

Thoracic Aortic Transection Treated by Thoracic Endovascular Aortic Repair: Predictors of Survival

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Abstract

Background: We reviewed all patients presenting to our institution with a traumatic thoracic aortic injury (TTAI) between January 2006 and May 2007. Age, gender, injury severity score (ISS), location of injuries, surgical intervention, and length of stay were assessed to determine what characteristics might be predictive of survival. Of the 56 patients who were identified, 23 (41%) were dead on arrival, 15 (20%) died on that admission, and 18 (32%) survived to discharge. Injury severity score was elevated in mortalities (57) compared to survivors (34). Penetrating and blunt aortic injuries had 89% and 58% mortality rates, respectively. Female gender was associated with increased survival ($P = .032$), as was receiving surgical intervention ($P = .03$). Patients with a prolonged ICU stay demonstrated increased survival. All eight patients who received thoracic endovascular aortic repair survived to discharge. Injury severity score, mechanism, thoracic endovascular aortic repair (TEVAR), female gender, and surgical treatment were associated with survival after TTAI.

Keywords

Thoracic Aortic Injury, TEVAR, Thoracic Endovascular Aortic Repair

Introduction

Acute traumatic thoracic aortic injury (TTAI) is a highly lethal condition. It often results from a mechanism of injury in which the patient (or the object striking the patient) is traveling at a high velocity; a significant amount of energy is required to generate the shearing forces that disrupt the walls of the aortic isthmus within the thoracic cavity.¹ The magnitude of this force frequently results in multiple associated injuries in these patients, which contribute to their mortality.² Of patients with TTAI, 80% to 90% die from exsanguination at the scene. Of those that reach the hospital, 50% do not survive more than 24 hours and approximately 90% may die if their aortic injuries are not addressed within the first month.^{3,4} In 2008, there were 67,183 moderate-severe traumatic thoracic injuries with an overall case-fatality rate of 8.75%, second only to the head as a focus for traumatic injury.⁵

The traditional approach to treatment of TTAI has been emergent posterolateral thoracotomy, cross clamping of the aorta with or without cardiopulmonary bypass, and either direct repair or placement of an interposition graft.⁶ Delayed treatment of aortic injuries after establishing hemodynamic stability and addressing associated injuries has been shown to improve morbidity and mortality to approximately 15% to 54% overall.^{3,7,8} The high incidence of pulmonary and renal complications associated with open repair contributes to these

poor outcomes. A high percentage of patients (8.7%-37%) experience postoperative paraplegia,^{9,10} the etiology of which is poorly understood and has been attributed to exacerbation of associated injuries secondary to anticoagulation during cardiopulmonary bypass and/or interruption of blood flow to the anterior spinal cord. Techniques such as heparin-less bypass have been shown to reduce paraplegia and overall mortality in patients undergoing open repair.¹¹

Dake et al initially published their series using endovascular stents for the treatment of descending thoracic aortic aneurysms. This was later adapted by Semba et al to the management of most acute ruptures of the descending thoracic aorta. In the past decade, endovascular stent graft repair has emerged as a relatively safe and efficacious treatment modality for TTAI.^{12,13} This technique avoids the risks associated with thoracotomy, single lung ventilation, aortic cross clamping, and

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prolonged systemic anticoagulation. A 2008 meta-analysis of 17 studies comparing open and endovascular treatment showed a significant reduction in immediate and 30-day mortality as well as a lower overall risk of paraplegia (0% compared with 7% in open repair).¹⁴ Despite the immediate appeal, this approach is not without drawbacks related to the technology. Recent prospective data from the American Association for the Surgery of Trauma regarding endovascular stenting shows a 20% device-related complication rate due to access complications (4.8%) and endoleaks (13.6%).¹⁵ These complications can be managed without the need for cardiopulmonary bypass and its associated risks. The low morbidity profile of this intervention has lead to widespread adoption of the thoracic endograft as the preferred treatment in patients who are physiologically compromised. However, there is no data regarding predictors of survival in these patients; as of now there is no way to predict postoperative morbidity and mortality in these patients. A recent study by Day et al was unsuccessful in applying systems such as the Glasgow Aneurysm Score and Society of Thoracic Surgeons risk score to predicting postoperative mortality in patients undergoing thoracic endovascular aortic repair (TEVAR).¹⁶ The purpose of this retrospective study was to review our experience with TTAI and to identify the data for potential predictors of survival.

