Update on blunt thoracic aortic injury: Fifteen-year single-institution experience

Anthony L. Estrera, MD,[a] Charles C. Miller III, PhD,[b] Gustavo Guajardo-Salinas, MD,[a] Sheila Coogan, MD,[a] Kristofer Charlton-Ouw, MD,[a] Hazim J. Safi, MD,[a] and Ali Azizzadeh, MD[a]

Objectives: Despite improvements in the management of blunt thoracic aortic injury, mortality remains high. We report our experience with blunt thoracic aortic injury at a level 1 trauma center over the past 15 years.

Methods: Between January 1, 1997, and January 1, 2012, data on 338 patients who presented with suspected blunt thoracic aortic injury were entered into the University of Texas Medical School at Houston Trauma Center Registry. A total of 175 patients (52%) underwent thoracic aortic repair; 29 (17%) had open repair with aortic crossclamping, 77 (44%) had open repair with distal aortic perfusion, and 69 (39%) had thoracic endovascular aortic repair. Outcomes were determined, including early mortality, morbidity, length of stay, and late survival. Multiple logistic regression analysis was used to compute adjusted estimates for the effects of the operative technique.

Results: The early mortality for all patients with blunt thoracic aortic injury was 41% (139/338). Early mortality was 17% (27/175) for operative aortic interventions, 4% (3/69) for thoracic endovascular aortic repairs, 31% (11/29) for open repairs with aortic crossclamping, and 14% (11/77) for open repairs with distal aortic perfusion. Survival for thoracic endovascular aortic repair at 1 year and 5 years was 92% and 87%, respectively. Survival for open repair at 1, 5, 10, and 15 years was 76%, 75%, 72%, and 68%, respectively.

Conclusions: Blunt thoracic aortic injury remains associated with significant early mortality. Delayed selective management, when applied with open repair with distal aortic perfusion and the use of thoracic endovascular aortic repair, has been associated with improved early outcomes. The long-term durability of thoracic endovascular aortic repair is unknown, necessitating close radiographic follow-up. (J Thorac Cardiovasc Surg 2013;145:S154-8)

Blunt thoracic aortic injury (BTAI) remains the second leading cause of traumatic death, surpassed only by head injuries.[1] In a recent autopsy series involving traffic accidents, 33% of the victims had associated BTAI; 80% died at the scene before hospital arrival.[2] Considering that 37,661 motor vehicular deaths occurred in 2010 according to the National Vital Statistics Report, 12,553 (33%) of the deaths may have involved BTAI. In comparison, aortic aneurysms and dissection accounted for 10,397 deaths during the same year.[3]

In Dr Mattox's 1996 presidential address[4] to the American Association for the Surgery of Trauma (AAST), advancements in the management of BTAIs were outlined. Specifically, he described that the "standard" at that time involved contrast aortogram for diagnosis, permissive hypotension for preintervention management, and open repair with distal aortic perfusion (DAP) for definitive treatment. At the time, paraplegia remained a significant concern, and mortality remained as high as 30%. In his conclusion, he did recognize that intravascular ultrasound would be used to diagnose BTAI and that surgeons would be "inserting *stented grafts* through peripheral arteries in the aorta to reconstruct rents in the Red River."[4]

Fifteen years later, in his address to the American College of Surgeons, Dr Demetriades[5] updated the state of management for BTAI. In his address, he reported on advancements that included the use of computed tomographic angiography for diagnosis, the application of delayed selective management (DSM), nonoperative management for minimal aortic injury, and the use of thoracic endovascular aortic repair (TEVAR) for definitive treatment. However, he acknowledged the unknown long-term results of TEVAR, especially when used for young patients.

Our experience at Memorial Hermann Hospital has mirrored the experience of the AAST with the use of DAP for open BTAI repair, the application of DSM, and the implementation of TEVAR for most injuries.[6] This report will

From Cardiothoracic & Vascular Surgery,[a] University of Texas Medical School at Houston, Memorial Hermann Heart and Vascular Institute, Houston, Tex; Foster School of Medicine,[b] Texas Tech University Health Sciences Center El Paso, El Paso, Tex.

