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Functional outcomes of motor vehicle crash head injuries in pediatric and adult occupants

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Abstract

Objective: The objective of the study was to develop a disability-based metric for motor vehicle crash (MVC) injuries, with a focus on head injuries, and compare the functional outcomes between the pediatric and adult populations.

Methods: Disability risk (DR) was quantified using Functional Independence Measure (FIM) scores within the *National Trauma Data Bank—Research Data System* (NTDB-RDS) for the top 95% most frequently occurring Abbreviated Injury Scale (AIS) 3, 4, and 5 head injuries in NASS-CDS 2000–2011. Pediatric (ages 7–18), adult (19–45), middle-aged (46–65), and older adult (66+) patients with an FIM score available who were alive at discharge and had an AIS 3, 4, or 5 injury were included in the study. The NTDB-RDS contains a truncated form of the FIM instrument, including 3 items (self-feed, locomotion, and verbal expression), each graded on a scale of 1 (*full functional dependence*) to 4 (*full functional independence*). Patients within each age group were classified as disabled or not disabled based on the FIM scale. The DR was calculated for each age group by dividing the number of patients who sustained a specific injury and were disabled by the number of patients who sustained the specific injury. To account for the impact of more severe associated coinjuries, a maximum AIS (MAIS) adjusted DR (DR_{MAIS}) was also calculated for each injury. DR and DR_{MAIS} ranged from 0 (0% disability risk) to 1 (100% disability risk).

Results: An analysis of the most frequent FIM components associated with disabling MVC head injuries revealed that disability across all 3 items (self-feed, locomotion, and expression) was the most frequent for pediatric and adult patients. Only locomotion was the most frequent for middle-aged and older adults. The mean DR_{MAIS} for MVC head injuries was 35% for pediatric patients, 36% for adults, 38% for middle-aged adults, and 44% for older adults. Further analysis was conducted by grouping the head injuries into 8 groups based on the structure of injury and injury type. The pediatric population possessed higher DR_{MAIS} values for brain stem injuries as well as loss of consciousness injuries. Older adults possessed higher DR_{MAIS} values for contusion/

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hemorrhage injuries, epidural hemorrhage, intracerebral hemorrhage, skull fracture, and subdural/subarachnoid hemorrhage.

Conclusion: At-risk populations such as pediatric and older adult patients possessed higher DR_{MAIS} values for different head injuries. Disability in pediatric patients is critical due to loss of quality life years. Disability risk can supplement severity metrics to improve the ability of such metrics to discriminate the severity of different injuries that do not lead to death. Understanding of age-related differences in injury outcomes when compared to adults could inform future age-specific modifications to the AIS.

Keywords

Disability; motor vehicle crash; head injuries; Abbreviated Injury Scale; pediatric

Introduction

Though injury is the leading cause of deaths in pediatric patients, mortality rates are typically low (Burd and Madigan 2009; Centers for Disease Control and Prevention, National Centers for Injury Prevention and Control 2013). However, despite low mortality rates, these serious injuries can result in short-and long-term disability, which is especially critical in pediatric patients and loss of quality life years. Motor vehicle crashes (MVCs) are a leading cause of death and disability for pediatric and adult patients (Bergen et al. 2014; Crandall et al. 2012; Peden 2008). In 2013, MVCs resulted in a total of 2,462,684 occupants treated in hospital emergency departments for nonfatal injuries (Centers for Disease Control and Prevention, National Centers for Injury Prevention and Control 2013). Children aged 5–14 accounted for 131,806 of these occupants.

The Abbreviated Injury Scale (AIS) is considered the global system of choice for injury data collection and has become the basis for a number of derivative scales in use (Association for the Advancement of Automotive Medicine 2008). The purpose of the AIS severity is to measure the threat to life, tissue damage, complexity of treatment, and impairment of an injury on an ordinal scale. Although AIS is largely based on mortality risk and threat to life, there may be age-specific differences in injury outcomes. Given the low mortality rates especially in the pediatric population, it is difficult to assess the severity of injuries solely based on mortality. Information regarding functional outcomes and disability can supplement mortality rates in order to improve the assessment of injury severity especially for injuries that do not necessarily lead to death.