Methods

The electronic medical records of 56 patients who had been coded as having been treated for TTAI between January 4, 2006 and May 1, 2007 were retrospectively reviewed at our level I trauma center. The medical examiners' reports for patients who expired en route or in the resuscitation bay before the extent of their injuries could be completely assessed were reviewed to catalog associated injuries and determine the cause of death. Patients were classified according to outcome. The mortality group consisted of 38 patients who died en route to the hospital, during resuscitation in the trauma bay, or during admission. The survival group is composed of 18 patients who survived to discharge from the hospital. The inpatient mortality group—15 patients who survived to admission but died while in the hospital—were also compared to patients surviving to discharge to determine potential predictors of survival.

Our treatment protocol for TTAI is initial hemodynamic resuscitation and stabilization of the patient. Associated traumatic injuries necessitating operative intervention as per the ATLS guidelines are addressed first.¹⁷ Patients with evidence of active extravasation took priority for early stenting and stable, contained pseudoaneurysms were treated once they were stable (Figure 1). Hemodynamically stable patients had systolic blood pressure maintained below 120 mmHg with the use of β blockers prior to any endovascular intervention. Patient with an injury in a location favorable to stenting (distal to the left subclavian), who were hemodynamically stable received TEVAR if their injury was visualized on repeat imaging prior to stent placement. Patients not meeting these criteria were excluded (Table 1). Patients that had radiological evidence of aortic

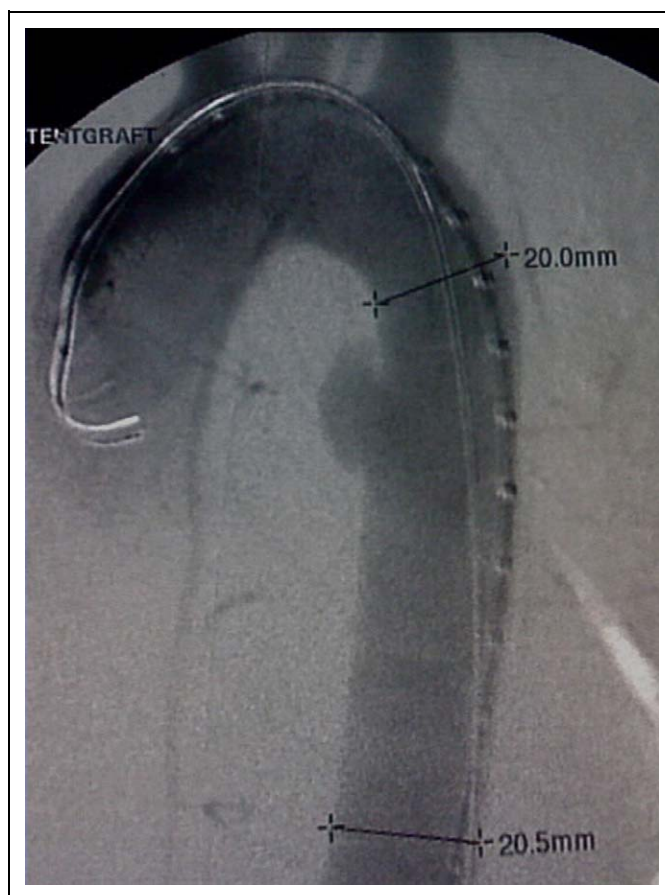


Figure 1. Thoracic aortogram in a patient with traumatic thoracic injury. Note the pseudoaneurysm along the medial side of the descending thoracic aorta distal to the left subclavian.

