Predicting Pediatric Patients Who Require Care at a Trauma Center: Analysis of Injuries and Other Factors

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BACKGROUND: Triage decision correctness for children in motor vehicle crashes can be affected by occult injuries. There is a need to develop a transfer score (TS) metric for children that can help quantify the likelihood that an injury is present that would require transfer to a trauma center (TC) from a non-TC, and improve triage decision making. Ultimately, the TS metric might be useful in an advanced automatic crash notification algorithm, which uses vehicle telemetry data to predict the risk of serious injury after a motor vehicle crash using an approach that includes metrics to describe injury severity, time sensitivity, and predictability.

STUDY DESIGN: Transfer score metrics were calculated in 4 pediatric age groups (0 to 4, 5 to 9, 10 to 14, 15 to 18 years) for the most frequent motor vehicle crash injuries using the proportions of children transferred to a TC or managed at a non-TC using the National Inpatient Sample years 1998 to 2007. To account for the maximum Abbreviated Injury Scale (MAIS) injury, a co-injury adjusted transfer score (TS_{MAIS}) was calculated. The TS and TS_{MAIS} range from 0 to 1, with 1 indicating highly transferred injuries.

RESULTS: Injuries in younger patients were more likely to be transferred (median TS 0.48, 0.35, 0.25, and 0.23 for 0 to 4, 5 to 9, 10 to 14, and 15 to 18 years, respectively). Injuries more likely to be transferred in younger children occurred in the thorax and abdomen. Regardless of age, spine (median TS_{MAIS} 0.59), head (median TS_{MAIS} 0.48), and thorax (median TS_{MAIS} 0.46) injuries had the highest frequency for transfer.

CONCLUSIONS: The TS metrics quantitatively describe age-specific transfer practices for children with particular injuries. This information can be useful in advanced automatic crash notification systems to alert first responders to the possibility of occult injuries and reduce undertriage of commonly missed injuries. (J Am Coll Surg 2018;226:70–79. © 2017 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Seriously injured children treated at trauma centers (TCs) compared with non-TCs have decreased morbidity and mortality. Although debate exists about children's need for treatment at pediatric trauma centers (PTCs) vs adult trauma centers (ATCs),[1-4] the evidence overwhelmingly supports the fact that TCs in general (including PTCs and

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Abbreviations and Acronyms

AACN = advanced automatic crash notification
AIS = Abbreviated Injury Scale
ATC = adult trauma center
MAIS = maximum Abbreviated Injury Scale
MVC = motor vehicle crash
NASS-CDS = National Automotive Sampling System-Crashworthiness Data System
NIS = National Inpatient Sample
PTC = pediatric trauma center
TC = trauma center
TS = transfer score

ATCs) achieve superior outcomes for injured children compared with non-TCs. To reduce death and disability, it is important that the right triage decision is made.

One of the most important factors in the treatment of traumatic injuries in children is trauma triage, or the process by which children in need of treatment at a TC are identified by first responders on the scene and are appropriately transported to such facilities. The correctness of the triage decision can be affected by multiple factors, including the presence of occult, or unpredictable, injuries.[5] An occult injury is one that is difficult to detect and might not be detected until after the patient is triaged to a lower level of care. Such incorrect triage decisions lead to inter-facility transfers. Transfers increase time to definitive treatment,[6-8] which can affect outcomes. Transfers can also be costly because 2 hospital system resources are used (non-TC and TC emergency departments) instead of the TC emergency department only, and because 2 transports are required (from scene to non-TC and from non-TC to TC) instead of 1 (from scene to TC).[8] Injuries that are more highly transferred between facilities might be of a more occult nature.