There have been numerous studies involving functional outcomes in both children and adults following trauma (Aitken et al. 1999; Andersen et al. 2010; Gabbe et al. 2011; Scarboro et al. 2005; Willis et al. 2006; Winthrop et al. 2005; Zonfrillo et al. 2013, 2014). Various instruments were used to assess functional outcomes including the Child Health Questionnaire, Glasgow Outcome Scale, the Pediatric Quality of Life Inventory, Functional Independence Measure (FIM), and Medical Outcomes Study 36-Item Short Form Survey (Gabbe et al. 2011; McCarthy 2007). These studies typically focus on a cohort of patients with a given injury or multiple injuries in an effort to analyze demographics and injury pattern data to better understand functional outcomes. In an effort to supplement data on

mortality rates, a metric quantifying the disability of specific injuries is needed. The objective of the study was to develop a disability-based metric for MVC injuries, with a focus on head injuries, and compare the functional outcomes between the pediatric and adult populations.

Methods

Top 95% AIS 3, 4, and 5 NASS-CDS injuries

The top 95% most frequently occurring AIS 3, 4, and 5 injuries in MVCs were identified using NASS-CDS years 2000–2011 (NHTSA 2011). NASS-CDS provides a detailed record on a representative, random sample of thousands of minor to fatal tow-away crashes in the United States. A national estimate of the number of MVCs can be determined by applying weighting factors to the NASS-CDS data. AIS 3, 4, and 5 injuries were our primary focus because the most minor injuries (AIS 1–2) are less likely to be associated with diminished functional outcomes and the most severe injuries (AIS 6) are less survivable and therefore less relevant to long-term outcome studies of morbidity. MVC occupants were grouped into 4 age groups: pediatric patients (ages 7–18), adult (19–45), middle-aged adult (46–65), and older adult (66+). The top 95% most frequently occurring AIS 3, 4, and 5 injuries for pediatric patients consisted of a list of 118 injuries (unique AIS codes). The top 95% most frequently occurring AIS 3, 4, and 5 injuries for adult, middle-aged, and older adult consisted of a list of 112 injuries.

Disability risk

Disability risk (DR) was calculated using the *National Trauma Data Bank—Research Data System* (NTDB-RDS) version 7.1 years 2002–2006 (American College of Surgeons 2007). NTDB-RDS is supported by the American College of Surgeons (ACS) and is the largest aggregation of trauma registry data. The data collected from participating trauma centers are rigorously examined using both the National Trauma Registry of the ACS (NTRACS) software institutionally and a logical check system enforced by the NTDB administrators. MVC cases were subselected using the *International Classification of Diseases*, Ninth Revision (ICD-9) external cause of injury codes (E-codes) 810–819 with post dots of 0 or 1. An AIS-98 to ICD-9 mapping approach was used to match each of the ICD-9 codes present in the NTDB-RDS with its corresponding AIS code (Barnard et al. 2013). In order to calculate DR, FIM scores within NTDB-RDS were used. The FIM instrument provides a uniform system of measurement for disability based on the International Classification of Impairment, Disabilities, and Handicaps. The FIM instrument measures the level of disability and determines the amount of assistance required to carry out daily living activities (Uniform Data System for Medical Rehabilitation 2007). The FIM instrument has been validated for use in children 7 years of age or older (Aitken et al. 1999; Arthurs et al. 2009; Winthrop et al. 2005). The FIM instrument is composed of 18 items, 13 of which evaluate physical function and 5 of which evaluate cognitive function. Each of the 18 items is graded on a scale of 1 (indicating complete functional dependence or disability) to 7 (indicating complete functional independence). The NTDB-RDS contains a truncated form of the FIM instrument, including 3 items (self-feed, locomotion, and verbal expression), each graded on a scale of 1 (*full functional dependence*) to 4 (*full functional independence*). The

