Functional and survival outcomes in traumatic blunt thoracic aortic injuries: An analysis of the National Trauma Databank

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Objective: Blunt thoracic aortic injury (BAI) remains a leading cause of trauma deaths, and off-label use of endovascular devices has been increasingly utilized in an effort to reduce the morbidity and mortality in this population. Utilizing a nationwide database, we determined the incidence of BAI, and analyzed both functional and survival outcomes at discharge compared with matched controls.

Methods: Patients with BAI were identified by International Classification of Disease-9 codes from the National Trauma Data Bank (Version 6.2), 2000-2005. Patients were analyzed based on aortic repair, associated physiologic burden, and coexisting injuries. Control groups were matched by age, mechanism, major thoracic Abbreviated Injury Scale score (AIS ≥ 3), major head AIS, and major abdominal AIS. Outcomes were assessed using the functional independence measure (FIM) score and overall mortality. FIM scores were scored from 1 (full assistance required) to 4 (fully independent) for three categories: feeding, locomotion, and expression.

Results: During the study period, 3,114 patients with BAI were identified among 1.1 million trauma admissions for an overall incidence of 0.3%. One hundred thirteen (4%) were dead on arrival, and 599 (19%) died during triage. Sixty-eight percent (1,642) underwent no repair, 28% (665) open aortic repair, and 4% (95) endovascular repair with associated mortality rates of 65%, 19%, and 18%, respectively (P < .05). Aortic repair independently improved survival when controlling for associated injuries and physiologic burden (odds ratio (OR) = 0.36; 95% confidence interval (CI), 0.24-0.54, P < .05). Compared with matched controls, BAI resulted in a higher mortality (55% vs. 15%, P < .05), and independently contributed to mortality (OR = 4.04; 95% CI, 3.53-4.63, P < .05). In addition, BAI patients were less likely to be fully independent for feeding (72% vs. 82%, P < .05), locomotion (33% vs. 55%, P < .05), and expression (80% vs 88%, P < .05).

Conclusion: This manuscript is the first to define the incidence of BAI utilizing the NTDB. Remarkably, two-thirds of patients are unable to undergo attempts at aortic repair, which portends a poor prognosis. When controlling for associated injuries, blunt aortic injury independently impacts survival and results in poor function in those surviving to discharge. (J Vasc Surg 2009;49:988-94.)
managing strategies, their impact on survival, and to determine the functional impact of BAI on patients at the time of discharge.

METHODS

This study is a retrospective analysis of the National Trauma Data Bank (Version 6.2), 2000-2005. The American College of Surgeons developed and maintains this ongoing database, which currently includes prospectively collected data from over 1.1 million trauma admissions nationwide. The database includes information pertaining to demographics, mechanism of injury, prehospital data, initial physiologic data, diagnoses, Injury Severity Score (ISS), procedures, and outcomes. All data is limited to the hospital trauma admission. The ISS is an established trauma score that defines the extent of polytrauma and expected mortality. The ISS is based upon the Abbreviated Injury Scale (AIS) of the three most injured of the following body regions: head, face, thorax, abdomen, and extremities (pelvis included). The AIS describes the severity to one body region: 1-Minor, 2-Moderate, 3-Serious, 4-Severe, 5-Critical, and 6-Maximal. In this study, major injury was defined as AIS > 3.

The database was queried for all adult patients (age >16 years old) with traumatic blunt thoracic aortic injuries utilizing International Classification of Diseases-9 codes (901.0) and mechanism of injury. Patients who were dead on arrival and died during triage were excluded from analysis. Patients were divided into three groups by type of aortic repair (non-operative management, operative repair, and endovascular repair) for comparative analysis. Binomial logistic regression modeling was utilized to determine the individual impact of physiologic status and associated injuries on mortality in BAI patients. Logistic regression modeling was repeated for predictors of both early (<2 days and equivalent to 72 hours from admission) and late in-hospital mortality.