In adults, a metric to describe the frequency of transfer for particular injuries was created.[9] This revealed that trauma systems vary in their ability to appropriately triage patients and that transfer is dependent on factors other than injury severity. These transfer scores can help identify commonly undertriaged and occult injuries and are useful in the development of triage protocols and injury prediction algorithms, such as advanced automatic crash notification (AACN) systems.[10] The AACN systems use vehicle telemetry data, such as speed of the crash, airbag deployment, and belt status, to determine which occupants of motor vehicle crashes (MVCs) are likely to need treatment at a TC, and can be used by first responders to improve the speed and accuracy of the triage process. The AACN algorithms require an objective measure for defining seriously injured patients and existing algorithms rely on metrics based on the Abbreviated Injury Scale (AIS), such as a maximum Abbreviated Injury Scale (MAIS) of 3+ or an Injury Severity Score of 15+, to define seriously injured patients.[11,12] To improve on the severity scoring systems used by AACN algorithms and better evaluate an occupant's need for treatment at a TC after MVC, an injury-based approach using 3 facets of injury (severity, time sensitivity, and predictability) was developed in adults.[5,9,13-15] The injury-based approach identifies a list of injuries that are associated with a patient's need for TC treatment. The AACN algorithm is developed using this list of injuries as well as MVC case data, including information on the occupants, crash conditions, and injuries, to generate a multivariable logistic regression model to predict the risk of an occupant sustaining an injury on the developed list. Given a child's constant growth and development, use of currently developed AACN algorithms in children is problematic because they provide no method for modification of injury risk based on a child's developmental stage. Therefore, pediatric-specific metrics describing severity, time sensitivity, and predictability—the focus of this study—are needed to develop a similar AACN algorithm for children.

The overall goal of this work was to develop a metric describing transfer frequencies in children. To accomplish this goal, a transfer score (TS) metric was developed for each of the most frequently occurring MVC-induced injuries within 4 pediatric age groups (0 to 4, 5 to 9, 10 to 14, and 15 to 18 years). The TS metrics developed in the current study cam be incorporated into pediatric-specific AACN algorithms in the future to identify injuries associated with a high frequency of inter-facility transfer.

METHODS

Top 95% Abbreviated Injury Scale 2+ National Automotive Sampling System-Crashworthiness Data System injuries

Institutional Review Board approval was obtained for retrospective review of the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) data. The NASS-CDS years 2000 to 2011 were used to determine the most common injuries among pediatric MVC occupants. The NASS-CDS collects data on a representative, random sample of thousands of minor, serious, and fatal tow-away crashes in the US. Weighting factors are applied to provide a population-based estimate of the incidence of particular injuries associated with US MVCs.[16] Requirements for NASS-CDS crash investigations changed in 2009, such that many variables after this time were not collected for model-year vehicles more than 10 years old. Therefore, cases with such missing data were excluded from our analysis. To account for potential overly influential weighting factors in NASS-CDS, we used the technique described by Samaha and

colleagues.[17] The NASS-CDS weighting factors >99th percentile in each stratified vehicle-type group (passenger car, van, or truck) were trimmed to this percentile.

Pediatric MVC occupants 18 years of age or younger were analyzed and divided into 4 age classifications (0 to 4, 5 to 9, 10 to 14, and 15 to 18 years) based on injury patterns studied by our group previously,[18] and coinciding with commonly used CDC groupings.[19] To capture the most salient injuries, AIS 1 severity injuries, which are mostly minor abrasions and contusions, were excluded. Within each age group, the weighted injury counts of each AIS 2+ injury were summed and the injuries were ranked in order of decreasing incidence. The most frequently occurring injuries comprising the top 95% of the cumulative weighted injury count were included on that age group's "top 95% injury list."

Transfer scores

Sample identification

The National Inpatient Sample (NIS) years 1998 to 2007 were used to calculate a TS metric for each of the injuries on each age group's top 95% list.[20] The NIS is a database that contains hospital discharge data from approximately 8 million TC and non-TC stays each year and is supported by the Healthcare Cost and Utilization Project. The NIS contains patient injury information coded with the ICD-9 lexicon. Children were defined as those 18 years of age or younger. As such, those aged 19 years and older or with unknown ages were excluded. The scores were calculated using a subset of the NIS database, including children in traffic and nontraffic MVCs, and other road vehicle accidents specified by external cause of injury codes 810 to 829 and 846 to 848, using all post-dot numbers.

