TAI intended to rate the degree of severity of the injury (**Figure 2**) [19, 20]. Nevertheless, this grading system has failed to find reliable clinical correlation with risk of aortic rupture and death [15, 19–22], because this classification is qualitative but not quantitative, since can be useful to define the type of injury (intimal laceration versus intramural hematoma, versus pseudoaneurysm, versus free rupture), but does not include parameters to define size and extension of the injury. In our experience of blunt aortic injuries from 3 Level I Trauma Centers in the US from July 2008 to December 2016, we reviewed a total of 76 patients [12]. We analyzed overall mortality and TAI-related mortality (directly caused by the effects of the aortic injury) at 30 days in relation to factors such as: hemodynamic parameters on presentation (SBP, HR and need for vasopressor medications), timing of treatment, injury severity score (ISS) and aortic injury grade as defined by the Society for Vascular Surgery Clinical Practice Guidelines. Aortic injury (AI) grade was dichotomized as stable, grade I-II, and unstable, grade III-IV [12]. Using a new injury scale system, we classified the AI as "Severe" (Radiographic Severe Injury, RSI) when they included findings of [1] total/partial aortic transection (**Figure 3**), [2] active contrast extravasation (**Figure 4**), or [3] the association of 2 of more of the following: contained contrast extravasation >10 mm in bigger dimension, periaortic hematoma and/or mediastinal hematoma with >10 mm thickness, or left pleural effusion (**Figure 5**). We found that mortality caused by the aortic injury was associated with high ISS, SBP < 100, HR ≥ 100, and vasopressors requirement. Also, our

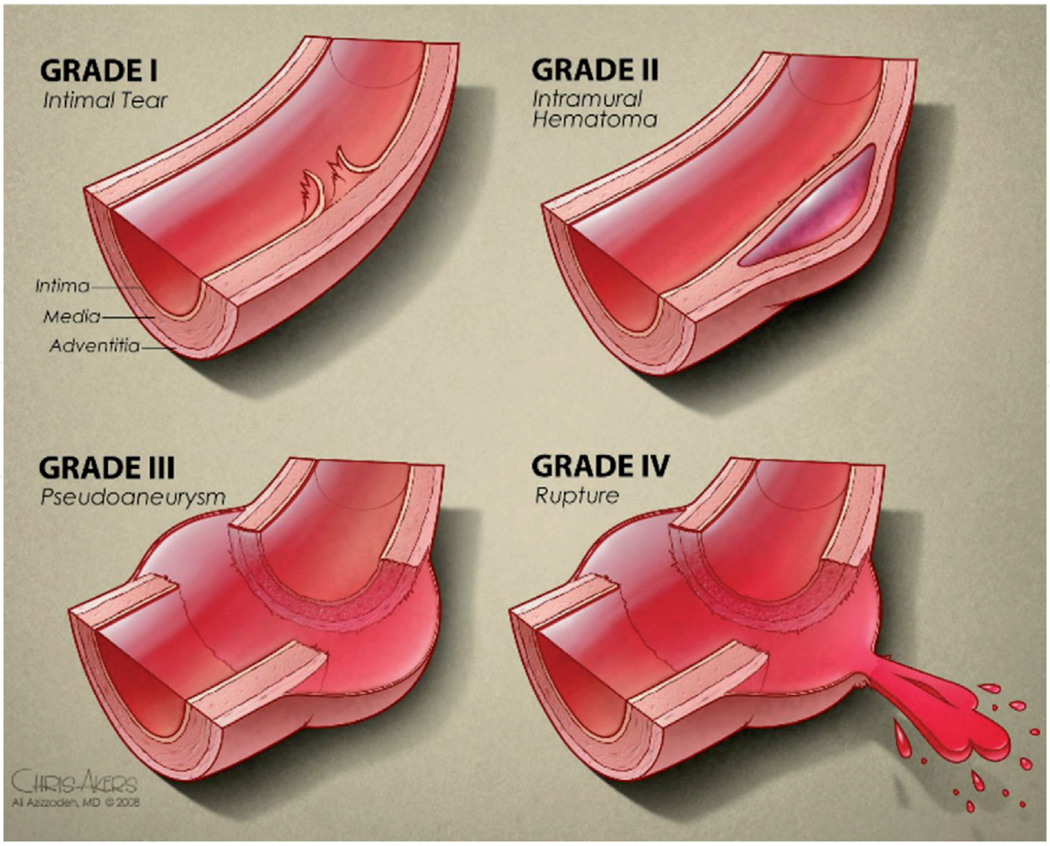

Figure 2.
The Society for Vascular Surgery classification of traumatic aortic injury. Grade I: Intimal tear; grade II: Intramural hematoma; grade III: Pseudoaneurysm; grade IV: Rupture. This grading system has failed to find reliable clinical correlation with risk of aortic rupture and death and therefore cannot find use to indicate the lethal potential of the aortic injury and support the necessary choices that need to be made to select the most appropriate therapeutic strategy to improve the prognosis of the polytrauma patient with TAI (modified with permission) [19].