Table 1. Exclusion Criteria for Thoracic Endovascular Aortic Repair (TEVAR) for Traumatic Thoracic Aortic Injury (TTAI) Ascending aortic injury

Involvement of multiple arch vessels
Active extravasation in unstable patients
Penetrating injuries requiring open repair
Small intimal injuries not visualized in subsequent imaging (aortogram, computed tomography aortography [CTA], or Transesophageal Echocardiography [TEE])

injury but subsequently did not on repeat imaging were also excluded (Figure 2). In this series, 8 patients with an average ISS of 36.38 (SD $\pm$ 9.86) received endovascular stenting. Seven were stented within 24 hours of admission, and 1 patient was observed for 4 days prior to treatment.

Patients were further stratified using the injury severity score (ISS),¹⁸ age, gender, associated injuries, ICU length of stay, hospital length of stay, and time on ventilator. Data regarding patients receiving TEVAR was reviewed to determine subsequent procedure or access-related complications. Data was analyzed using the Student *t* test to determine differences in means, with categorical data analyzed using Fisher exact test and statistical analysis performed with SPSS 17.0 for Windows.

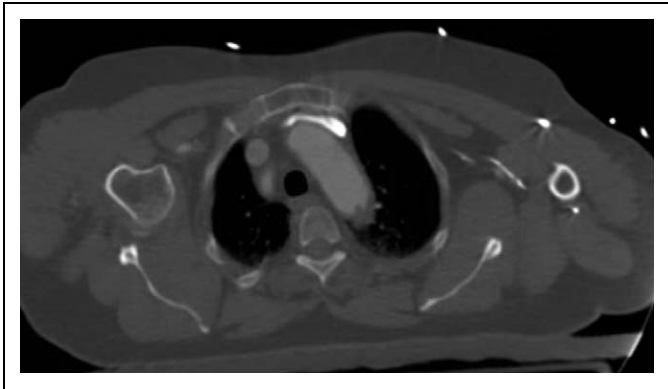


Figure 2. CT angiogram of the thoracic aorta with a small intimal defect in the descending portion which was read as an intimal tear. This defect was not seen on subsequent imaging and was likely an artifact or component of an atherosclerotic plaque.

Table 2. All Patients

	Overall mortalities (N = 38)	Survivors (N = 18)	P value
Age	42.6 ± 22.4	41.4 ± 22.9	.662
Gender			
Male	81.5% (31)	66.6% (12)	.032
Female	18.4% (7)	33.3% (6)	
ISS	57.3 ± 12.7	34.0 ± 10.6	<.001
Associated injuries:			
Head	26.3% (10)	10.5% (2)	.301
Thoracic	57.8% (22)	66.6% (12)	.572
Abdominal	71.1% (27)	72.2% (13)	1.000
Extremity	10.5% (4)	33.3% (6)	.060
Mechanism			
Blunt	57.9% (22)	88.8% (16)	.031
Penetrating	42.1% (16)	11% (2)	
Received operation	34.2% (13)	77.7% (14)	.004

NOTE: ISS = injury severity score.

Results

Of the 56 patients studied, 18 survived to discharge (Table 2). Of the surviving patients, 8 were treated with TEVAR. Average age was 42.63 years (SD ± 22.4). Age was not found to be significantly predictive of overall mortality (OR 1.002, 95% CI 0.9-1.029, *P* = .662). The majority of the participants were male (76.8%, *N* = 43). Females were more likely to survive until discharge (*P* = .032). The majority of patients presented with associated injuries, the distribution of which was not determined to be statistically significant between the survivors and fatalities. The most common locations for these injuries were the chest and abdomen (Figure 3).

