Evolution of the Incidence, Management, and Mortality of Blunt Thoracic Aortic Injury: A Population-Based Analysis

Charles de Mestral, MD, Andrew Dueck, MD, MSc, FACS, Sunjay S Sharma, MD, Barbara Haas, MD, PhD, David Gomez, MD, PhD, Mavin Hsiao, MD, Andrea Hill, MSc, Avery B Nathens, MD, PhD, MPH, FACS

BACKGROUND: In the last decade, CT angiography has become the dominant diagnostic modality for blunt aortic injury and endovascular repair has become the leading aortic repair strategy. The impact of these shifts on incidence, aortic repair rate, and mortality remains poorly characterized. Our objective was to perform a population-based analysis of secular trends in the incidence, management, and in-hospital mortality of blunt thoracic aortic injury.

STUDY DESIGN: From the population-based Canadian National Trauma Registry, we identified a cohort of all adults hospitalized between April 2002 and March 2010 with a diagnosis of thoracic aortic injury after blunt trauma. Trends over time in the incidence of hospitalization, frequency and type of aortic repair, as well as risk-adjusted in-hospital mortality, were evaluated.

RESULTS: A total of 487 incident cases of blunt thoracic aortic injury were identified. During the study period, the incidence of hospitalization for blunt thoracic aortic injury remained stable (trend \( p = 0.16 \)). Although the proportion of repairs undertaken via an endovascular approach increased (11% to 78% of repairs; trend \( p < 0.001 \)), the frequency of any repair (endovascular or open) declined (55% to 36%; trend \( p = 0.003 \)). Across all patients, when controlling for age, sex, mechanism of injury, and presence of severe extrathoracic injuries, mortality remained unchanged during the study period (odds ratio = 0.92 per 1 year; 95% CI, 0.82–1.03). However, in patients managed nonoperatively, risk-adjusted mortality decreased over time (odds ratio = 0.85 per 1 year; 95% CI, 0.80–0.98).

CONCLUSIONS: The increasing frequency of patients managed nonoperatively and decreasing risk-adjusted mortality in these patients suggests that defining the evolving role of nonoperative management should be a major focus of research in the endovascular era. (J Am Coll Surg 2013;216:1110–1115. © 2013 by the American College of Surgeons)

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Supported by a Canadian Institutes of Health Research Strategic Teams grant in Applied Injury Research. Dr de Mestral is supported by an Ontario Doctoral Award. Dr Hsiao is supported by a Canadian Institutes of Health Research doctoral award. Dr Nathens is supported by a Canada Research Chair in Systems of Trauma Care.

Abstract presented at the 2011 Annual Scientific Meeting of the Trauma Association of Canada.

Received November 15, 2012; Revised January 2, 2013; Accepted January 3, 2013.

Blunt thoracic aortic injury (BAI) remains associated with a substantial mortality rate after blunt trauma. Most patients die before hospitalization and, in the remaining survivors, in-hospital mortality is as high as 46%.

In patients reaching the hospital alive, 2 major shifts have occurred in the last decade with respect to the diagnosis and surgical management of BAI. First, CT angiography has become the diagnostic imaging modality of choice, potentially leading to a rise in the incidence of BAI due to previously undetected minimal aortic injuries. Second, an endovascular approach has become the dominant repair strategy, based on the following favorable outcomes when compared with open repair: reduced mortality, spinal cord ischemia, graft and systemic infections, and blood product requirements. Although these 2 major shifts are frequently described in recent surgical literature, their impact on BAI incidence, aortic repair rate, and
mortality remains poorly characterized. To better inform future therapeutic and research efforts, we performed a population-based analysis of secular trends in the incidence of hospitalization, surgical management, and in-hospital mortality of BAI.

METHODS

Design

We designed a retrospective cohort study of patients with BAI hospitalized within the fiscal years 2002 to 2009 (April 1, 2002 to March 31, 2010). We evaluated changes over time in the incidence of hospitalization, frequency and type of aortic repair, as well as risk-adjusted in-hospital mortality. This study was approved by the Research Ethics Board of St Michael’s Hospital.