Disclosures: Dr Azzizadeh reports consulting fees from Gore and Medtronic. Drs Estrera, Miller III, Salinas-Guajardo, Coogan, Charlton-Ouw, and Safi have nothing to disclose with regard to commercial support.

Read at The American Association for Thoracic Surgery Aortic Symposium, New York, New York, April 26-27, 2012.

Received for publication May 12, 2012; revisions received Aug 20, 2012; accepted for publication Nov 28, 2012; available ahead of print Dec 26, 2012.

Address for reprints: Anthony L. Estrera, MD, 6400 Fannin St, Suite 2850, Houston, TX 77030 (E-mail: Anthony.l.estrera@uth.tmc.edu).

0022-5223/$36.00

http://dx.doi.org/10.1016/j.jtcvs.2012.11.074

Abbreviations and Acronyms

AAST	= American Association for the Surgery of Trauma
AXC	= aortic crossclamping
BTAI	= blunt thoracic aortic injury
DAP	= distal aortic perfusion
DSM	= delayed selective management
LOS	= length of stay
TEVAR	= thoracic endovascular aortic repair

provide an update of our level 1 trauma center experience with BTAI over the past 15 years.

MATERIALS AND METHODS

The University of Texas Medical School at Houston's Committee for the Protection of Human Subjects approved data collection and analysis for this study. Consent requests were waived by the Committee for the Protection of Human Subjects.

Between January 1, 1997, and March 1, 2012, data on 77,567 patients from a level 1 trauma center (Memorial Hermann Hospital) were entered in the University of Texas Medical School at Houston Trauma Center Registry. A total of 338 patients (0.4%) with the suspected diagnosis of BTAI were identified from the registry. Of this group, 35 patients (10%) had confirmed aortic injury and survived without operative intervention, or underwent nonoperative management for minimal aortic injury or grade 1 as previously classified (Figure 1)[7]; 114 patients (34%) died early in their hospital course, unable to undergo aortic intervention; and 7 patients had unknown status. Patients requiring total cardiopulmonary bypass for arch involvement were not included in this analysis (7 patients). Thus, 175 patients (52%) underwent thoracic aortic repair and were the focus of this analysis.

Operative Cohort

The median age of patients was 31 years (range, 13-87 years), and 55 (31%) were women. The mean Injury Severity Score was 36.3 ± 10.4. The mean Glasgow Coma Scale was 11.3 ± 5.1 (Table 1). The blunt mechanism of injury included motor vehicle collision (136), motorcycle (16), fall (8), pedestrian (12, one train), bicycle (2), and parachuting (1).

Repair approach included open repair with aortic crossclamping (AXC) only (before 1999) in 29 patients (17%), open repair with DAP in 77 patients (44%) since 1999, and TEVAR in 69 patients (39%) since 2005.

Initial Presentation

Diagnosis of BTAI was achieved by chest computed tomography, aortography, transesophageal echocardiography, intravascular ultrasound, or exploration. Although prompt repair of the BTAI was preferred, delayed repair of BTAI as adopted and applied as reported by the EAST Practice Work Group.[8] This was considered for patients with more immediately life-threatening injuries that require nonaortic intervention, such as emergency laparotomy or craniotomy, or if the patient was a poor operative candidate because of age or comorbidities. Delayed management was defined as intervention occurring after 24 hours from admission.[9] Medical management of blood pressure was instituted until definitive repair was accomplished.[10] All patients were admitted to the shock/trauma intensive care unit under the care of the trauma service. The decision to undertake delayed repair was made by the cardiothoracic and vascular surgical service in conjunction with the trauma service.

Operative Technique

Open procedures were performed via a standard left lateral thoracotomy using single lung ventilation. We currently use DAP, left-sided heart bypass, during the repair. Inflow cannulation was initially performed via the left common femoral artery, but was later established via the distal descending thoracic aorta.