Blunt trauma comprised the majority (67.8%, *N* = 38) of the injuries encountered and was an independent predictor of survival (*P* = .031). Of these patients, 20 died of acute hemorrhage. One 84-year-old male went into cardiac arrest on hospital day 3 and expired. One 16-year-old patient who had

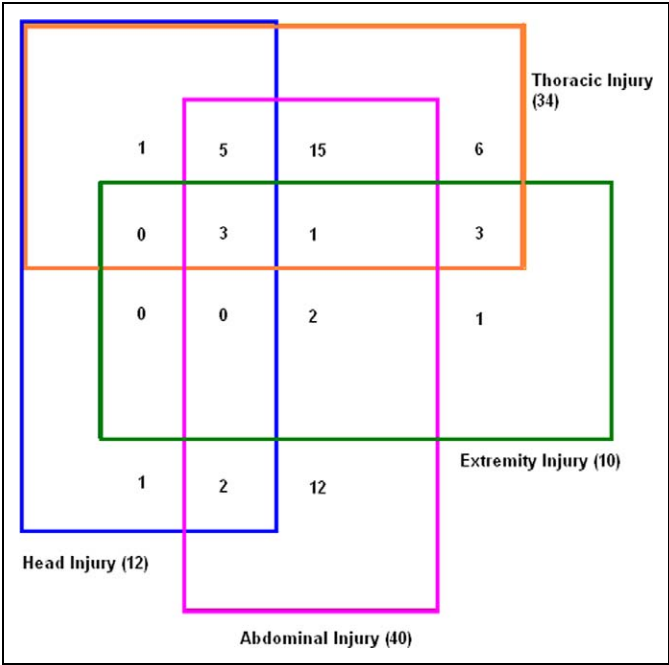


Figure 3. Distribution of injuries. The majority of patients suffered injuries to multiple areas.

suffered tracheal and esophageal rupture died on hospital day 16 as the result of acute intrapulmonary hemorrhage. The ISS takes into account the distribution of injuries as well as the severity at each location. In this series, the ISS was strongly predictive of overall mortality, with an average ISS of 57.38 among the fatalities and 34 for the survivors (*P* < .001, CI 16.9-29.8). Patients who reached the operating room were conferred with a definitive survival benefit (77.7% vs. 34.2%, *P* = .006). All 8 patients receiving TEVAR survived to discharge. The average ISS of these patients was 36.38 ± 9.86, significantly less than the overall mortality group (*P* < .001) and the inpatient mortality group (*P* = .01), but not significantly different from the group who survived without undergoing TEVAR (*P* = .297).

The inpatient mortality group was separately compared with that of the survivors to determine what factors influenced survival to discharge among patients after admission (Table 3). Again, age did not confer a survival benefit (*P* = .985). The patients who expired in the hospital had significantly higher ISSs than those who survived to discharge (Mean 49.87 vs. 33.39, *P* < .001). Associated injury to the chest, abdomen, or head was not found to be an independent predictor of survival. However, more patients who survived to discharge had extremity injuries (33.3% vs. 0%, *P* = .021). Mechanism of injury was an independent predictor of survival, and patients suffering a blunt injury were 48.8% more likely to survive to discharge (*P* = .008). The patients that survived had significantly longer overall length of stay, intensive care unit time, and duration of mechanical ventilation. The average time in hospital for surviving patients was 25.2 days and for the mortality group was 2.7 days (± 4.2).