new classification system of RSI, identifying patients with 'unstable' injuries, found statistically significant association with mortality (**Table 1**).

Therefore, our proposed system of grading of the aortic injury based on radiologic findings and the evaluation of clinical parameters, by the assessment of hemodynamic conditions (SBP, HR, and pressors requirement), is the most important elements to define the severity of the aortic injury and its lethal potential [12].

Besides the exceptional technical advancement of imaging studies that has allowed to increase tremendously the sensitivity to diagnose TAI, the most significant stride in the management of these injuries has been made by the rise of endovascular therapy, since treatment can be delivered with a faster approach using this much less invasive transcatheter technique and with substantial less operative and perioperative risk, compared to the 'open' surgical technique of aorta replacement used as the standard approach until a decade ago [15, 23–25].

Nonetheless, the choice of the most adequate timing for treatment of the aortic injury, particularly with respect to other major traumatic injuries, remains an area of active study. There are currently no clear guidelines for determining which patients may benefit from delayed aortic repair, nor there are validated methods of assessment of the severity of the aortic injury which would allow to choose when prioritize treatment of the aorta [15, 21]. A recent review of a small number of cases has suggested that some patients with small size pseudoaneurysms may be safely managed nonoperatively for the long-term [15, 25, 26]. Nevertheless, the ideal management for stable pseudoaneurysms after BAI remains a subject needing further study.