Trauma center identification

A list of all unique hospitals in the NIS database was compiled to classify the hospital as a TC (including Level I/II ATCs and PTCs) or a non-TC. The presence of a Level I or II designation is determined by state regulatory agencies and can then be verified by a third party, such as the American College of Surgeons. For the purposes of this study, state-designated Level I or II centers and pediatric centers with or without American College of Surgeons verification were classified as TCs, with all other hospitals being classified as non-TCs.

Level I and Level II ATCs and PTCs were grouped together for several reasons. According to the ACS Committee on Trauma Classification System of Trauma Center Level, Level II centers must meet essentially the same criteria as a Level I except for the volume performance standards of 1,200 admissions per year, or 240 major trauma patients per year, or an average of 35 major trauma patients per surgeon.[21] In the literature, Level I and Level II TCs are typically analyzed together because the criteria are essentially the same.[22,23] Pediatric TCs were included with ATCs because access to PTCs (particularly during the years evaluated in this study) is highly variable, ranging from 22.9% in the most rural areas to 93.5% in the most urban areas. If one evaluates ground transportation access, only 43% of children in the US have access to a PTC within 60 minutes.[1] One can assume that if emergency medical services personnel suspected a seriously injured child, he or she would be transported directly to the nearest trauma center. Overwhelmingly, this would likely be an ATC. Conversely, one can assume that if emergency medical services personnel did not recognize the severity of a child's injuries, he or she would most likely be taken to the nearest non-TC. If serious injuries were present, this facility would likely transfer the child and this transfer would be captured in our dataset.[4,24]

Classification of the trauma designation was completed using a list obtained from the Trauma Information Exchange Program and through manual verification.[25] The complete list of hospitals in the NIS database contains 3,872 unique hospitals. Of these hospitals, 64% (n = 2,483) included the hospital name. Classification of trauma designation was completed using the list from the Trauma Information Exchange Program (22%) and manually (78%) using the American College of Surgeons website, state-level trauma designation websites, and individual hospital websites. Six researchers were involved in the manual classification procedure, with 1 researcher verifying the entire list. The reproducibility of the classification was deemed sufficient. Two researchers each classified 100 hospitals and the inter-observer agreement was 100%. At the conclusion of the classification, 2,413 hospitals with corresponding TC classifications were included in the study (2,381 Level I/II ATCs with or without associated PTCs and 32 stand-alone PTCs). Seventy hospitals were excluded from the study because there was missing information or the hospital was no longer in operation.

Abbreviated Injury Severity Scale to International Classification of Diseases, 9th edition, mappings

An AIS98 to ICD-9 mapping approach was used to match each of the ICD-9 codes present in the NIS with its corresponding AIS code.[26] Of the 253 unique injuries that existed across all 4 top 95% injury lists, AIS to ICD-9 maps existed for 246 of them. Maps were reviewed manually by experienced clinicians. Based on this manual review, 25 AIS codes were assigned new ICD-9 maps. For example, AIS code 853000.3 (femur fracture, not further specified) originally mapped to ICD-9 code 808.2 (closed fracture of the pubis). This ICD-9 code was reassigned to 821.0 (closed fracture of unspecified portion of femur). Those maps that were not