Table 3. Patients Surviving to Admission

	Inpatient mortalities (N = 15)	Survivors (N = 18)	P value
Age	41.6 ± 26.0	41.4 ± 20.9	.985
Gender			
Male	66.6% (10)	66.6% (12)	1.000
Female	33.3% (5)	33.3% (6)	
ISS	49.8 ± 12.5	33.3 ± 10.6	<.001
Associated injuries			
Head	20% (3)	10.5% (2)	.639
Thoracic	40% (6)	66.6% (12)	.170
Abdominal	86.7% (13)	72.2% (13)	.413
Extremity	0% (0)	33.3% (6)	.021
Mechanism			
Blunt	40% (6)	88.8% (16)	.008
Penetrating	60% (9)	11% (2)	
Hospital LOS	2.7 ± 4.1 (N = 15)	25.2 ± 19.7 (N = 18)	<.001
ICU LOS	6.2 ± 6.1 (N = 5)	21.5 ± 19.5 (N = 14)	.012
Days on ventilator	2.7 ± 4.1 (N = 15)	19.6 ± 18.7 (N = 13)	.007
Received operation	86.7% (13/15)	73.7% (14/18)	.665

NOTES: ICU = intensive care unit; ISS = injury severity score; LOS = length of stay

There were 2 device-related complications: 1 intraoperative type II endoleak that had resolved on a computed tomography (CT) scan performed the following day and 1 Type I endoleak secondary to enfolding of the Thoracic Aortic Graft (TAG - Gore Medical Products) (this is a known problem with oversizing). This was repaired by extending another TAG cuff (26 × 10mm) without significant consequence. There was no paraplegia or stroke in this small series.

A total of 10 patients diagnosed with TTAI survived to discharge without endovascular repair. Of these, 3 were injuries to the ascending aorta not amenable to stenting and were managed medically. The 2 patients who survived penetrating aortic injuries were tangential gunshot wounds to the thorax, which had small distal descending aortic defects amenable to primary repair via thoracotomy. The remaining 5 patients had small intimal tears diagnosed on CT angiography that were not subsequently visualized on repeat CT or transesophageal echocardiogram. Injury severity score did not differ significantly between survivors managed medically and those receiving TEVAR (31 ± 11.00 vs. 36.375 ± 9.86, $P = .297$)

Discussion

The sample of patients reviewed represents the 15% to 20% of patients who reach the hospital alive after suffering a TTAI.¹⁹ Previously, the standard of care for this type of injury was emergent thoracotomy and repair of the injury. The treatment paradigm has shifted toward observation, stabilization, and repair of associated injuries prior to aortic stenting. The repair process itself has evolved over the past 15 years toward endovascular repair as the primary treatment modality, with open repair reserved for young patients with no associated injuries.²⁰ By contrasting the data regarding the survivors with that of the fatalities, we can better understand the potential predictors of

survival in these patients and identify injury patterns for early intervention.

As penetrating aortic injury is almost uniformly fatal, the majority of studies thus far have only examined aortic injury resulting from blunt trauma. Recent retrospective analyses of patients admitted with blunt injury show an overall mortality rate of 53% to 65% (including patients who were dead on arrival or died in the resuscitation area) and 13% to 26% mortality in patients admitted to the hospital.^{4,11,15} Our data regarding patients with blunt injury is consistent with these figures, with 55% overall mortality, and 25% in patients admitted to the hospital.

Patient mortality was significantly influenced by gender and mechanism of injury. Gender has not been shown to influence outcome for this kind of injury. However, males have a greater than a 3-fold risk of death from motor vehicle collisions (the most common etiology for blunt TTAI) and are 70% of all injury deaths and 56% of nonfatal injuries.²¹ Penetrating injury to the thoracic aorta is known to carry a grave prognosis; the only reported penetrating injuries amenable to repair have been contained aortic ruptures incurred secondary to rib fractures.²²

Distribution of individual areas of injury was not significantly different between the 2 groups; the ISS accounts for any discrepancies in injury distribution by factoring in the severity at various locations. The only difference noted is that patients surviving to discharge were more likely to have suffered an extremity injury. Injury severity score has been proven as a predictor of patient mortality as fatalities had significantly higher scores than those of survivors.¹⁸ Injury severity score divides the body into 6 regions: head/neck, face, abdomen, chest, extremities, and external. These are each assigned an acute injury score (AIS) on a scale from 1 to 6. The 3 areas with the largest AIS are used to calculate the ISS. If any area has an AIS of 6, the ISS automatically designated as 75 (the maximum). The

average ISS of patients treated with TEVAR was 36.38 (SD $\pm$ 9.86), a value with a predicted mortality of greater than 50%.