Utilizing a search algorithm, a control group of patients without BAI were identified. These patients were matched for age, mechanism of injury, and major thoracic injury (AIS > 3). Logistic regression modeling was then utilized to determine the overall impact of BAI on mortality in a population with major thoracic injuries. For patients surviving until hospital discharge, a control group was not only matched for age, mechanism of injury, and major thoracic injury, but also for major head and abdominal injuries (AIS > 3). Utilizing surviving BAI patients and the matched control group, complications were compared. The major functional outcome was analyzed utilizing the functional independence measure (FIM). This score has previously been validated and assesses functional status in three areas: feeding, locomotion, and expression. Summation of the three categories results in a FIM total score with a minimum of 3 (fully dependent) to a maximum of 12 (fully independent at discharge). Major disability in each category was defined as a score less than 3, and full independence was defined as a score of 4 in each category (FIM total = 12).

All selection algorithms and statistical analyses were performed utilizing SPSS 16.0.2 (SPSS Inc, Chicago, IL). Continuous variables were analyzed with the independent Student’s t test or Mann-Whitney U test for nonparametric variables when appropriate. Dichotomous proportions were analyzed using the Chi-squared test with the Cochran-Mantel-Haenszel statistic (common odds ratio = 1). Binary logistic regression was utilized to determine the impact of both continuous and categorical covariates on mortality. Variables that demonstrated \( P < .10 \) were entered into multivariate analysis. During modeling, variables were removed for \( P > .10 \), and were entered into the model if \( P < .05 \) for a maximum of 20 iterations. Significant variables were tested for collinearity. Regression models were tested on a 50% random sample of the population to examine for untested influential covariates. Values are reported as odds ratios (OR) ± 95% and confidence intervals (CI) with respective P values.

RESULTS

During the study period, 3,114 BAI were identified among 1.1 million trauma admissions for an overall incidence of 0.3%. One hundred thirteen (4%) were dead on arrival, and 599 (19%) died during triage. The remaining 2,402 patients comprised the study population for this study. Seventy-two percent (1,850) were men, and the mean age was 41 (± 20) years. Associated injuries were common: head injuries 31% (745), major abdominal injuries 29% (696), and pelvic injuries 15% (360). Mean injury severity score (ISS) was 40 (± 17) for the population with an overall mortality of 55% (1,321). Sixty-eight percent (1,642) were managed nonoperatively, 28% (665) underwent open repair, and 4% (95) underwent endovascular repair with associated mortality rates of 65%, 19%, and 18% respectively. Among the 760 patients who underwent aortic repair, 87% (665) underwent open repair and 13% (95) underwent endovascular repair.

Table I lists the demographic and outcome differences among patients stratified by repair type. There were no statistical differences in age, and only minor differences in presenting base deficits and hemodynamics. Patients that were managed nonoperatively were more likely to have a major head injury (32%) with associated lower Glasgow Coma Scale (GCS). Overall, the injury severity score (ISS) was higher in the cohort that did not undergo repair with a resultant higher mortality.

Comparing open repairs with endovascular repairs, only minor differences were noted. Patients treated with endovascular repair were more likely to have major abdominal injuries and a much lower incidence of major head injuries, but more patients in the endovascular cohort (17%) had combined major abdominal and head injuries \( (P < .05) \). Presenting age, GCS, hypotension, and ISS were all similar irrespective of repair type. The two groups also had similar intensive care unit stays and overall hospital length of stays. In addition, there was no statistical differ-
Table I. Demographics and outcomes of all patients with blunt thoracic aortic injuries stratified by nonoperative management, open repair, and endovascular repair

