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Functional outcomes of thoracic injuries in pediatric and adult occupants

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Abstract

Objective: To develop a disability metric for motor vehicle crash (MVC) thoracic injuries and compare functional outcomes between pediatric and adult populations.

Methods: Disability risk (DR) was quantified using Functional Independence Measure (FIM) scores within the National Trauma Data Bank (NTDB) for the top 95% most frequently occurring AIS 2, 3, 4, and 5 thoracic injuries in NASS-CDS 2000–2011. The NTDB contains a truncated form of the FIM score, including three items (self-feed, locomotion, and verbal expression), each graded from full functional dependence to full functional independence. Pediatric (ages 7–18), adult (19–45), middle-aged adult (46–65), and older adult (66+) MVC occupants were classified as disabled or not disabled based on the FIM scale. The DR was calculated for each injury within each age group by dividing the number of patients who were disabled that sustained the specific injury by the number of patients who sustained the specific injury. To account for the impact of more severe co-injuries, a maximum AIS (MAIS) adjusted DR (DR_{MAIS}) was also calculated. DR and DR_{MAIS} could range from 0 (0% disability risk) to 1 (100% disability risk).

Results: The mean DR_{MAIS} for MVC thoracic injuries was 20% for pediatric occupants, 22% for adults, 29% for middle-aged adults, and 43% for older adults. Older adults possessed higher DR_{MAIS} values for diaphragm laceration/rupture, heart laceration, hemo/pneumothorax, lung contusion/laceration, rib fracture, and sternum fracture compared to the other age groups. The pediatric population possessed a higher DR_{MAIS} value for flail chest compared to the other age groups.

Conclusions: Older adults had significantly greater overall disability than each of the other age groups for thoracic injuries. The developed disability metrics are important in quantifying the significant burden of injuries and loss of quality life years. Such metrics can be used to better characterize severity of injury and further the understanding of age-related differences in injury outcomes, which can impact future age-specific modifications to AIS.

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Keywords

Disability; Functional Outcome; Motor Vehicle Crash; Thoracic Injuries; Pediatric Trauma

INTRODUCTION

Thoracic injuries rank second only to head injuries in terms of the number of fatalities and serious injuries in motor vehicle crashes (MVCs) in the United States[1]. There are age-related differences in both thoracic injury risk and mortality risk[2,3], with adults (ages 19+) having significantly greater mortality risk compared to pediatric occupants aged 5–14 years old. Although mortality risk is a useful measure for threat to life, it does not accurately capture the significant burden of injury or the severity of non-fatal injuries. This is especially critical for pediatric patients where mortality rates tend to be very low. In an effort to supplement data on mortality rates, a metric quantifying the disability of specific injuries was developed using Functional Independence Measure (FIM) scores within the National Trauma Data Bank-Research Data Set (NTDB-RDS) for the top 95% most frequently occurring AIS 3, 4, and 5 MVC injuries[4]. This previously developed disability risk ranged from 0 to 90% disability for AIS 3, 4, and 5 thoracic injuries across the pediatric and adult age groups. The objective of this study was to further explore the disability metric for thoracic injuries by developing a disability metric for AIS 2, 3, 4, and 5 thoracic injuries and comparing the functional outcomes between the pediatric and adult populations.

METHODS

Disability Risk (DR)

The top 95% most frequently occurring AIS 2, 3, 4, and 5 thoracic injuries in MVCs were identified using the National Automotive Sampling System–Crashworthiness Data System (NASS-CDS) years 2000–2011[5]. MVC occupants were grouped into four age groups: pediatric (ages 7–18), adult (19–45), middle-aged (46–65), and older adult (66+). For pediatric occupants, the top 95% most frequently occurring AIS 2–5 thoracic injuries consisted of a list of 18 unique AIS codes. For the stratified adult age groups, the top 95% most frequently occurring AIS 2–5 thoracic injuries consisted of a list of 32 unique AIS codes.

Disability risk (DR) was calculated using the largest aggregation of trauma registry data, the NTDB-RDS version 7.1 years 2002–2006, as described in the previous study[4,6]. Briefly, MVC cases were selected using the ICD-9 external cause of injury codes (E-codes) 810–819 with post dots of 0 or 1, and an AIS-98 to ICD-9 mapping approach was used to match each of the patient's ICD-9 codes with its corresponding AIS code[7]. The Functional Independence Measure (FIM) scores, which measures the level of disability and amount of assistance required to carry out daily living activities, were used to calculate DR[8]. The FIM instrument has been validated for use in children 7 years and older[9–11]. The FIM instrument in the NTDB-RDS contains a validated truncated form of the measure with 3 items evaluating the areas of self-feed, locomotion, and verbal expression, each graded on a scale of 1 (full functional dependence) to 4 (full functional independence)[11–18]. Patients in each of the four age groups were classified as disabled if any of the three items (self-feed, locomotion, or verbal expression) possessed a FIM score of 1 or 2, indicating full functional or modified dependence.