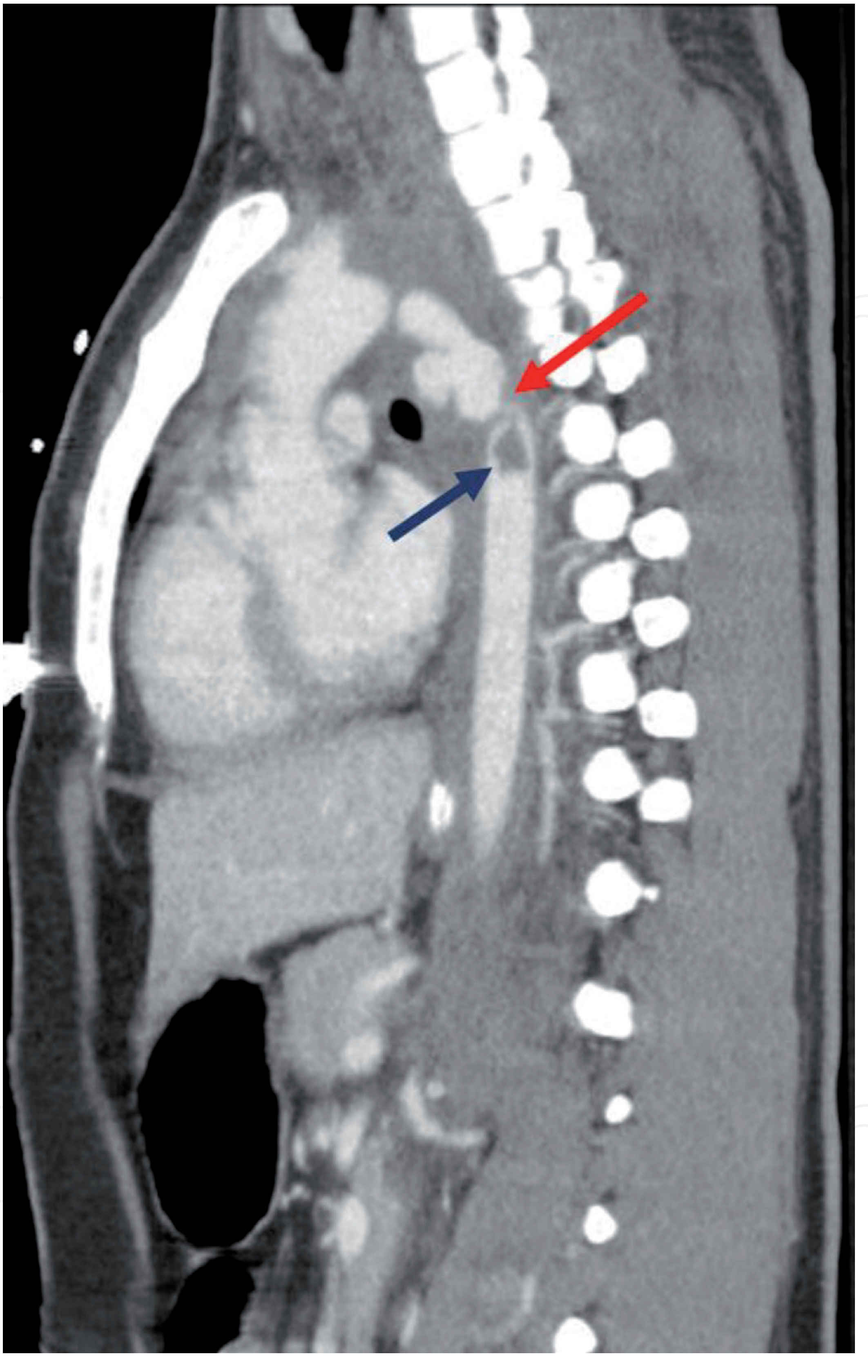

Figure 3.
CT scan of the chest with IV contrast demonstrating aortic transection near the isthmus (red arrow), also associated with intraluminal aortic thrombus as shown by the blue arrow. (transection is defined by total or partial interruption of the column of intra-venous contrast flowing within the aortic lumen).

In this contest, our system of classification created criteria for radiographic assessment of the degree of aortic injury used as a binary variable (severe versus non-severe), allowing to identify the patients in needs for immediate aortic repair.

The standard 'open' surgical technique of repair of TAI has been the replacement of the damaged aortic segment with a synthetic vascular graft. The most common