<table>
<thead>
<tr>
<th>Variable</th>
<th>No repair (n = 1642)</th>
<th>Open repair (n = 665)</th>
<th>Endovascular repair (n = 95)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>42 (± 21)</td>
<td>39 (± 18)</td>
<td>41 (± 21)</td>
<td>NS</td>
</tr>
<tr>
<td>Glasgow Coma Scale (≤ 8)</td>
<td>66%</td>
<td>24% (± 5)</td>
<td>21%</td>
<td>.05</td>
</tr>
<tr>
<td>Hypotension (SBP &lt; 90 mmHg)</td>
<td>88%</td>
<td>98%</td>
<td>98%</td>
<td>.05</td>
</tr>
<tr>
<td>Base deficit</td>
<td>5.1 (± 9)</td>
<td>3.8 (± 6)</td>
<td>6 (± 9)</td>
<td>NS</td>
</tr>
<tr>
<td>Major head injury (AIS ≥ 3)</td>
<td>32%</td>
<td>24%</td>
<td>15%</td>
<td>.05</td>
</tr>
<tr>
<td>Associated injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major abdominal injury (AIS ≥ 3)</td>
<td>31%</td>
<td>27%</td>
<td>45%</td>
<td>.05</td>
</tr>
<tr>
<td>Major pelvic injury (AIS ≥ 3)</td>
<td>14%</td>
<td>19%</td>
<td>18%</td>
<td>NS</td>
</tr>
<tr>
<td>Combined major head and abdominal injury</td>
<td>4%</td>
<td>5%</td>
<td>17%</td>
<td>.05</td>
</tr>
<tr>
<td>Injury severity score</td>
<td>39 (± 16)</td>
<td>36 (± 12)</td>
<td>37 (± 14)</td>
<td>.05</td>
</tr>
<tr>
<td>Delayed aortic repair (&gt;72 hours)</td>
<td>—</td>
<td>5%</td>
<td>8%</td>
<td>NS</td>
</tr>
<tr>
<td>Time to aortic repair (hours)</td>
<td>—</td>
<td>4 (2.2-7.1)</td>
<td>9.8 (2.3-9)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Complications

<table>
<thead>
<tr>
<th>Variable</th>
<th>No repair (n = 1642)</th>
<th>Open repair (n = 665)</th>
<th>Endovascular repair (n = 95)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARDS</td>
<td>4%</td>
<td>7%</td>
<td>2%</td>
<td>.05</td>
</tr>
<tr>
<td>PNA</td>
<td>9%</td>
<td>18%</td>
<td>12%</td>
<td>.05</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>22%</td>
<td>25%</td>
<td>4%</td>
<td>.05</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>5%</td>
<td>6%</td>
<td>10%</td>
<td>.05</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.2%</td>
<td>0.6%</td>
<td>0%</td>
<td>NS</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>0.3%</td>
<td>0.3%</td>
<td>2%</td>
<td>NS</td>
</tr>
<tr>
<td>ICU length of stay (days)</td>
<td>11.5 (± 13)</td>
<td>12 (± 12)</td>
<td>13 (± 11)</td>
<td>NS</td>
</tr>
<tr>
<td>Hospital length of stay (days)</td>
<td>12 (± 19)</td>
<td>19 (± 20)</td>
<td>23 (± 23)</td>
<td>.05</td>
</tr>
<tr>
<td>30 day hospital mortality</td>
<td>65%</td>
<td>19%</td>
<td>18%</td>
<td>.05</td>
</tr>
</tbody>
</table>

AIS, abbreviated injury score; ICU, intensive care unit; SBP, systolic blood pressure.

*Continuous variables reported as means (± SD) or median (interquartile range), and categorical variables as percentage of patients.

Open and endovascular repair are significant compared with no repair.

Endovascular repair is significantly lower than both open and no repair, and open repair is significantly lower than no repair.

Open repair is significant compared with both no repair and endovascular repair.

ence in overall mortality between open and endovascular repair of the aortic injury (19% and 18%, P > .05). The paraplegia rates between open and endovascular repair were both very low (2% vs. 1.6%). Open repair was associated with higher cardiopulmonary complications (acute respiratory distress syndrome, pneumonia, and myocardial infarctions), whereas endovascular repair was associated with higher rates of acute renal failure.