Data sources

The cohort was derived from the Canadian National Trauma Registry—Minimum Dataset. Maintained by the Canadian Institute for Health Information, this dataset contains demographic, diagnostic, procedural, and discharge disposition data from all admissions due to traumatic injury to acute care hospitals in Canada. These data were deterministically linked across an episode of injury care using encrypted patient identifiers. This linkage prevented double counting of patients who are transferred across institutions for care.

Cohort

We included all adult (aged 16 years and older) Canadian residents hospitalized between April 1, 2002 and March 31, 2010, in all Canadian provinces and territories, with the exception of Quebec (because of differences in the data-collection process). To identify patients injured after blunt trauma, mechanism of injury categories were derived based on the Centers for Disease Control and Prevention’s ICD-10 external cause of injury code classification matrix. Among patients sustaining blunt trauma, those with a thoracic aortic injury were identified through the presence of the ICD-10 diagnosis code S25.0 (traumatic injury to the thoracic aorta).

Exposure

Given the focus on temporal trends, the exposure of interest was fiscal year.

Study outcomes

Incidence of hospitalization

Annual incidence was calculated using inter-censal population estimates from Statistics Canada.

Frequency and type of aortic repair

We classified the type of repair as either open or endovascular based on the ICD-10 procedure code categorization in Table 1. Repair was captured within the initial episode of injury care, which could include multiple admissions due to inter-hospital transfer. We were not, however, able to capture subsequent elective admissions for aortic repair after the initial episode of injury care.

Clinical outcomes

The primary clinical outcome of interest include in-hospital mortality during the initial episode of injury care.

Covariates

We considered the possibility that patient or injury-related factors might confound the relationship between fiscal year and in-hospital mortality. We therefore considered the following factors as potential confounders: age, sex, mechanism of blunt injury, Injury Severity Score (ISS)9 and presence of severe (Abbreviated Injury Scale score ≥3) extrathoracic injuries involving the head, abdomen, or extremities. Abbreviated Injury Scale and ISS were derived using a validated ICD-10 to Abbreviated Injury Scale crosswalk algorithm.10

Analytic approach and statistical analysis

Incidence of blunt thoracic aortic injury and frequency of aortic repair

The incidence of hospitalization for BAI and the proportion of patients undergoing aortic repair (all-type and endovascular) were calculated for each fiscal year. Trends over time in these measures were tested with the Mantel-Haenszel chi-square trend test. A secondary analysis was also undertaken to better understand contemporary management practices in the endovascular era. In doing so, the cohort was restricted to the latter half of the study period (fiscal years 2006 to 2009) and differences in patient characteristics across management strategy (repair, no repair) were explored. A t-test or Wilcoxon-rank test

| Table 1. Canadian Classification of Health Interventions Procedure Codes for Repair of the Thoracic Aorta |
|--------------------------------------------------|--------------------------------------------------|
| Open repair codes                                | Endovascular repair codes                        |
| Ascending aorta and aortic arch                  | 1IA57LA, 1IA76NB, 1IA79LA, 1IA80LA, 1IA87LA, 1IB57LA, 1IB76LA, 1IB79LA, 1IB80LA, 1IB87LA, 1IA50GQ, 1IA57GQ, 1IA80GQ, 1IB50GQ, 1IB57GQ, 1IB80GQ |
| Descending aorta                                 | 1ID57LA, 1ID80LA, 1ID80QF, 1ID87LA, 1ID87QF, 1IC50GQ, 1IC57GQ, 1IC80GQ |
| Thoracic aorta, not further specified            | 1IC50LA, 1IC57LA, 1IC76NB, 1IC76MI, 1IC80LA, 1IC87LA, 1IC87QF, 1IC50LA, 1IC57LA, 1IC76NB, 1IC76MI, 1IC80LA, 1IC87LA, 1IC87QF |

Source: de Mestral et al. Population-Based Analysis of Aortic Injury.
and a Pearson chi-square or Fisher’s exact test were used, as appropriate, for these comparisons.