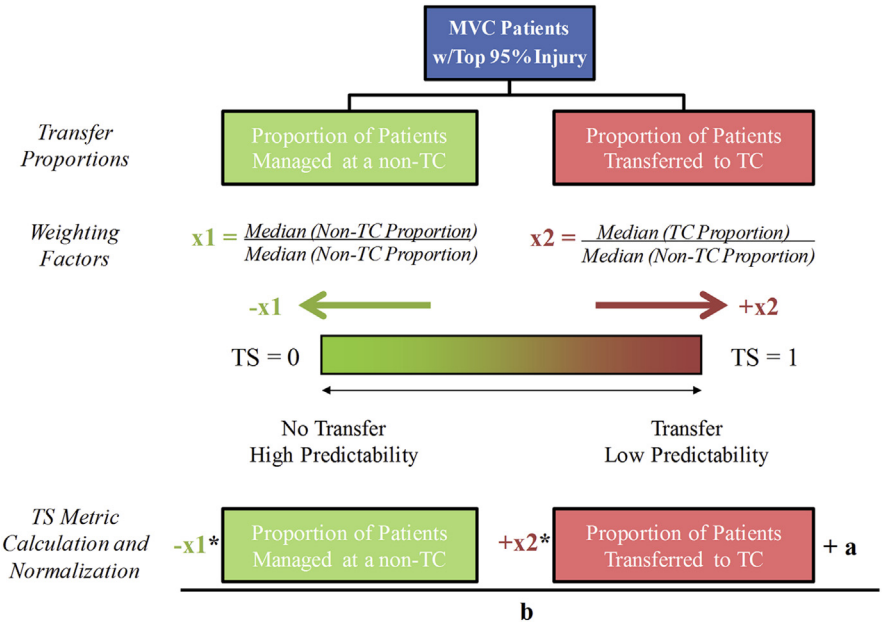


Figure 1. Overview of the calculation of the transfer score (TS) metric using the "x1" and "x2" weighting factors to compute a weighted sum of the proportion of patients managed at a non-trauma center (non-TC) and the proportion of patients managed at TC. The overall TS metric was normalized on a 0 to 1 scale using the normalization values "a" and "b." The TS metrics closer to 1 indicate more highly transferred injuries. MVC, motor vehicle crash.

altered by clinician reviewers were deemed accurate. Additionally, the 7 AIS codes without ICD-9 maps were assigned ICD-9 codes during this manual review by clinicians. A complete list of the AIS to ICD-9 maps used in this study can be reviewed in eTable 1.

Injury grouping

Initial review of the sample sizes for each injury revealed small sample sizes for some injuries, with many injuries having 0 to 1 patient with a known transfer status. To augment the analysis, injuries were grouped by clinician experts. Injuries were grouped together based on body region affected by the injury, AIS severity, and mechanistic aspects of injury (ie whether the injury involved hemorrhage, fracture, contusion, or laceration). For example, all AIS codes indicating AIS severity 2 or 3 concussions were grouped together, which encompassed 10 unique AIS codes. Similarly, all AIS codes indicating AIS severity 3 fractures of the femur were grouped together, also encompassing 10 AIS codes. After the injuries were grouped, the 253 unique AIS codes were consolidated into 54 unique injury groupings (eTable 1).

Transfer score metrics

A detailed description of the methodology and rationale behind the calculation of the TS and the co-injury adjusted transfer score (TS_{MAIS}) is documented within the adult population.[9] An overview of the determination of the pediatric transfer proportion, weighting factors, and final TS metric calculation and normalization is provided in Figure 1. Children within the NIS data were stratified into 2 groups: transferred from a non-TC to a TC or managed at a non-TC. Patients admitted directly to a TC were excluded from the analysis because of the bias of patients with lower-severity injuries being treated at a TC due to the proximity of the TC.[27,28] Within each age and injury group, the proportion of patients managed at a non-TC and the proportion of patients transferred to a TC were determined using Equations 1 and 2. For each age and injury group, the sum of the proportions described in Equations 1 and 2 equals 1.

$$\text{Proportion of patients managed at a non} - \text{TC} = \frac{\text{Patients Managed at a non} - \text{TC}}{\text{Patients Transferred to TC} + \text{Patients Managed at a non} - \text{TC}} \quad (1)$$

$$\text{Proportion of patients transferred to a TC} = \frac{\text{Patients Transferred to TC}}{\text{Patients Transferred to TC} + \text{Patients Managed at a non} - \text{TC}} \quad (2)$$

The TS metric was determined using a weighted sum of the 2 proportions and was subsequently normalized on a 0 to 1 scale. Briefly, weighting factors

were determined using median values of the 2 proportions to reflect the high importance placed on the injuries transferred to TC relative to the non-TC proportion from a trauma triage standpoint. The weighting factor (x1) related to the proportion of patients managed at a non-TC was assigned a negative value, which shifts the TS metric closer to 0, indicating more highly predictable and less transferred injuries. Subsequently, the weighting factor (x2) related to the proportion of patients transferred to a TC was assigned a positive value, which shifts the TS metric closer to 1, indicating less predictable and more likely to be transferred. As shown in Figure 1, the final TS metric calculation was determined by weighting each proportion as described and normalizing the metric on a 0 to 1 scale using the normalization values a and b.