subelements of the truncated FIM scores have been validated (Ottenbacher et al. 1996). The truncated FIM scores in NTDB have been used to evaluate functional outcomes in adults and children in several published studies (Arthurs et al. 2009; Brown et al. 2010; Haider et al. 2009, 2011; Martin, Mullenix, et al. 2005; Martin, Weng, et al. 2005; Spaniolas et al. 2008). A similar truncated FIM score, consisting of 5 items (feeding, locomotion, transfer, social, and expression), also graded on a scale of 1 through 4, has been used to assess functional outcomes in children (Potoka et al. 2001). Pediatric, adult, middle-aged, and older adult patients were classified as disabled or not disabled based on the FIM scale in NTDB-RDS. If the patient possessed an FIM score of 1 or 2 (full functional/modified dependence) on any of the 3 items (self-feed, locomotion, or expression), the patient was classified as disabled.

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

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

To account for the impact of more severe associated coin-juries, a maximum AIS (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 (Equation (2)). For example, if the given injury was an AIS 3, then occupants with AIS 4+ injuries would be excluded from the calculation. DR and DR_{MAIS} for each injury within each age group resulted in values ranging from 0 (0% disability risk) to 1 (100% disability risk).

$$\text{MAIS Adjusted Disability Risk (DR}_{\text{MAIS}}) = \quad (2)$$

$$\frac{\begin{array}{l} \text{\#Patients who were disabled who sustained a given injury} \\ \text{and had an MAIS = AIS severity of the given injury} \end{array}}{\begin{array}{l} \text{\#Patients who sustained a given injury} \\ \text{and had an MAIS = AIS severity of the given injury} \end{array}}.$$

DR and DR_{MAIS} values for injuries on each of the respective top 95% lists were compared across the 4 age groups. Oneway analysis of variance was used to examine group differences between age groups and body regions. Pairwise comparisons were also evaluated, using a conservative Bonferroni adjustment to account for multiple comparisons. A more detailed analysis of the DR_{MAIS} for head injuries was undertaken as the focus of the paper. For the DR_{MAIS} for head injuries, patients with head injuries were included in the calculation regardless of other injuries sustained. Calculation of DR_{MAIS} using patients with head

injuries alone or exclusion of other injuries to other body regions would have resulted in too small of sample sizes. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC) and JMP Pro 11.0 (SAS Institute) and a P -value less than .05 was considered statistically significant.

Results

The sample sizes of occupants who were 7 years and older, alive at discharge, and possessed an AIS 3, 4, or 5 injury on the top 95% lists included 28,713 pediatric occupants, 96,908 adult occupants, 37,330 middle-aged occupants, and 21,230 older adult occupants. FIM scores were available for 15,507 pediatric occupants (54%), 54,473 adult occupants (56%), 20,842 middle aged occupants (56%), and 11,762 older adult occupants (55%). Those with missing FIM scores were compared to those with FIM scores and there were no statistically significant differences across patient characteristics such as gender, race, payment, length of stay, or intensive care unit days or across hospital characteristics such as region, teaching status, or bed size. Classification of disability using the FIM scores determined that 22% of pediatric patients (3,408 occupants), 22% of adults (11,992 occupants), 28% of middle-aged adults (5,813 occupants), and 41% of older adults (4,867 occupants) were disabled. The most frequently occurring type of disability (FIM component) for each age group was locomotion alone followed by the combination of self-feeding, locomotion, and expression. The occupants across all ages sustained an average of 5.7 ± 3.7 injuries. The average ISS for each age group was 17.7 ± 11.0 for pediatric patients, 17.1 ± 10.7 for adults, 16.4 ± 10.0 for middle-aged adults, and 16.2 ± 9.5 for older adults.