All 8 patients who received endovascular stent repair survived to discharge. The maximum delay in treatment of aortic injury was 4 days. There was no incidence of paraplegia or stroke. No patient required coverage of the left subclavian artery.^{23,24} This subgroup of patients did not have a mean ISS significantly higher than that of the other surviving patients (36.38 vs. 31, $P = .297$); the natural history of patients with minor radiological findings as seen in 5 of our patients that resolved in further imaging is not known. With the transition away from aortography to helical CT scanning as the primary diagnostic imaging tool, small intimal tears that might have gone otherwise undiagnosed are being easily detected on CT scan. In the AAST study, only 8.3% of diagnoses of TTAI were made via arteriography, with 96.8% of patients receiving endovascular treatment diagnosed by CT scan. In 2003, Richard Hayward coined the term VOMIT (Victims of Modern Imaging Technology), which Maddox subsequently applied to the diagnosis of aortic injury.^{25,26} The possibility exists that minor defects or artifacts are being read as aortic injuries and subsequently treated with a thoracic aortic stent graft. Our series featured 5 cases in which patients were diagnosed with small intimal tears; after the patients had been stabilized and placed on β blockers, the injuries were not visualized on repeat imaging. If these patients are excluded from analysis, patients receiving TEVAR account for 72.7% (8 of 11) of all survivors of blunt trauma, making it an independent predictor of survival in patients with blunt injury ($P = .009$). At our institution, all patients presenting with blunt injury undergo CT angiography with 3D reconstruction (Terra-recon), and stents are not used unless the lesion seen on CT angiogram is confirmed under angiography in the operating room. The incidence of VOMIT in this study underscores the need for discretion when considering TEVAR in these patients.

The postoperative device-related complication rate was 12.5%. In most published device-related complications such as endoleak and iatrogenic injury to access vessels range from 3% to 20%.^{15,27} This complication involved a proximal ring rupture of a TAG 28 $\times$ 10 endograft, which resulted in a Type I endoleak visualized on CT angiogram performed 1 week postoperatively. The leak was repaired via deployment of an additional 26 $\times$ 10 mm TAG graft to secure the initial graft in place. The patient suffered no clinical sequelae as a result of the device failure and was discharged 8 days later. Enfolding and collapse of the TAG graft secondary to oversizing has been reported in previous case series.²⁸

Despite almost a decade of the endovascular stent as a therapeutic modality for the treatment of TTAI, the fatality of this injury is still very high. We attempted to analyze our data to identify patients that would benefit from early diagnosis and treatment. This retrospective analysis has shown that patients of female gender, lower ISS, who have suffered blunt trauma, and have received any initial operative intervention are conferred an overall survival benefit. This study is limited by the small overall sample size, which may result in confounding

variables such as VOMIT exerting a greater than normal effect on data regarding patient survival.

Long-term follow-up is required to determine the durability and reliability of these stents as the patients age and the aorta enlarges since the majority of these patients are young. Repairs still rely upon straight, oversized grafts initially designed for the treatment of aneurysmal disease and applied off-label to the treatment of TTAI. The smallest graft available is 22 mm, while aortic diameters can range from 16 to 24 mm.²⁹ Surgeons have recently attempted to address this problem by using a series of smaller aortic cuffs to treat these injuries.^{30,31}

We found that lower ISS, blunt injury, female gender, and surgical intervention were independent predictors of overall survival in patients with TTAI. TEVAR is the preferred method of treatment of blunt thoracic aortic injury. However, until the device's long-term durability and natural history is affirmed, it is important to proceed with caution in the use of these devices, particularly in young patients with only minor radiological findings.

Declaration of Conflicting Interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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