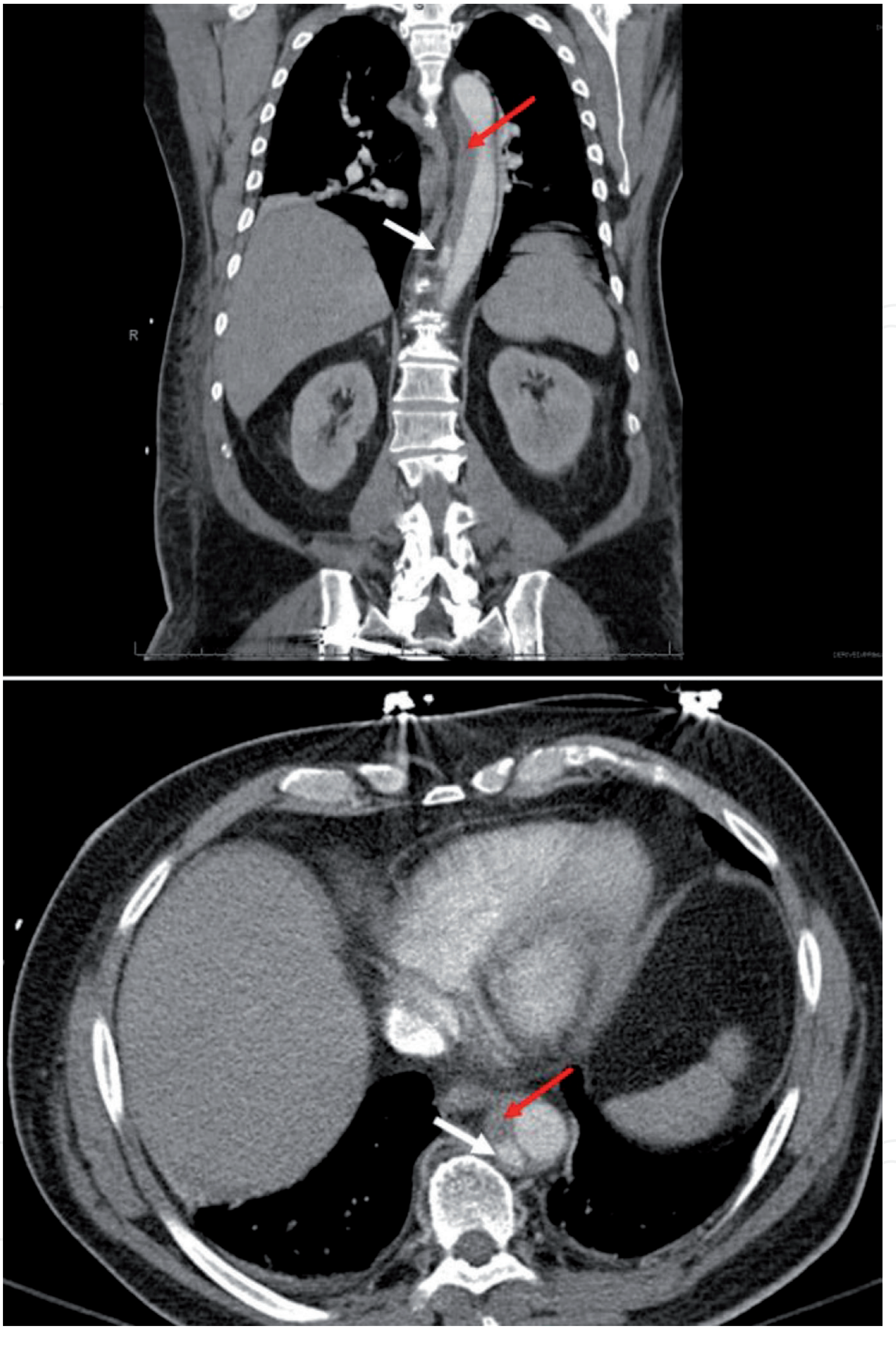

Figure 4.
Sagittal and transverse CT scan images of large intravenous contrast extravasation as shown by red arrows (irregular IV contrast contour outside the aortic wall boundaries).

location of the injury at the aortic isthmus requires a left thoracotomy approach, completing the aortic replacement with left atrial to femoral by-pass (**Figure 6**). This technique had replaced the previous approach of 'clamp and saw' (without use of partial cardiopulmonary bypass), which was associated with a very high incidence of complications, of which paraplegia secondary to spinal cord ischemia was the most common and devastating one. The strategy of replacement using left atrial to femoral bypass allows to maintain perfusion of the lower body after

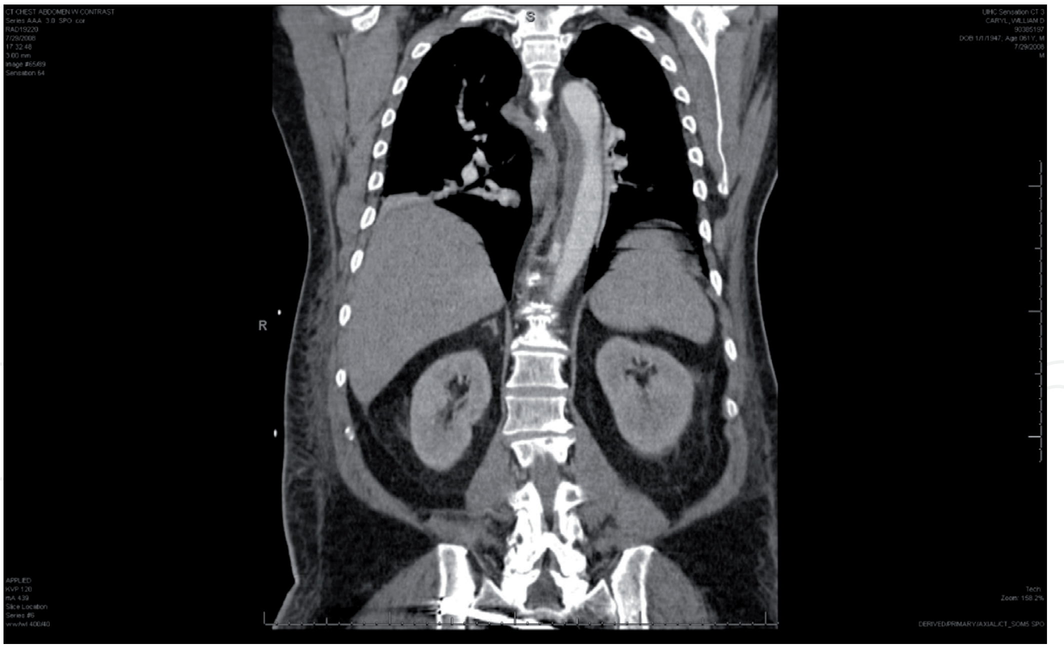

Figure 5.
Coronal and transverse CT scan images of periaortic hematoma (red arrows) and aortic pseudoaneurysm as shown by white arrows (pseudoaneurysm is defined by a regular intravenous contrast contour outside the aortic wall boundaries).

cross-clamping of the aorta above the injured segment, providing a better degree of protection of the spinal cord and other end organs from ischemia (**Figure 6**).