Endovascular Repair

We initiated the use of TEVAR for BTAI in 2005 after Food and Drug Administration approval of the first thoracic endovascular stent graft in 2005 (off-label use). All endovascular procedures were performed in a hybrid operating room equipped with fixed imaging equipment (Axiom, Seimens Medical, Malvern, Pa). An arch aortogram was performed through percutaneous femoral access. Intravascular ultrasound was used selectively at the discretion of the attending surgeon. Open exposure of the contralateral femoral artery was obtained through a transverse inguinal incision. The patient was anticoagulated with a weight-based heparin protocol. Thoracic devices (off-label, before 2012) were selected using computed tomography images and the manufacturer's sizing recommendations. The devices were delivered and deployed using a standard technique without any pharmacologic adjunct. Post-deployment balloon angioplasty was performed selectively. The left subclavian artery was covered when necessary to obtain an adequate proximal landing zone. Patients returned to the shock/trauma intensive care unit with nonvascular injuries managed by the trauma service. Our follow-up protocol consisted of a clinic visit and computed tomographic angiography.[7] Since September 2005, 81% of patients (68/84) treated with BTAI were repaired with TEVAR.

Trauma Registry and Statistical Analysis

Trauma Registry Process includes data prospectively collected by a 9-member team. Inclusion/exclusion criteria were in compliance with National Trauma Data Bank and the State of Texas Trauma Registry. Data registrars are certified as Specialist in Trauma Registry (American Trauma Society) and certified Abbreviated Injury Scale Specialist (Abbreviated Injury Scale Certification Board). Univariate data were analyzed by contingency table for categoric variables and by unpaired *t* test for continuous variables. Multiple logistic regression analysis was used to compute adjusted estimates for effects of operative technique.

RESULTS

Mortality

The early (hospital and 30-day) mortality for all arriving with BTAI was 41% (139/338). Early mortality for those who underwent operative aortic intervention was 17% (27/175). Hospital mortality for patients with BTAI who did not undergo aortic intervention was 69% (112/163). Use of TEVAR was associated with a 4% (3/69) early mortality, which was significantly less than that of open repair with AXC (31% [9/29], $P < .002$), but not when compared with open repair with DAP (Table 2). Delayed repair was used in 42% (72/175) of repairs and associated with only 1 death (1.3%) before intervention. The early mortality of patients undergoing immediate/urgent repair was 22% (23/103), which was significantly higher than when delayed repair was undertaken: 5.5% (4/72) ($P = .004$).

In the patients who underwent operative intervention, a mortality reduction of 3.0% per year ($P < .001$) over the course of the study was observed (Figure 2). Moreover,