Within each age group, for each of the top 95% most frequently occurring AIS 2, 3, 4, and 5 MVC thoracic injuries, the DR was calculated by dividing the number of patients who were disabled that sustained a specific injury by the number of patients who sustained the specific injury (Eq. (1)).

$$Disability\ Risk\ (DR) = \frac{\#\ \ Patients\ who\ were\ disabled\ that\ sustained\ a\ given\ injury}{\#\ \ Patients\ that\ sustained\ a\ given\ injury} \quad (1)$$

To account for the impact of higher severity co-injuries, a MAIS-adjusted DR (DR_{MAIS}) was also calculated for each injury. The calculation of the DR_{MAIS} for each injury includes only occupants with a MAIS equal to the AIS severity of the given injury (Eq. (2)). For example, if the given injury was an AIS 2, then occupants with AIS 3+ injuries would be excluded from the calculation. DR and DR_{MAIS} for each injury within each age group resulted in possible values ranging from 0 (0% disability risk) to 1 (100% disability risk).

$$MAIS - Adjusted\ Disability\ Risk\ \left(\mathrm{DR_{MAIS}}\right) \quad (2)$$

$$= \frac{\begin{array}{c} Patients\ who\ were\ disabled\ that\ sustained\ a\ given\ injury \\ and\ had\ a\ MAIS = AIS\ severity\ of\ the\ given\ injury \end{array}}{\begin{array}{c} Patients\ that\ sustained\ a\ given\ injury \\ and\ had\ a\ MAIS = AIS\ severity\ of\ the\ given\ injury \end{array}}$$

DR and DR_{MAIS} values for injuries on each of the respective top 95% lists were compared across the four age groups. One-way analysis of variance was used to examine group differences between age groups. Pairwise comparisons were also evaluated, using a conservative Bonferroni adjustment to account for multiple comparisons. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC) and JMP Pro 12.0 (SAS Institute, Cary, NC) and a p-value less than 0.05 was considered statistically significant.

RESULTS

The DR and DR_{MAIS} for the given injuries ranged from 0 (0% disability risk) to 0.9 (90% disability risk). The mean, standard deviation, and median DR and DR_{MAIS} values with interquartile ranges (IQR) for the AIS 2, 3, 4, and 5 thoracic injuries on the top 95% lists for each age group are reported in Table 1. For the DR values, pairwise comparisons demonstrated that older adults had significantly greater overall disability than each of the other age groups (older adult (50.0 ± 15.4%) vs. pediatric patients (29.0 ± 13.7%), vs. adult (30.9 ± 9.1%) vs. middle-aged (34.7 ± 13.1%); all p<0.0001). The DR values ranged from

12.5% to 70% for pediatric occupants, 20% to 53% for adults, 0% to 67% for middle-aged adults, and 0% to 90% for older adults. For the DR_{MAIS} values, pairwise comparisons also demonstrated that older adults had significantly greater DR_{MAIS} values than each of the other age groups (older adult (42.9 ± 19.5%) vs. pediatric patients (19.6 ± 15.8%), vs. adult (22.4 ± 12.5%), vs. middle-aged (28.6 ± 15.7%); all $p < 0.01$). The DR_{MAIS} values ranged from 0% to 64% for pediatric occupants, 0% to 48% for adults, 0% to 64% for middle-aged adults, and 0% to 90% for older adults.

Further analysis was performed using the DR_{MAIS} metric as it is a better estimate of the disability of an individual injury since it excludes the influence of occupants with higher severity co-injuries from the calculation. The DR_{MAIS} for each injury was compared to its corresponding MAIS-adjusted mortality risk (MR_{MAIS}) for pediatric and adult patients (Figure 1)[3,19]. The thoracic injuries across all the age groups had mortality risks values less than 50%, however, the associated disability risk ranged upwards to 90%. For low MR_{MAIS} values (0 – 5%), there were large variations in DR_{MAIS} with some injuries having high disability risks (0 – 38%). Linear regression models were fit to the data with R^2 values of 0.239 for pediatric patients, 0.509 for adults, 0.445 for middle-aged adults, and 0.635 for older adults.