Nonetheless, the operation is still associated with significant morbidity and difficult postoperative recovery, considering that has to be accomplished under the very dangerous conditions of an extreme emergency in patients most likely affected by multiple other traumatic injuries.

The real revolution in the treatment of TAI has been accomplished with the uprise of endovascular aortic repair, which has impacted remarkably on the overall prognosis of these patients allowing to obtain an expedite aortic repair, without the need of an open surgical approach, which translates in much lesser procedural stress, much lesser operative risk, especially in the contest of the common poor general condition of the polytrauma patient, and much easier postprocedural recovery.

The other significant progress in the treatment of TAI has been the realization that under certain conditions the repair of TAI ought to be deferred, prioritizing the treatment of other major concomitant traumatic injuries which represented a more immediate danger for the patient. In a relatively recent prospective multicenter study sponsored by the American Association for the Surgery of Trauma (AAST), the effect of early versus delayed repair was observed in 178 patients admitted with BAI between 2005 and 2007. The study concluded that 'delayed repair of 'stable' blunt thoracic aortic injuries is associated with improved survival [16].

The decision establishing the timing of treatment of TAI should be exclusively based on the characteristics of the injury as seen on CT scan imaging and on the assessment of clinical factors in relation to other associated injuries [15, 21–24]. The Injury Severity Score (ISS) has been used to predict risk of morbidity and mortality associated with blunt trauma since the 1970s. It was demonstrated initially to correlate well with length of stay, need for major surgery, significant disability, and death [27, 28]. ISS does have known limitations, such as more limited applicability to penetrating trauma or other trauma patients in which injuries are localized only to one body area [28]. However, it continues to be a valuable tool used prominently in trauma databases to assign an objective value to traumatic injuries and predict risk for significant morbidity/mortality.

	Unadjusted Mortality		Unadjusted BAI-related mortality	
	OR (CI)	**P value[1]**	**OR (CI)**	**P value[1]**
Age	1.01 (0.98, 1.04)	0.406	1.01 (0.98, 1.04)	0.665
ISS	1.07(1.02, 1.11)	0.003	1.07 (1.02, 1.12)	0.004
SBP < 100	10.54(2.61, 42.65)	<0.001	24.00 (2.84, 203.14)	0.004
HR ≥ 100	4.88 (1.37, 17.44)	0.015	7.48 (1.47, 38.17)	0.016
Pressors	7.S6 (2.12, 29.12)	0.002	6.33 (1.52, 26.33)	0.011
AI grade(SVS)	2.65 (0.67, 10.45)	0.164	6.63 (0.79, 55.41)	0.081
RSI	3.02 (0.92, 9.90)	0.068	5.37 (1.28, 22.90)	0.023
	Adjusted Mortality		**Adjusted BAI-related mortality’**	
	OR (CI)	**P value[2]**	**OR (CI)**	**P value[2]**
ISS	1.04(1.00, 1.09)	0.074	1.05 (1.00, 1.11)	0.062
SBP < 100	5.54(0.71, 43.47)	0.103	13.16 (0.59, 195.18)	0.061
HR ≥ 100	0.99 (0.14, 6.88)	0.991	1.16 (0.12, 10.74)	0.898
Pressors	1.55 (0.28, 8.66)	0.616	0.77(0.12, 4.96)	0.786
RSI	—		2.51 (0.46, 13.75)	0.290

[1]*Univariate logistic regression.*
[2]*Multivariate logistic regression.*
Abbreviations: AI, aortic injury grade group: BAI, blunt aortic injury CI, 95% confidence interval; HR, heart rate; ISS, injury severity score; OR, odds ratio; RSI, radio graphic severe injury; SBP, systolic blood pressure; SVS, society for vascular surgery.

Table 1.
Logistic regression of factors predicting risk of overall mortality and BAI-related mortality [12].