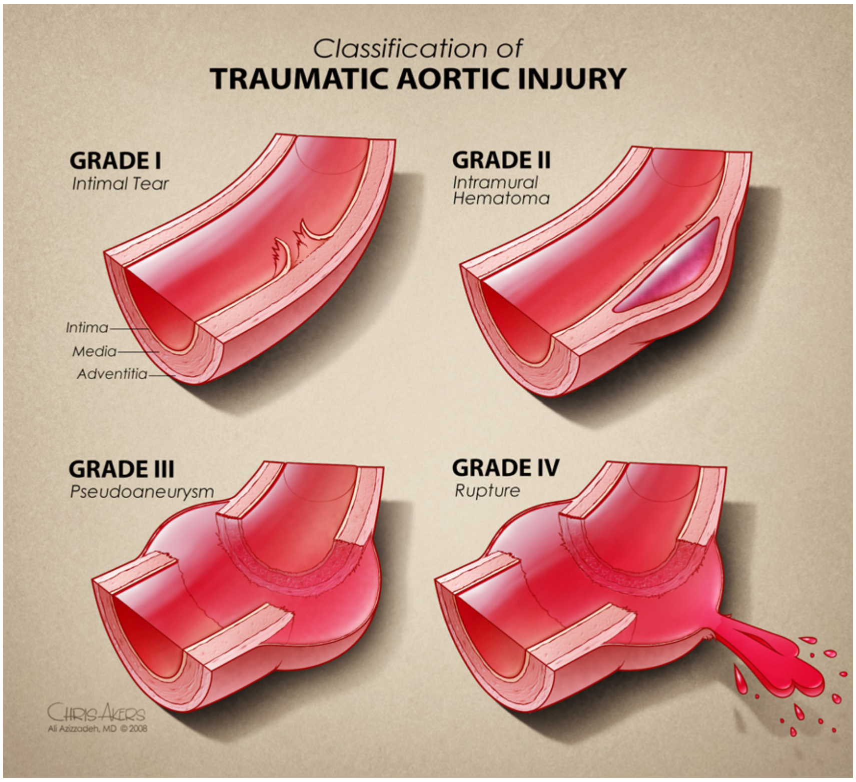

FIGURE 1. Classification of BTAIs.

in all patients admitted with BTAI, the mortality reduction was maintained at 3.6% per year ($P < .002$) (Figure 3).

By logistic regression analysis, the only significant independent variable protective against early mortality was DSM (odds ratio, 0.16; $P = .004$). DSM and TEVAR were highly correlated (DSM used in 65% [45/69] of TEVAR cases vs 31% [24/77] of open repair with DAP cases, $P = .001$), but DSM accounted for most of the variance in outcome. DSM was used in only 10% (3/29) of open repair with AXC cases. For TEVAR, early mortality was 4% whether DSM was applied or not. For open repair with DAP with DSM, the early mortality was 3%, but when DSM was not applied, the early mortality was 27%. Thus, DSM correlated with improved mortality with open

TABLE 1. Variables by procedure

Total = 175	Open (AXC) N = 29	Open (DAP) N = 77	TEVAR N = 69	*P* value
Mean age (y)	37.5 ± 18.7	35.5 ± 17.0	41.3 ± 19.6	NS
Female (%)	9 (31%)	25 (32%)	21 (30%)	NS
Mean ISS (admit)	40.9 ± 15.2	36.7 ± 9.9	33.9 ± 9.7	NS .03†
Mean GCS (admit)	11.4 ± 5.1	11.5 ± 5.0	11.1 ± 5.2	NS
Delayed repair (n,%)	3 (10%)	24 (32%)	45 (65%)	.04* .0001† .0001‡
Mean time from admit to OR (h)	8.8 ± 21.5	48.2 ± 131.3	198.7 ± 362.4	.02* .0001† .002‡
Mean hospital LOS (d)	34.4 ± 23.0	29.5 ± 26.8	25.0 ± 21.5	NS
Mean post-repair LOS (d)	28.4 ± 17.6	24.8 ± 25.8	17.0 ± 12.7	NS* .003† .03‡

AXC, Aortic crossclamp; *DAP,* distal aortic perfusion; *TEVAR,* thoracic endovascular aortic repair; *ISS,* Injury Severity Score; *GCS,* Glascow Come Scale; *OR,* operating room; *LOS,* length of stay; *NS,* not significant. *AXC versus DAP. †AXC versus TEVAR. ‡DAP versus TEVAR.

TABLE 2. Mortality and morbidity by procedure

Total = 145	Open (AXC) N = 29	Open (DAP) N = 77	TEVAR N = 69	P value
Paraplegia	3 (10%)	0 (0%)	0 (0%)	NS
Stroke	1 (3%)	0 (0%)	2 (3%)	NS
Mortality	9 (31%)	11 (14%)	3 (4%)	NS* .002† NS‡

AXC, Aortic crossclamp; *DAP,* distal aortic perfusion; *TEVAR,* thoracic endovascular aortic repair; *NS,* not significant. *AXC versus DAP. †AXC versus TEVAR. ‡DAP versus TEVAR.

repair and DAP, but did not influence early mortality with TEVAR.