To adjust for patients with higher severity co-injuries, a co-injury adjusted TS_{MAIS} was computed, which factors in the patient's MAIS severity injury. TS_{MAIS} was calculated using the proportions of patients with MAIS equal to the AIS severity of a given injury. This excludes patients with a higher severity co-injury to minimize low-severity injuries appearing as if they required TC transfer. Similar to the TS metric, the same methodology was applied to derive weighting factors and normalization values.

For the grouped injuries on each age group's top 95% list, the TS and TS_{MAIS} were computed. The TS and TS_{MAIS} values were stratified by age, body region, mechanistic aspects of injury, and AIS ranges. Differences between aggregate TS and TS_{MAIS} within these stratifications (age, body region, mechanistic aspects of injury, and AIS ranges) were determined using nonparametric Kruskal-Wallis tests. Statistical analyses were completed using JMP Pro, version 11.0.0 (SAS Institute) and p values <0.05 were considered statistically significant.

RESULTS

Top 95% list of injuries in National Automotive Sampling System-Crashworthiness Data System

Evaluation of the NASS-CDS 2000-2011 dataset with defined exclusions produced 3,648 pediatric MVC occupants (unweighted) with 12,496 unweighted and 972,674 population-weighted AIS 2+ injuries. Trimming of overly influential weighting factors reduced the weighting factors of 79 unique injuries and reduced the weighted injury count to 903,177. The Top 95% injury list was composed of 112 unique AIS codes for 0- to 4-year-olds, 125 unique AIS codes for 5- to 9-year-olds, 156 unique AIS codes for 10- to 14-year olds, and 194 unique AIS codes for 15- to 18-year-olds. However, injuries on the top 95% lists were often overlapping, with 162 AIS codes appearing on more than 1 list. This resulted in 253 unique AIS 2+ injuries spanning all 4 age groups' top 95% lists.

Grouping of similar injuries consolidated the top 95% lists to 28 injuries for 0- to 4-year-olds, 31 injuries for 5- to 9-year-olds, 37 injuries for 10- to 14-year-olds, and 45 injuries for 15- to 18-year-olds (of which 17, 21, 28, and 37 injury groups had sufficient sample sizes to calculate a TS in the respective age groups).

National Inpatient Sample patient dataset

The NIS 1998-2007 database contained 126,260 children younger than 19 years in traffic and non-traffic MVCs and other road traffic accidents. Of these children, 66,891 had an injury on their age group's top 95% list. Trauma center treatment information was known for 42,874 of these children, of which 30,212 were directly admitted to a TC and therefore excluded from the analysis. Of the remaining children, 2,106 were transferred to a TC and 10,556 were managed at a non-TC. Of those admitted to a non-TC or transferred to a TC, 5.1% were 0 to 4 years old, 11.9% were 5 to 9 years old, 25.4% were 10 to 14 years old, and 57.6% were 15 to 18 years old.

Transfer score and co-injury adjusted transfer score

The TS and TS_{MAIS} ranged from 0 to 1, with 1 indicating injury groupings that were more frequently transferred. The values of the TS and TS_{MAIS} for each injury grouping in each age group can be found in eTables 2 and 3.

The TS_{MAIS} values for injury groupings were consistently lower than the unadjusted TS values. For example, among 0- to 4-year-olds, the TS of AIS 2 and 3 tibia and/or fibula fractures was 0.10 and the TS_{MAIS} was 0.00. When an AIS 2 or 3 tibia and/or fibula fracture was the most severe injury sustained among 0- to 4-year-olds, very few of these patients required transfer to a TC. Similarly, among 15- to 18-year-olds, the TS of an AIS 2 clavicle fracture was 0.21 and the TS_{MAIS} was 0.12. When an AIS 2 clavicle fracture was the most severe injury sustained, far fewer patients required transfer to a TC than when there were other more severe associated injuries.