The sample sizes of occupants who were 7 years and older, alive at discharge, possessed an AIS 3, 4, or 5 injury on the top 95% lists, and were included in the DR_{MAIS} calculation included 22,808 pediatric occupants, 78,417 adult occupants, 30,555 middle-aged occupants, and 17,351 older adult occupants. FIM scores were available for 10,592 pediatric occupants (46%), 38,474 adult occupants (49%), 14,391 middle-aged occupants (47%), and 8,779 older adult occupants (51%). Classification of disability using the FIM scores determined that 19% of pediatric patients (1,988 occupants), 20% of adults (7,716 occupants), 28% of middle-aged adults (4,006 occupants), and 41% of older adults (3,596 occupants) were disabled. Similar to the patients in the DR calculation, the most frequently occurring type of disability (FIM component) for each age group was locomotion alone followed by the combination of self-feeding, locomotion, and expression. The occupants across all ages sustained an average of 5.0 ± 3.2 injuries. The average ISS for each age group was 14.7 ± 8.3 for pediatric patients, 14.3 ± 8.1 for adults, 14.0 ± 7.7 for middle-aged adults, and 14.0 ± 7.6 for older adults.

Overall DR and DR_{MAIS}

The DR and DR_{MAIS} ranged from 0 (0% disability risk) to 1 (100% disability risk). The mean, standard deviation, and median DR and DR_{MAIS} values with interquartile ranges (IQRs) for the AIS 3, 4, and 5 injuries on the top 95% lists for each age group are reported in Table 1; there were very few injuries with 0% or 100% disability. For the DR values, pairwise comparisons demonstrated that older adults had significantly greater overall

disability than each of the other age groups (pediatric patients [$36.9 \pm 20.4\%$] vs. older adult [$53.1 \pm 16.2\%$]: $P < .001$; adult [$35.8 \pm 13.0\%$] vs. older adult [$53.1 \pm 16.2\%$]: $P < .001$; middle aged [$40.5 \pm 14.1\%$] vs. older adult [$53.1 \pm 16.2\%$]: $P < .001$). In addition, middle-aged adults had significantly greater disability than the adult age group ($P = .03$), although this value was no longer significant after adjusting for multiple comparisons. 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 (pediatric patients [$27.0 \pm 20.5\%$] vs. older adult [$48.0 \pm 18.8\%$]: $P < .001$; adult [$28.8 \pm 16.4\%$] vs. older adult [$48.0 \pm 18.8\%$]: $P < .001$; middle aged [$34.9 \pm 15.7\%$] vs. older adult [$48.0 \pm 18.8\%$]: $P < .001$). Pairwise comparisons also demonstrated that middle-aged adults had significantly higher disability than pediatric patients ($P = .001$) and adults ($P = .01$), the latter of which fell out of significance after multiple comparison adjustment.

Because the DR_{MAIS} excludes occupants with higher severity coinjuries, this metric is a better estimate of the disability for an individual injury. Thus, further analysis was performed using the DR_{MAIS} values. The DR_{MAIS} for each injury was compared to its corresponding MAIS-adjusted mortality risk (MR_{MAIS}) for pediatric and adult patients (Doud et al. 2015; Weaver et al. 2013). The trends for the pediatric and adult patients were similar as shown in Figure 1. For low MR_{MAIS} values (~ 0.00), there were large variations in DR_{MAIS} with some injuries having high disability risks. Linear regression models were fit to the data with R^2 values of 0.325 and 0.128 for pediatric and adult patients, respectively.

Disability risk may vary based upon the body region injured. The DR_{MAIS} for each age group was compared to its corresponding body (Figure 2). For all age groups, injuries to the head and lower extremity are responsible for higher disability risks. After adjustments for multiple comparisons, head injuries ($37.9 \pm 22.5\%$) had significantly higher disability than the abdomen ($27.4 \pm 18.8\%$; $P = .009$) and spine ($24.7 \pm 15.2\%$; $P = .001$). Lower extremity injuries ($42.4 \pm 15.6\%$) had significantly higher disability than the thorax ($33.4 \pm 17.0\%$; $P = .003$), abdomen ($27.4 \pm 18.8\%$; $P < .001$), spine ($24.7 \pm 15.2\%$; $P < .001$), and upper extremities ($25.7 \pm 11.6\%$; $P = .003$), all of which remained significant after multiple comparison adjustment. Head injuries alone were evaluated to determine whether there were differences in disability risk based upon age. Overall, there were no significant differences when comparing the disability risk across the 4 age groups for head injuries.