**In-hospital mortality**

The trend in crude in-hospital mortality over time was tested with the Mantel-Haenszel chi-square test. Given evidence supporting a mortality benefit of an endovascular approach among patients managed with repair, we also tested the trend in crude mortality when stratifying on whether or not repair (open or endovascular) was undertaken.

Two multivariable logistic regression models were then developed to test for change in in-hospital mortality during the study period. In both models, the main exposure was fiscal year and the binary outcomes included in-hospital mortality. The covariates in the first model included age, sex, mechanism of blunt injury, and presence of extrathoracic severe injuries by body region. Fiscal year and age were included as continuous variables. Sex (male or female), mechanism (motor vehicle collision or other blunt mechanism), and presence of severe extrathoracic injuries (yes or no) were included as dichotomous covariates. The second logistic regression model was developed to test the trend in risk-adjusted mortality within similarly managed patients. In addition to the covariates included in the first model, the second model included a binary management flag (repair or no repair) and an interaction term between fiscal year and management. Discrimination of the models was quantified with the c-statistic and calibration tested with the Hosmer-Lemeshow test. A 2-tailed p < 0.05 was considered statistically significant. All analyses were performed using SAS 9.2 (SAS Institute).

**RESULTS**

There were 487 incident cases of hospitalization for blunt thoracic aortic injury, yielding an overall rate of 3.1 hospitalizations per 1,000,000 person-years. Most patients were male (n = 350 [72%]) and mean age was 45 ± 20 years. The vast majority of thoracic aortic injuries resulted from a motor vehicle collision (n = 437 [90%]). Patients in the cohort were severely injured, with a median ISS of 38 (interquartile range 30 to 50) and an overall case fatality rate of 18%.

**Incidence**

During the study period, the incidence of hospitalization for BAI ranged between 2.5 and 4.5 per 1,000,000 person-years. There was no significant change over time, as evaluated by the Mantel-Haenszel chi-square trend test (trend p = 0.16; Fig. 1).

**Frequency and type of aortic repair**

Although a majority of patients (55%; n = 28 of 51) underwent aortic repair (endovascular or open) in 2002, this proportion decreased during the study interval to <40% in 2009 (trend p = 0.003; Fig. 2). In addition, among patients who underwent aortic repair, an endovascular approach became the dominant repair strategy, from 11% to 78% during the interval of study (trend p < 0.001; Fig. 2).

In fiscal year 2006 and beyond, the year when endovascular repair became the dominant repair strategy, patients who were managed operatively (endovascular or open repair) had lower overall injury severity and less frequently had severe head and extremity injuries compared with patients managed nonoperatively (Table 2). There were no differences across measured characteristics between patients managed with endovascular vs open repair.
During the study period, the crude mortality did not change significantly (p = 0.10; Fig. 3). However, although mortality was unchanged in those managed with repair (p = 0.78; Fig. 3), mortality declined in patients managed nonoperatively (p = 0.011; Fig. 3). In both patients managed with repair and those managed nonoperatively, median ISS did not change significantly across the study period (p = 0.31 and p = 0.23, respectively). In addition, after endovascular repair became the dominant repair strategy in 2006, patients managed with endovascular repair had the lowest in-hospital mortality (6% for endovascular repair, 13% for open repair, and 23% for nonoperative management; p = 0.005).

Multivariable analysis results were consistent with the crude mortality trends. When controlling for age, sex, mechanism of injury, and presence of severe head, abdominal, and extremity injury, the adjusted odds of mortality remained stable across the study period in all patients (Table 3). Consistent again with crude trends, risk-adjusted mortality decreased over time in patients managed nonoperatively, and remained unchanged in patients who underwent aortic repair (Table 3).