To compare the differences in disability for individual thoracic injuries between the pediatric cohort and stratified adult groups, the DR_{MAIS} for each thoracic injury in the pediatric group is plotted for the same injury in each adult age group (Figure 2). Injuries appearing above the equivalency line demonstrate a greater DR_{MAIS} for pediatric patients than for the given adult age group. Comparing pediatric patients with the adult group, the disability values across each of the AIS severity values were very similar, as the majority of injuries fell along the equivalency line. This pattern shifted when comparing the pediatric patients to the middle-aged adult group. The middle-aged adult group tended to have higher DR_{MAIS} values across each of the AIS severity values. In comparing the older adult group and pediatric patients, the older adult group tended to have much higher DR_{MAIS} values for each AIS severity value.

DISCUSSION

MVC-induced thoracic injuries can result in varying levels of mortality and morbidity depending on the age of the occupant. Supplementation of mortality and AIS severity information with information regarding disability and functional outcomes can better characterize the severity of injuries especially for injuries with low mortality rates. In this study, a disability metric was quantified for the most frequently occurring AIS 2, 3, 4, and 5 MVC-induced thoracic injuries across the pediatric population, adults, middle-aged adults, and older adults using FIM scores from the NTDB-RDS. Overall, for both DR and DR_{MAIS}, older adults had significantly higher disability risks in comparison to pediatric patients, adults, and middle-aged adults for thoracic injuries.

To observe the varying levels of mortality and morbidity, a comparison of DR_{MAIS} and the mortality equivalent MR_{MAIS} was analyzed for each age group. Across all the age groups, low mortality risk thoracic injuries resulted in varying levels of disability spanning the range of 0 to 38%. The wide variability in disability risk for injuries of a given mortality risk highlights the ability of disability metrics to supplement mortality metrics to provide more information regarding the severity of injury.

The differences in disability for individual thoracic injuries across age groups were analyzed by comparing the pediatric cohort to each stratified adult age group. The disability risks across each AIS severity between the pediatric cohort and adult occupants were very similar. Middle-aged and older adults tended to have higher disability across each AIS severity in comparison to the pediatric occupants. An interesting injury comparison included an AIS 4 rib cage flail chest injury with lung contusion that resulted in higher disability for the pediatric occupants (64%) in comparison to the adults (35%), middle-aged adults (37%), and older adults (60%). Clinically, pediatric occupants often sustain lung injuries without the presence of rib fractures, while adults almost always sustain lung injuries in conjunction with rib fractures. When rib fractures are present in pediatric occupants, this often indicates severe trauma and thus can result in more debilitating outcomes as indicated by the higher disability risk[20,21].

In conclusion, a disability-based metric was computed for the most frequently occurring MVC-induced thoracic injuries for different age groups. Similar to varying levels of incidence and mortality associated with thoracic injuries, there were age-related differences in disability risk and injury outcomes. These differences across age groups highlight the effects of development and aging on the risk of morbidity. This information supplemented with AIS severity and mortality risk can lead to a better characterization of the severity of injury and better capture the significant burden of non-fatal injuries. The characterization of injury severity by age can help further the understanding of age-related differences in injury outcomes, which can impact future age-specific modifications to AIS.

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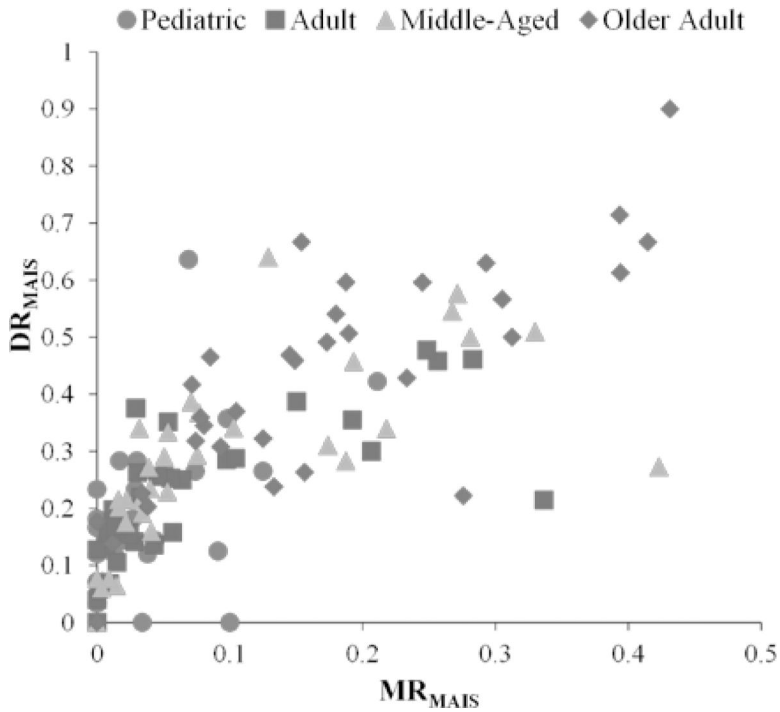

Figure 1.