DR_{MAIS} for head injuries

Due to the higher disability risks associated with head injuries and the implications of such injuries, further analysis of disability was performed focusing on head injuries. The DR and DR_{MAIS} values for the AIS 3, 4, and 5 head injuries for each age group including the sample sizes used in the calculation can be found in Table A1 (see online supplement). The mean DR_{MAIS} for MVC head injuries was 35% for pediatric patients, 36% for adults, 38% for middle-aged adults, and 44% for older adults with ranges of values from 0 to 100% for pediatric patients, adults, and older adults and ranges of values from 12.5 to 100% for middle-aged adults. For the patients included in the DR_{MAIS} calculation with a head injury, the FIM component cited the most for pediatric and adult patients was the combination of self-feeding, locomotion, and expression, accounting for 50 and 45% of the pediatric and

adult patients, respectively. The most frequently occurring type of disability for middle-aged and older adults was only locomotion, accounting for 39 and 41%, respectively. Excluding patients with lower extremity and spinal injuries, self-feeding, locomotion, and expression were the most common disability for pediatric patients (56%), adults (52%), and middle-aged adults (46%). Only locomotion was still the most frequent disability for older adults (37%).

To compare the differences in disability for individual head injuries between the pediatric cohort and stratified adult groups, the DR_{MAIS} for each head injury in the pediatric group is plotted for the same injury in each adult age (Figure 3). Injuries appearing above the equivalency line demonstrate a greater DR_{MAIS} for pediatric patients than for the given adult age group. Comparing pediatric patients and the adult group, pediatric patients tended to have higher DR_{MAIS} across each AIS severity. Compared to the middle-aged group, pediatric patients tended to have lower DR_{MAIS} for AIS 2 and AIS 3 injuries and higher DR_{MAIS} for AIS 5 injuries. Lastly, comparing pediatric patients and the older adult group, pediatric patients tended to have lower DR_{MAIS} for AIS 2 and AIS 3 injuries and higher DR_{MAIS} for AIS 5 injuries.

Due to the large variations in the DR_{MAIS} as well as small sample sizes on an individual injury-level basis, further analysis was conducted by grouping the head injuries into 8 groups based on the structure of injury and injury type. Across the 4 age groups, there were 54 unique AIS head injury codes present. The 8 injury groups included brain stem injury, contusion or hemorrhage to the cerebrum/cerebellum, diffuse axonal injury, epidural hemorrhage, intracerebral hemorrhage, loss of consciousness, skull fracture, and subdural/subarachnoid hemorrhage. The DR_{MAIS} was calculated for each injury group by age group (Table 2). Sample sizes for the calculation can also be found in Table 2. The pediatric population possessed higher DR_{MAIS} values for brain stem injuries as well as loss of consciousness injuries. Older adults possessed higher DR_{MAIS} values for contusion/hemorrhage injuries, epidural hemorrhage, intracerebral hemorrhage, skull fracture, and subdural/subarachnoid hemorrhage.

Discussion

Due to the low mortality rates due to MVC injuries, especially in the pediatric population, the severity of injury, in terms of mortality and morbidity, can be difficult to determine. Information regarding functional outcomes and disability risk can supplement mortality information to better describe the severity of injury. In addition, there may be age-specific differences in injury outcomes that may better describe the severity of injury. Previous studies have analyzed functional outcomes with a focus on providing summary statistics regarding the patient cohort and injury patterns. To the best of our knowledge, no study has quantified the disability risk using a continuous metric. In this study, the disability risk for common MVC injuries across pediatric population, adults, middle-aged adults, and older adults was quantified, with a specific focus on head injuries, to compare the functional outcomes across the pediatric and adult populations.