**DISCUSSION**

The last decade has seen CT angiography become the dominant diagnostic modality for blunt aortic injury, and endovascular repair become the leading aortic repair strategy. Although these shifts have been well characterized, accurate estimates of trends in the incidence, aortic repair rate, and mortality of patients with BAI are lacking. Such information is highly relevant for quality improvement and future research efforts.

This population-based analysis of patients with BAI revealed 3 main findings. First, the incidence of hospitalization for BAI was stable during the 8-year study period. Second, although an endovascular approach became the dominant aortic repair strategy, the proportion of patients who underwent repair (endovascular or open) decreased over time. Finally, a constant mortality rate was seen across all patients and in those who underwent repair and mortality decreased over time in patients managed nonoperatively.

Given improvements in vehicle safety and reductions in motor vehicle collision deaths, it is reasonable to hypothesize that the true incidence of aortic injury, including deaths in the prehospital setting, is likely decreasing. The stable observed incidence of hospitalization with aortic injury in this study might therefore reflect a balance between a decrease in the true incidence and an increase in detection of minimal aortic injuries driven by the increased use of screening CT angiogram. Because aortic injury severity was unavailable, this hypothesis cannot be proven. However, additional support for such a premise is found in the observation that the rate of aortic repair (open or endovascular) declined during the study period. In their recent position statement on management of aortic injury, the Society for Vascular

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Aortic repair (n = 40)</th>
<th>No repair (n = 166)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean ± SD</td>
<td>43 ± 19</td>
<td>46 ± 19</td>
<td>0.65</td>
</tr>
<tr>
<td>Male sex, n (%)</td>
<td>81 (75)</td>
<td>109 (66)</td>
<td>0.10</td>
</tr>
<tr>
<td>Motor vehicle collision as mechanism of injury, n (%)</td>
<td>99 (92)</td>
<td>146 (88)</td>
<td>0.33</td>
</tr>
<tr>
<td>Injury Severity Score, median (IQR)</td>
<td>34 (29–45)</td>
<td>38 (30–50)</td>
<td>0.046</td>
</tr>
<tr>
<td>Severe head injury, n (%)</td>
<td>23 (21)</td>
<td>57 (34)</td>
<td>0.017</td>
</tr>
<tr>
<td>Severe abdominal injury, n (%)</td>
<td>25 (23)</td>
<td>33 (20)</td>
<td>0.52</td>
</tr>
<tr>
<td>Severe extremity injury, n (%)</td>
<td>34 (31)</td>
<td>74 (45)</td>
<td>0.030</td>
</tr>
</tbody>
</table>

IQR, interquartile range.

Figure 3. The crude in-hospital mortality in all patients remained stable during the study period (Mantle-Haenszle trend test, p = 0.10). However, stratifying patients based on management reveals that crude in-hospital mortality was stable over time in patients who underwent repair (trend p = 0.78), but decreased in patients managed nonoperatively (trend p = 0.011). Black line, all patients; red line, no repair; blue line, repair.
Surgery supports initial nonoperative management for intimal tears, with endovascular repair reserved for injury progression. An increase in the proportion of aortic injuries that are minimal because of improved detection could therefore partially explain a drop in the rate of aortic repair. In addition, because nonoperative management was being used with success in Canada at least as early as the start of the study period, the observed decrease over time in overall repair rate might then be interpreted as an appropriate application of the indications for aortic repair.

Although the underlying causes for in-hospital death are not captured in this analysis, the observed mortality trends remain hypothesis generating. In keeping with the reported mortality benefit of endovascular over open repair, our analysis showed that, once endovascular repair became the dominant repair strategy in 2006, mortality was lowest in patients managed with endovascular repair. However, despite a substantial shift toward endovascular over open intervention, mortality in patients managed with aortic repair did not decrease over time. This stable mortality in patients who underwent repair might be related to an increase in perioperative risk not captured in our risk-adjustment model. With respect to patients managed nonoperatively, a decrease in mortality was observed. Because mortality would only be infrequently due to aortic rupture, except in the case of severe aortic injury, the observed mortality reduction supports the suggestion of appropriate use of nonoperative management. The reduced mortality also raises the possibility of an increase in the proportion of minimal aortic injury translating into less aorta-specific mortality.