The distributions of the scores varied based on age. The TS and TS_{MAIS} distributions in the youngest age group (0 to 4 years) were more left-skewed, reflecting more injuries that required transfer, and TS and TS_{MAIS} distributions in the oldest age group (15 to 18 years) were more right-skewed, with fewer injuries requiring transfer. Such alterations in distributions can be appreciated with the box-and-whisker plots of the TS and TS_{MAIS} values for each age group in Figure 2.

Although overall TS and TS_{MAIS} scores were not significantly different between age groups as a whole, younger children tended to have higher scores than older children. For

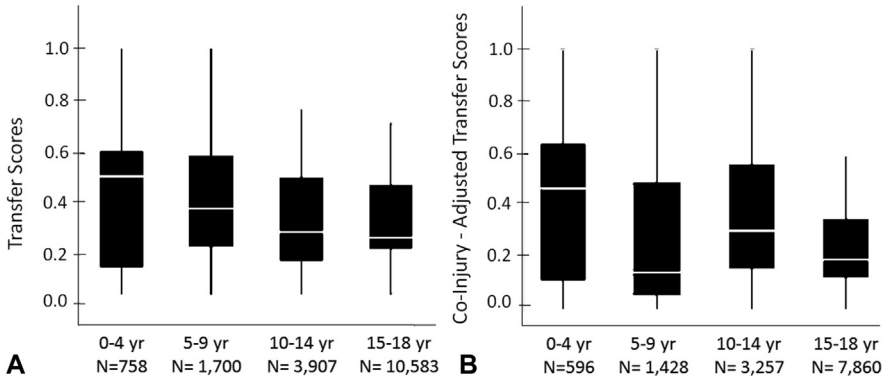


Figure 2. Box-and-whisker plots showing median and interquartile ranges (IQRs) for (A) transfer score (TS) and (B) median co-injury adjusted transfer score to account for maximum Abbreviated Injury Scale (TS_{MAIS}) within each age group. The white line in the center of the box represents the median of each age-specific TS and TS_{MAIS}. The upper and lower limits of the boxes show the 25% and 75% quantiles of the TS and TS_{MAIS} within each age group. The lower limit of each line (whisker) represents the value at the $25^{th}\% - 1.5 \times$ IQR and the upper limit of each line represents the value at the $75^{th}\% + 1.5 \times$ IQR. The n values denote the number of children included in each calculation. Data source: National Inpatient Sample, years 1998 to 2007.

example, the median TS among 0- to 4-year-olds was 0.48 compared with 0.35 among 5- to 9-year-olds, 0.25 among 10- to 14-year-olds, and 0.23 among 15- to 18-year-olds. This reflects a trend of increasing proportions of younger children undergoing transfer to TCs than older children.

Co-injury adjusted transfer score and body region

As the TS_{MAIS} eliminates children with more severe co-injuries from the calculation, an injury's TS_{MAIS} would signal that the injury to that body region was of equal or greater severity than any of the other injuries sustained by children included in the calculation. Because it could be presumed that a child's most severe injury was the most important factor contributing to their transfer, significant differences in the aggregate TS_{MAIS} of injury groups to the same body region were evaluated.

Evaluation of the TS_{MAIS} based on body region for all injury groupings, regardless of age, demonstrated that injuries to the spine (median TS_{MAIS} 0.59), head (median TS_{MAIS} 0.48), and thorax (median TS_{MAIS} 0.46) had the highest propensity for transfer. Aggregate injuries for each of these 3 body regions had significantly greater TS_{MAIS} values than aggregate upper extremity injuries (vs head, $p < 0.01$; vs thorax, $p < 0.01$; and vs spine, $p = 0.01$). Similarly, aggregate injuries within these 3 body regions had significantly greater TS_{MAIS} values than aggregate lower extremity injuries (vs head, $p < 0.01$; vs thorax, $p < 0.01$; and vs spine, $p = 0.01$).