DR and DR_{MAIS} were calculated using FIM scores from NTDB-RDS for the top 95% most frequently occurring AIS 3, 4, and 5 MVC injuries. Overall for both DR and DR_{MAIS}, older adults had significantly higher disability risks in comparison to pediatric patients, adults, and middle-aged adults. To control for patients with higher severity coinjuries, DR_{MAIS} was used for further analysis because it is the better estimate of disability of an individual injury. DR values are calculated using the complete sample of occupants who were 7 years and older, alive at discharge, and possessed an AIS 3, 4, or 5 injury on the top 95% lists. However, the DR of lower severity injuries such as AIS 3 injuries might be overestimated due to higher severity coinjuries, especially because most trauma patients sustain multiple injuries. A calculation of DR_{MAIS} is limited by smaller sample sizes but it does provide a better estimation of the disability of an individual injury. The calculation of true disability of an individual injury would have even smaller sample sizes than the DR_{MAIS} calculation because it would require patients who sustained the injury in isolation. An example of the DR_{MAIS} estimation of an individual injury includes an AIS 3 cranial vault fracture (150404.3). The DR_{MAIS} for each age group was 23% (pediatric patients), 23% (adults), 29% (middle-aged adults), and 27% (older adults). These AIS 3 cranial vault fractures were often accompanied with AIS 4 and 5 subdural and epidural hematoma injuries. As a result, the DR for each group was 34% (pediatric patients), 31% (adults), 36% (middle-aged adults), and 39% (older adults). Thus, the DR_{MAIS} captures the disability of this AIS 3 cranial vault fracture excluding the effects of these higher severity hematoma injuries.

A comparison of DR_{MAIS} and MR_{MAIS} was conducted to observe the differences in disability and mortality across the pediatric and adult populations. For both the pediatric and adult patients, there was wide variability in associated disability for injuries with low mortality. This observation highlights the ability of disability risk metrics to describe more information regarding injury severity, especially for injuries with low mortality risks. Analysis of DR_{MAIS} by body region revealed that head and lower extremity injuries resulted in significantly greater disability across all age groups. Literature has shown that extremity fracture and head injuries tend to have poor initial functional outcomes in children (Gabbe et al. 2011). Over time, extremity fracture outcomes tend to improve, whereas head injuries show little improvement from 6 to 12 months postinjury. Similar findings have also been reported for adults following MVC trauma (Jurkovich et al. 1995; Read et al. 2004; Scarborough et al. 2005; Thornhill et al. 2000).

Head injuries, the focus of this article, were further analyzed due to the higher disability rates as well as the large variations in disability across the 4 age groups. A comparison of disability for individual head injuries between the pediatric cohort and stratified adult groups was conducted to delineate differences in disability with age. Pediatric patients tended to have higher disability across each AIS severity in comparison to the adult group and lower disability for AIS 2 and 3 injuries in comparison to the middle-aged and older adult groups. This analysis highlights the differences in disability risk across the age groups, which can ultimately affect injury outcomes. Differences in head and brain injuries across young, middle-aged, and older patients have demonstrated poorer outcomes for those with increasing age (Hukkelhoven et al. 2003; LeBlanc et al. 2006; Mosenthal et al. 2002). Additional analysis of head injuries was conducted by grouping head injuries into 8 injury groups based on the structure of injury and injury type. Overall, older adults had higher

associated disability for the majority of the injury groups, with pediatric patients having higher associated disability for brain stem injuries and loss of consciousness injuries. A comparison of younger (age < 64 years) and older (age ≥ 65 years) patients across head injury types including skull fracture, concussion, contusion, epidural hematoma, subarachnoid hemorrhage, and subdural hematoma noted that older patients were more likely to sustain subdural hematoma ($P < .001$; Mosenthal et al. 2002). There was little difference across the age groups for the other injury types. Older adults are also more likely to have poorer pre-injury health status and preexisting comorbidities that can influence the disability and recovery of aging patients.