The majority of repairs were performed in the first 72 hours of admission. The median time to open repair was 4.0 (interquartile range: 2.2-7.1) hours, and median time to endovascular repair was 9.8 (interquartile range: 2.0-39) hours. Only 5% of open repairs and 8% of endovascular repairs were delayed (>72 hours). Evaluating just delayed repairs (>72 hours), open aortic repair was associated with a 12% mortality, whereas there were no deaths in patients that underwent a delayed endovascular repair (0% mortality, P < .05).

Utilizing binary logistic regression, we evaluated initial physiologic variables, associated injuries, and type of aortic repair as potential factors associated with deaths in a population of blunt thoracic aortic injuries (Table II). Aortic repair was the only variable associated with improved survival (OR = 0.36; 95% CI, 0.24-0.54, P < .05) when controlling for physiologic presentation and associated injuries. Interestingly, endovascular repair was not associated with a survival advantage over open repair; therefore, the two groups were analyzed as one. Factors that predicted a worse outcome included: increasing age, hypotension on admission, hypothermia on admission, major head injury (AIS ≥ 3), major abdominal injury (AIS ≥ 3), and ISS >
trolled population of patients with major thoracic injuries. 25 contributed to in hospital mortality within this con-

major head injuries, major abdominal injuries, and ISS portion of the variability in survival. Major abdominal

impacts of BAI versus other major thoracic injuries (Table IV). There were 7,266 controls matched for age, major thoracic, head, and abdominal injuries. Among those surviving to discharge, functional outcome was much worse in patients with BAI. The BAI group had significantly higher rates of major functional disability in all three areas (Fig 2). For feeding (OR = 2.0; 95% CI, 1.6-2.4, \( P < .05 \)), locomotion (OR = 2.6; 95% CI, 2.2-3.1, \( P < .05 \)), and expression (OR = 2.2; 95% CI, 1.7-2.8, \( P < .05 \)), BAI patients were approximately twice as likely to suffer major functional disability at the time discharge. Respectively, BAI patients were less likely to be fully independent compared to matched controls: feeding (72% vs. 82%, \( P < .05 \)), locomotion (33% vs. 55%, \( P < .05 \)), and expression (80% vs 88%, \( P < .05 \)). Only 19% of BAI patients were fully independent in all three categories (FIM total score = 12) compared with 39% (\( P < .05 \)) of controls.

DISCUSSION

This manuscript represents the first contemporary national analysis of BAI and management strategies. The national incidence of BAI is 0.3% of all trauma admissions, but portends an unacceptably high morbidity and mortality. Twenty-four percent of patients are either dead on arrival or die during triage. Of the patients surviving triage, an astonishing two-thirds of patients are unable to undergo repair with an associated mortality of 68%. If the patient is able to undergo aortic repair, their mortality is reduced to 19%. Irrespective of hemodynamic status, associated injury patterns, and timing of repair, aortic repair is consistently associated with a lower mortality.

Early series describing the treatment of BAI focused on immediate diagnosis, typically using catheter angiography, and emergent open repair due to the fear of imminent rupture. This approach required an emergent thoracotomy in patients who typically had multiple associated injuries and who were in various stages of early trauma resuscitation. As would be expected, the attendant morbidity and mortality rates with this approach remained high.12,13 Several larger and more modern series subsequently reported improved mortality and morbidity rates with the selective use of delayed operative repair combined with strict early intensive care management focusing on resuscitation, treatment of associated injuries, and double product control.4,5,14 This approach has been demonstrated to result in a very low rate of in-hospital aortic rupture and improved outcomes, particularly among patients with severe associated injuries. In addition, the observation that some patients with BAI can be managed entirely nonoperatively.
Hypotension (SBP <90 mm Hg) and hypothermia (T < 35 C) \(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Early mortality (≤ 2 days)</th>
<th>Late mortality (&gt; 2 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted odds ratio</td>
<td>95% confidence interval</td>
</tr>
<tr>
<td>Age (per year)</td>
<td>1.01</td>
<td>1.00-1.03</td>
</tr>
<tr>
<td>Hypotension (SBP &lt;90 mm Hg) and hypothermia (T &lt; 35 C)</td>
<td>8.54</td>
<td>6.91-12.95</td>
</tr>
<tr>
<td>Major head injury (AIS ≥ 3)</td>
<td>1.13</td>
<td>0.83-1.52</td>
</tr>
<tr>
<td>Major abdominal injury (AIS ≥ 3)</td>
<td>2.89</td>
<td>1.36-5.14</td>
</tr>
<tr>
<td>Injury severity score &gt;25</td>
<td>1.56</td>
<td>1.09-2.24</td>
</tr>
<tr>
<td>Aortic repair(^b)</td>
<td>0.09</td>
<td>0.06-0.12</td>
</tr>
</tbody>
</table>