Morbidity

In the open repair with AXC group, stroke occurred in 1 case (3%) and procedure-related paraplegia occurred in 3 cases (10%) (Table 2). For the 3 cases with paraplegia, the AXC times were 20, 30, and 49 minutes. In the open repair with DAP group, no stroke or paraplegia occurred. In the TEVAR group, no paraplegia occurred, but 2 patients had a stroke (3%) (Table 2).

Length of Stay

There was no significant difference in the mean hospital length of stay (LOS) between the intervention groups (Table 1). However, post-repair LOS was significantly reduced with TEVAR compared with open repair (Table 1). The hospital LOS was significantly correlated with the Injury Severity Score ($P = .009$).

Late Survival

Mean follow-up for patients undergoing TEVAR was 2.5 years with 1-year and 5-year survival of 92% and 87%, respectively. Mean follow-up for open repair was 6.2 years with 1, 5, 10, and 15-year survivals of 76%, 75%, 72%, and 68%, respectively. Late survival after open repair appeared satisfactory, with discharge from initial hospitalization and little attrition over 15 years (Figure 4).

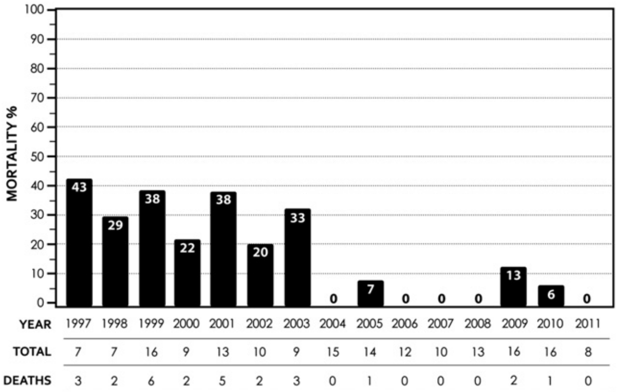

FIGURE 2. Operative mortality for BTAI by year (mortality reduction of 3.0%/year; $P < .001$).

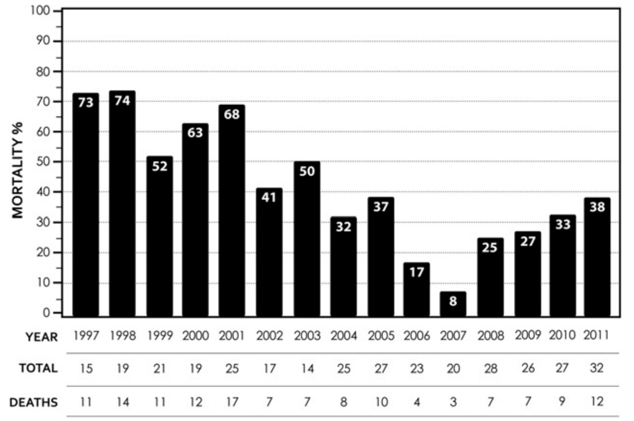

FIGURE 3. Overall mortality for admission for BTAI by year (mortality reduction of 3.6%/year; $P < .002$).

DISCUSSION

During the past 2 decades, the management of BTAI has evolved. As reported by the AAST in 1997 and later in 2008, management shifts have involved the use of DSM and the application of TEVAR.[11,12] As did the trauma centers cited in the AAST report, our center has observed similar changes in management strategy.