MAIS-adjusted disability risk (DR_{MAIS}) vs MAIS-adjusted mortality risk (MR_{MAIS}) for the top 95% list AIS 2, 3, 4, and 5 thoracic injuries by age group.

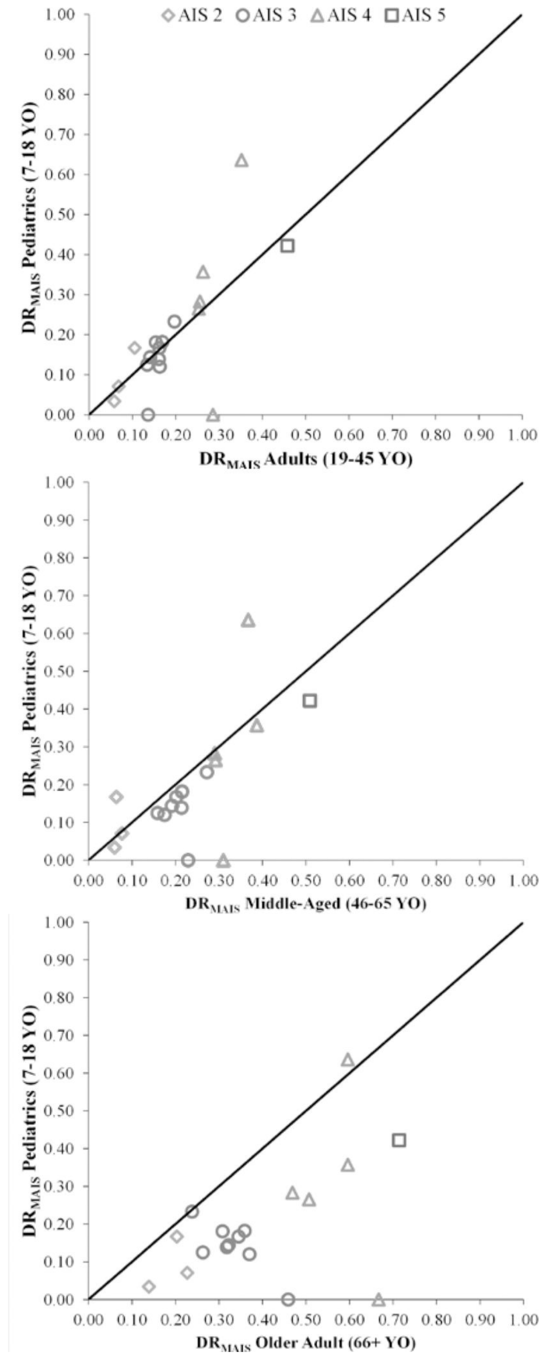

Figure 2.

DR_{MAIS} for AIS 2, 3, 4, and 5 thoracic injuries for pediatric patients versus adults (top), middle-aged (middle), and older adults (bottom). DR_{MAIS} for each injury in the pediatric group is plotted against the DR_{MAIS} of that injury for the adult age groups. Injuries are categorized by AIS severity as noted in the legend. Injuries appearing above the equivalency line demonstrate a greater DR_{MAIS} for pediatric patients than for the given adult age group.

Table 1.

Mean, standard deviation, and median disability risk (DR) and MAIS-adjusted disability risk (DR_{MAIS}) with interquartile ranges (IQR) for the top 95% AIS 2, 3, 4, and 5 thoracic injuries in each age group. Values are expressed as percentages.

Age Group	DR (%)				DR_{MAIS} (%)			
	Mean	Std Dev.	Median	IQR	Mean	Std Dev.	Median	IQR
Pediatric (7–18 YO)	29.0	13.7	26.6	20.1–35.2	19.6	15.8	16.7	10.8–27.0
Adult (19–45 YO)	30.9	9.1	29.2	23.5–36.8	22.4	12.5	20.6	13.8–29.7
Middle-Aged (46–65 YO)	34.7	13.1	32.8	25.4–41.0	28.6	15.7	27.8	19.4–36.1
Older Adult (66+ YO)	50.0	15.4	50.0	40.3–60.8	42.9	19.5	44.4	27.4–58.9