AIS, abbreviated injury score; SBP, systolic blood pressure.
\(^a\)Other variables tested include: delayed repair (>72 hours), Glasgow Coma Scale, base deficit, laparotomy, major pelvic injury, year of admission.
\(^b\)Hypotension and hypothermia demonstrated collinearity and were combined for analysis.

With spontaneous healing of the injury has been well described.\(^{18}\)

There have been two large, prospective observational studies evaluating the management and outcomes of blunt thoracic artery injuries (American Association for the Surgery of Trauma, AAST\(^1\)) and AAST\(^2,3,16\). In addition to providing useful information on the individual patient cohorts, comparison of these studies provides an interesting insight into the significant changes in diagnosis, management, and outcomes of BAI over the past decade.\(^{11}\) Comparison of the two study periods, 1994-1996 and 2005-2007, demonstrates that the diagnostic study of choice has evolved from catheter angiography to computed tomography, providing a faster and less invasive modality for early diagnosis. The most significant finding of this comparison is the marked change in operative management from overwhelmingly open repairs (100%)\(^2\) in the early period to a majority of endovascular repairs (65%)\(^{16}\) in the more modern series.

AAST1 enrolled 274 patients that underwent repair at an average of 16.5 hours, and AAST2 enrolled 193 patients that underwent repair at an average of 54.6 hours. Morbidity and mortality showed a significant improvement, with mortality declining from 22% to 13% and procedure associated paraplegia declining from 8.7% to 1.6% (both \(P < .05\)). Although our series confirmed the use of endovascular techniques for BAI nationwide, the majority of repairs were still performed open (87%). The only thoracic endoprostheses available in the United States, Gore TAG device (W.L. Gore & Associates Inc., Flagstaff, Ariz), received Food and Drug Administration (FDA) approval on March 23, 2005. Therefore, the devices utilized in this study represent the initial experience with custom-made devices or off-label use of aortic cuffs. The mortality rate reported in the current series of 18%-19% is also somewhat higher than the 13% in the AAST2 study. This likely reflects the fact that the multicenter studies included only a select group of level 1 trauma centers and is not a true representation of trends and outcomes at the national level. In comparison to AAST2, our series had similar ISS (39 vs. 39.5 in AAST2), but notably, nearly all (98%) patients in this series were initially hypotensive on arrival as compared with only 20% in AAST2. In addition, the current study had a much higher proportion of patients with major abdominal injuries (27% for open repair and 45% for endovascular repair) and major head injuries (24% for open repair and 45% for endovascular repair). Initial hypotension, major

Table III. Logistic regression analysis of factors impacting early and late deaths in blunt thoracic aortic injuries

Table IV. Multivariate analysis of factors impacting survival in a cohort of blunt thoracic aortic injuries matched for age, mechanism, and major thoracic injury

Table V. Demographics of matched controls for patients with blunt thoracic aortic injuries surviving to hospital discharge
abdominal injuries, and major head injuries were all highly predictive of death in this series and contribute to the higher mortality as compared to AAST2.