TEVAR has become our primary choice of repair technique. In a previous study, we reported that since approval of the TEVAR by the Food and Drug Administration in 2005, 69% of all BTAI repairs occurred with TEVAR.[6] In this current update, the use of TEVAR has increased to 81% of all repairs. Our aggressive application of TEVAR for BTAI has been based on the observed reduction in both operative and overall early mortality of BTAI at University of Texas medical school at Houston, Memorial Hermann Heart and Vascular Institute over the past 15 years

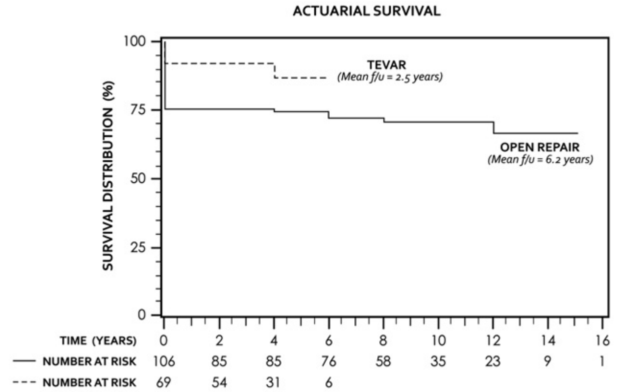

FIGURE 4. Kaplan–Meier actuarial survival for TEVAR and open repair for BTAI. *TEVAR,* Thoracic endovascular aortic repair.

(a reduction of 3.6% and 3.0% per year for operated and overall BTAI injuries, respectively) (Figures 1 and 2).

Of note, by using multivariate analysis, the only independent factor protective against early mortality was the use of DSM. However, DSM only conferred a benefit when used in conjunction with open repair. Although DSM was used more commonly with TEVAR (Table 1), low early mortality was observed with TEVAR in general (only 4%), and thus DSM did not confer a benefit when combined with TEVAR. Although multivariate analysis was performed to identify independent risk factors, it was difficult, in a retrospective manner, to account for the many variations that occurred in the overall management of trauma during the study period. Credit must be given to the trauma service for the improvements in outcomes over the past 15 years at University of Texas medical school at Houston, Memorial Hermann Heart and Vascular Institute, but many of these changes have occurred gradually, making accountability in statistically modeling difficult.

Early in our experience with TEVAR for BTAI, we were less inclined to perform TEVAR at initial presentation because of a concern about stent-graft infections in the multi-injured patient.[6] In our early TEVAR experience, the mean time from admission to TEVAR was 335 hours.[6] By this update, the mean time from admission to TEVAR had decreased to 199 hours (Table 1). Since 2010, the mean time from admission to intervention has further decreased to less than 53 hours in our experience. The less invasive nature of TEVAR, compared with open repair, has allowed for earlier intervention with potentially fewer untoward systemic effects in the otherwise severely injured patient.

Long-term durability still remains a concern. In this report, with a mean follow-up 2.5 years, those who underwent TEVAR had a good midterm survival of 87%. However, the durability of TEVAR in the long-term has recently been questioned.[13] The main limitation of TEVAR in our experience has been poor compliance with radiographic follow-up. We previously reported a compliance with radiographic surveillance of only 56%.[7] Despite this limitation, however, we continue to advocate the use of TEVAR for BTAI but emphasize the importance of maintaining a radiographic surveillance protocol.

Until long-term results of TEVAR for BTAI are known, questions about its use, especially in young patients, will remain. It stands to reason that, unlike the situation in aneurysmal disease, in which the aortic wall is broadly involved with medial degeneration, traumatic injury affects only a local part of the aorta with the remaining aorta (ie, landing zones free of disease). The significant benefit of TEVAR is in the reduction in early mortality for patients with multiorgan trauma; thus, TEVAR should be optimally poised for success. The need for reinterventions and ultimately the uncertainty about the performance of stent-grafts in the long term remain undetermined.[14] In contrast, prosthetic materials (eg, the Dacron used in open repair) have proven long-term durability, and little doubt exists when they are used, especially in young patients.

CONCLUSIONS

BTAI remains associated with significant early mortality. DSM when applied with open repair with DAP and the use of TEVAR have both been associated with improved early outcomes. The long-term durability of TEVAR is unknown, necessitating close radiographic follow-up.

The authors thank Edmundo Dipasupil for data registry support and Chris Akers, our medical illustrator.

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