This study has several limitations that should be noted. The NTDB-RDS is a large national database; however, it is not a population sample because it is skewed toward more severely injured patients from trauma centers. This bias is inherent to such a large retrospective review of a large national database. Another limitation is associated with the patients included in the study with available FIM scores. Because on average about 55% of the patient had FIM scores available, there may be some bias in the disability and injury distribution of the population. Though this bias exists, an analysis of patient and hospital characteristics revealed no statistically significant differences in those patients with and without FIM scores. In addition, pre-injury health status and preexisting comorbidities were not considered. These factors could affect the resulting disability status. Future work could study the effects of such conditions on disability to better discriminate an injury's disability. Another limitation involves the small sample sizes on a per injury basis for a given age group. Accurate calculation of disability risk is dependent on larger sample sizes to prevent skewing of the metric. The focus on the top 95% most frequently occurring AIS 3, 4, and 5 injuries was performed to exclude rare injuries, which likely had smaller sample sizes. This focus still resulted in small sample sizes for certain injuries, which is indicative of injuries that are likely infrequent within NTDB-RDS. NTDB-RDS is the largest aggregation of trauma registry data and therefore injuries with small sample sizes are perceived to be rarer. With the focus on head injuries, the calculation of the disability metric was performed by grouping similar injuries to increase sample sizes. In modeling these proportions we acknowledge that there is a floor and ceiling effect. However, overall, there are very few injuries with 0 and 100% disability; thus, the normal approximation to the binomial and subsequent analysis of variance is appropriate for analyses. Furthermore, we performed a sensitivity analysis in which we perturbed the data at the tails of the distribution, resulting in a normal distribution that extended beyond 0 and 1, and all significance levels and conclusions remained. In conclusion, this study demonstrates that there are age-related differences in disability risk and injury outcomes. Information regarding disability risk for at-risk populations of pediatric and older adult patients is important in understanding the age-related differences in injury outcomes. This is especially crucial for the pediatric population because disability can result in loss of quality life years. Disability risk could be used to supplement AIS severity and mortality risks in order to improve the assessment of severity of injury, especially for injuries that do not necessarily lead to death. In addition, understanding age-related differences in injury outcomes could inform future age-specific modifications to AIS including a possible pediatric-specific AIS.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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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 3, 4, and 5 injuries for pediatric (top) and adults (bottom) patients.

Figure 2.

Box-and-whisker plot of DR_{MAIS} by age group and body region. The bottom of the box is the 25th percentile, the middle is the median, and the top is the 75th percentile. The whiskers represent the maximum and minimum values.

Figure 3.

DR_{MAIS} for AIS 3, 4, and 5 head injuries for pediatric patients versus adults (top), middle-aged adults (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 DR and MAIS-adjusted disability risk (DR_{MAIS}) with IQRs for the top 95% AIS 3, 4, and 5 injuries in each age group.

Age group	DR (%)				DR_{MAIS} (%)			
	Mean	SD	Median	IQR	Mean	SD	Median	IQR
Pediatric (7–18 years old)	36.9	20.4	31.9	24.5–45.3	27.0	20.5	21.7	13.3–33.8
Adult (19–45 years old)	35.8	13.0	31.6	26.0–42.7	28.8	16.4	25.0	17.0–35.2
Middle-aged (46–65 years old)	40.5	14.1	38.1	30.4–48.0	34.9	15.7	31.1	23.4–44.8
Older adult (66+ years old)	53.1	16.2	50.4	44.7–62.5	48.0	18.8	47.1	37.5–60.3

Table 2.

Sample sizes and DR_{MAIS} values for injury groupings for head injuries by age group (I = total injured and D = total disabled).

Injury grouping	Pediatric			Adult			Middle-aged			Older adult		
	I	D	DR _{MAIS} (%)	I	D	DR _{MAIS} (%)	I	D	DR _{MAIS} (%)	I	D	DR _{MAIS} (%)
Brain stem injury	136	92	67.6	237	156	65.8	111	61	55.0	35	18	51.4
Contusion/hemorrhage	1837	562	30.6	4088	1118	27.3	3041	807	26.5	1245	519	41.7
Diffuse axonal injury	441	283	64.2	880	588	66.8	464	304	65.5	72	45	62.5
Epidural hemorrhage	336	74	22.0	532	134	25.2	274	86	31.4	99	41	41.4
Intracerebral hemorrhage	301	95	31.6	606	164	27.1	481	155	32.2	174	82	47.1
Loss of consciousness	43	12	27.9	49	12	24.5	31	7	22.6	5	1	20.0
Skull fracture	1970	466	23.7	3671	881	24.0	2306	619	26.8	516	209	40.5
Subdural/subarachnoid hemorrhage	1556	428	27.5	3717	984	26.5	3698	1022	27.6	2043	769	37.6