The majority of recent publications on BAI focus on the outcomes of endovascular and open repair. The results of this study, however, underscore the increasing use of nonoperative management. These data should serve to refocus our efforts on understanding the indications for nonoperative management. Additional multicenter studies, similar to the 2 American Association of Surgery for Trauma prospective cohort studies of blunt aortic injury, are required to better differentiate patients who can safely be managed nonoperatively from those that require endovascular repair. Such a study would ideally use standardized aortic injury gradient scoring, such as that proposed by Azizzadeh and colleagues and Starnes and colleagues, as well as capture detailed information on anatomic and physiologic injury severity and cause of death, and include long-term follow-up beyond the initial episode of injury care.

The main strengths of this study are its temporal and population-based scope; however, important limitations to our interpretation of the data should be made explicit. First, information on certain important determinants of management and mortality, such as the degree of aortic injury, aortic anatomy, and physiologic data were not available. Residual confounding related to aortic injury or unmeasured differences in global injury severity might explain the observed management and mortality trends. Second, although delayed intervention supported by medical management of blood pressure has also been associated with improved survival, these details were unfortunately not captured in our data. Third, the exact modality used to diagnose aortic injury was unknown in these data; however, the uptake of screening CT angiogram in Canada likely mirrored the increase reported in the United States. Finally, information on whether in-hospital death was related to aortic rupture is unavailable and would greatly enhance insight into appropriate indications for repair. These data show that the use of nonoperative management increased in association with a concurrent mortality reduction. Clarifying the underlying causes and appropriateness of this increase merits additional detailed investigation.

CONCLUSIONS
This large population-based study showed that, between April 2002 and March 2010, the incidence of hospitalization for BAI remained stable. Although an endovascular approach became the dominant repair strategy, the

---

**Table 3. Multivariable Analysis Showing Association of Fiscal Year and In-Hospital Mortality**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted odds ratio for in-hospital mortality (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1*</td>
<td></td>
</tr>
<tr>
<td>Fiscal year (per 1 y) all patients</td>
<td>0.92 (0.82–1.03)</td>
</tr>
<tr>
<td>Model 2†</td>
<td></td>
</tr>
<tr>
<td>Fiscal year (per 1 y) in patients managed with repair</td>
<td>0.97 (0.77–1.21)</td>
</tr>
<tr>
<td>Fiscal year (per 1 y) in patients managed without repair</td>
<td>0.85 (0.74–0.98)</td>
</tr>
</tbody>
</table>

*The model 1 result is adjusted for age, sex, mechanism of injury, and presence of severe head, abdomen, and/or extremity injury. The model showed fair discrimination (c-statistic = 0.71) and good calibration (Hosmer-Lemeshow p = 0.89).
†The model 2 results are also adjusted for the same covariates as model 1. The model showed fair discrimination (c-statistic = 0.75) and good calibration (Hosmer-Lemeshow p = 0.47).
proportion of cases managed nonoperatively increased and mortality in these same patients decreased. These results should underscore the need for a better understanding of the evolving role of nonoperative management of BAI in the endovascular era.

Author Contributions
Study conception and design: de Mestral, Dueck, Sharma, Haas, Gomez, Nathens
Acquisition of data: Hill, Nathens
Analysis and interpretation of data: de Mestral, Dueck, Sharma, Haas, Gomez, Hsiao, Hill, Nathens
Drafting of manuscript: de Mestral, Nathens
Critical revision: de Mestral, Dueck, Sharma, Haas, Gomez, Hsiao, Hill, Nathens

REFERENCES