Thoracic endovascular aortic replacement (TEVAR) offers the advantages of a fast delivery of therapy, preventing a dangerous operation with partial cardiopulmonary bypass or hypothermic circulatory arrest, and less risk of postoperative paraplegia. Furthermore, endovascular therapy can be delivered in the operating room under portable fluoroscopy, offering the tremendous benefit of allowing simultaneous delivery of other therapies for associated life-threatening injuries, such as cranial decompression, transcatheter embolization or exploratory laparotomy, which would be significantly delayed by performing an open surgical aortic repair. The benefit of endovascular therapy is supported by the findings in the literature that have consistently shown substantial advantages of TEVAR over open repair in TAI [15, 29–36]. In our series, open repair was selected only when TEVAR was not feasible, such as in cases with no peripheral aortic access due to presence of intraluminal aortic thrombus, small size of femoral vessels, or presence of a total aortic transection which prevented delivery of endovascular therapy, as seen in the case of **Figure 3**.

As last consideration, in our experience we have observed a relatively small number of patients who died before any treatment was established. If historical series had reported that number to be significant, most recent reports have shown that of the patients surviving BAI at the scene, less than 5% would die of a direct aortic complication after arrival at the hospital [23]. The improvement of the techniques of resuscitation and trauma management, along with a consistent and early application of anti-impulsive therapy have positively impacted on the post-admission hospital mortality [23].

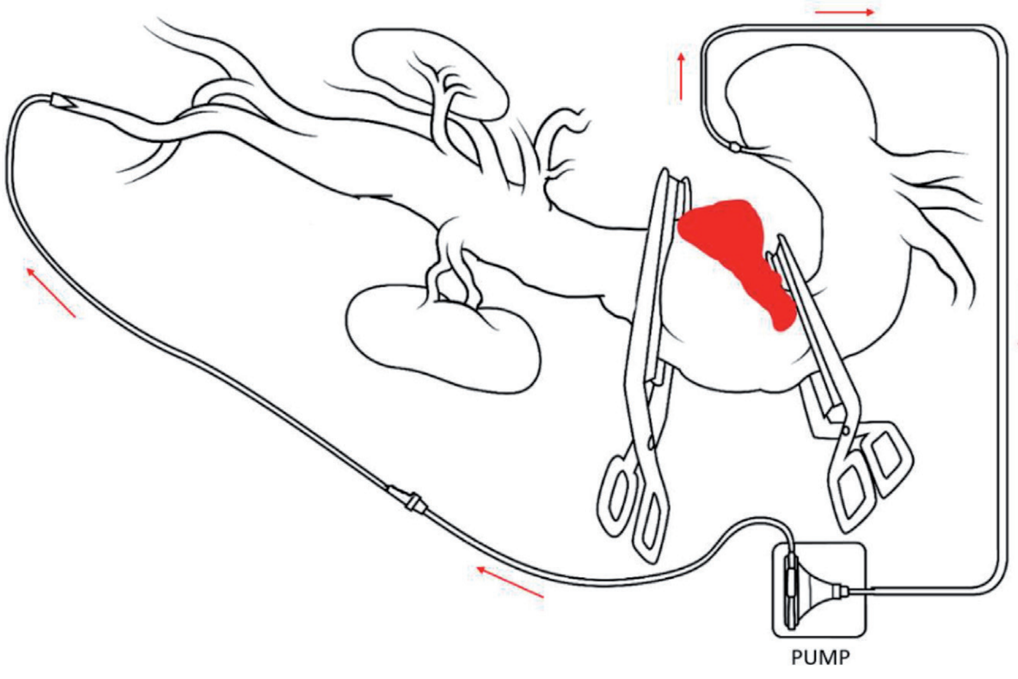

Figure 6.
Technique of proximal descending thoracic aortic replacement with partial cardiopulmonary bypass: Oxygenated blood is drained from the left inferior pulmonary vein and pumped in the left common femoral artery, allowing perfusion of end organs distal to the aortic cross-clamping.

4. Conclusion

The surge of TEVAR as the new standard for treatment for TAI has lowered the operative mortality for the treatment of this condition. However, the optimal timing for the delivery of therapy remains still unclear with respect to the identification of the patients who would require immediate intervention versus the ones for whom postponing treatment of the aortic injury would be preferable. The newly conceived radiologic classification system of TAI we use in our clinical experience is aimed at identifying the type of injuries associated with the highest mortality risk. Radiologic assessment of the severity of the aortic injuries with characterization of the presence of an 'unstable' and life-threatening condition should represent the primary factor to direct management strategy indicating the timing for the aortic repair and guiding treatment priorities.

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