Arguably the most significant advance in the management of BAI in the past decade has been the adoption of endovascular techniques and stent-grafting. This approach allows for the rapid and definitive management of these complex injuries using minimally invasive techniques. The avoidance of a prolonged operative procedure requiring a thoracotomy, single lung ventilation, and potential cardiopulmonary bypass in these severely injured patients represents an attractive and intuitive option for minimizing perioperative complications. Although initially described through case-reports and small case-series of “off-label” uses of commercial or custom-made devices,9 there has been a rapidly increasing experience with endovascular repair of thoracic BAI and the ongoing development of improved commercially designed thoracic endograft devices.4,7,17

Two systematic reviews of BAI treated with endovascular repair have been reported with mortality rates of 7%-7.6% and paraplegia rates of 0%-0.7%.7,8 Both studies concluded that endovascular repair was superior to open repair, and both of these reviews were based on a compilation of author-selected case series. Individual reports of BAI treated with endovascular repair are subject to reporting bias and often represent the best clinical outcomes. In the present study, reporting bias does not influence our results, and we were unable to demonstrate a survival advantage for endovascular repair over open repair. Both repair types statistically improved survival.

While delayed aortic repair has been reported to improve outcomes,4 delayed repair (> 72 hours) was not a significant covariate in our regression analysis, but it is important to note that the mortality rate for delayed endovascular repair was 0% versus 12% for delayed open repair. Although this was a small percentage of the total study population, it does agree with other series that have found decreased mortality with endovascular repair compared with open repair when performed on a semi-elective basis. This study also reinforces that a large number of patients undergo nonoperative management (mortality rate = 65%) either due to the severity of associated injuries that preclude repair, or as a planned management strategy for injuries that may heal spontaneously.

Although contemporary series have focused on mortality and paraplegia rates following BAI treatment, no study to our knowledge has evaluated functional status at the time of discharge. Our study has examined functional status using a reproducible metric of early function, the FIM. Compared with similarly matched patients with major thoracic injuries, BAI imparted nearly four times the risk in-hospital death, and among survivors, BAI patients were two times as likely to suffer major disability in one of three measured areas: feeding, locomotion, and expression. Despite only 2% of open patients and 1.6% of endovascular patients suffering documented paraplegia, only one-third of patients could independently walk at the time of discharge from the hospital. One-fifth of patients will suffer major feeding and expression disability. The rates of disability identified are much higher than surviving controls suggesting BAI independently contributes to overall functional status.

Limitations of the study deserve mention. The National Trauma Databank represents a voluntary group of select trauma centers and is not a pooled population-based

![Fig 2. Proportion of patients with severe functional disability surviving until discharged. BAI, blunt thoracic aortic injury. Controls are matched for age, major thoracic injuries, major abdominal injuries, and major head injuries. OR, odds ratios (±95% confidence intervals).](image-url)
sample. It is maintained and evaluated by the ACS; however, it is subject to potential reporting and entry errors. Details of the exact operative procedures and techniques utilized in any particular case are not available, allowing only broad categorization and comparison. Postoperative complications (such as paraplegia) are not reliably coded by all contributing centers, so are likely underestimated in these comparisons. In addition, the results in this paper are not free from selection bias as can be seen in the differences of patients treated with open repair vs endovascular repair. A randomized trial would be required to fully eliminate selection bias, which is unlikely for this patient population. There are potential unmeasured covariates not recorded within the database that could potentially influence outcomes or better explain the variance in morbidity and mortality.

CONCLUSION

Our series represents the largest contemporary report of BAI, and the only assessment of functional disability at discharge in this population. This study confirms that endovascular techniques are being utilized, but have not become widely available or utilized at most trauma centers. In addition, BAI independently impacts survival irrespective of associated injury patterns and accounts for significant disability at the time of discharge. Consistently, the patient’s ability to undergo aortic repair dramatically improves survival in this population.

AUTHOR CONTRIBUTIONS

Conception and design: ZA, BS, NS, MM, CA
Analysis and interpretation: ZA, BS, NS, MM, CA
Data collection: ZA, BS, MM
Writing the article: ZA, BS, NS, MM, CA
Critical revision of the article: ZA, BS, NS, MM, CA
Final approval of the article: ZA, BS
Statistical analysis: ZA, BS, NS, MM
Obtained funding: CA
Overall responsibility: ZA

REFERENCES