Transfer propensity also varied within each body region based on age (Figure 3). Although the number of injury groups within each age-specific body region was too small to make comments about the statistical significance of the differences between ages, there were important trends. Particularly, both thoracic and abdominal injuries more commonly required transfer among 0- to 4-year-olds compared with 5- to 18-year-olds.

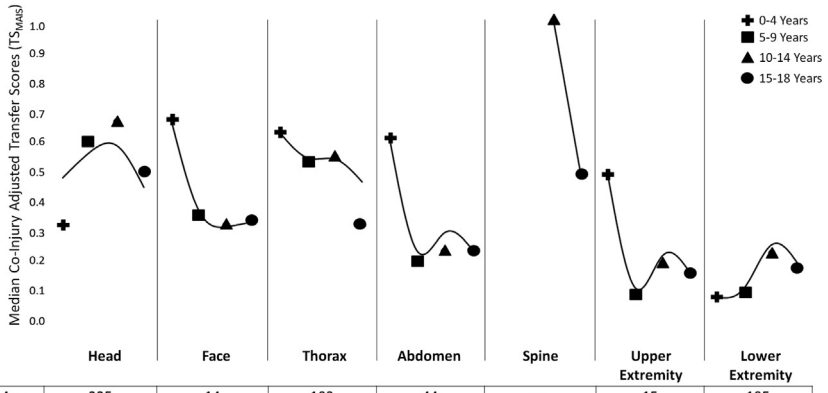
Co-injury adjusted transfer score and injury type

Transfer patterns also varied based on injury type. Aggregately, regardless of age, injury groups involving fractures and joint dislocations had lower median transfer scores (median TS_{MAIS} 0.17) than injury groups involving hemorrhage (median TS_{MAIS} 0.48) and internal contusions, nonhemorrhagic lacerations, and concussions (median TS_{MAIS} 0.28) ($p < 0.01$ for both).

Because injuries were grouped to achieve sufficient sample sizes, different levels of AIS severity injuries were grouped together. Therefore, transfer patterns within each AIS severity level could not be determined per se. However, injuries were assigned to the highest AIS severity level within their group. For example, the injury grouping including AIS 2 and 3, solid abdominal organ contusions, was assigned an AIS score of 3 and the injury grouping including AIS 3 and 4, skull fractures, was assigned an AIS score of 4. The TS_{MAIS} values of injury groupings within each assigned AIS severity level were analyzed across age groupings. Median, mean, and SD for the TS_{MAIS} of these injuries are reported in Table 1. In general, median and mean TS_{MAIS} values increased with increasing AIS severity categories.

DISCUSSION

The correctness of the triage decision can be affected by multiple factors, including the presence of occult or unpredictable injuries. Such injuries can result in a patient being transported to a non-TC, only to require transfer to a TC after the injury is recognized. Such inter-facility transfers



N								
	0-4yr	225	14	103	44	---	15	195
	5-9yr	260	134	161	105	---	176	592
	10-14yr	358	279	347	371	12	618	1272
	15-18yr	1058	676	1324	673	842	813	2474

Figure 3. Median co-injury adjusted transfer score to account for maximum Abbreviated Injury Scale (TS_{MAIS}) by age and body region. The symbol corresponds to the median TS_{MAIS} of the age group. The lines are drawn to allow the reader to better visualize the trends. The n values denote the number of children included in each calculation. Data source: National Inpatient Sample, years 1998 to 2007.

increase time to definitive treatment and cost of care[8,29] and can increase patient morbidity and mortality.[6,7] The TS and TS_{MAIS} were created to provide a quantitative predictability metric on a continuous scale to indicate the likelihood that an injury will require transfer from a non-TC to a Level I/II ATC or PTC. Presumably, injuries with high frequency of transfer (corresponding to higher TS and TS_{MAIS} values) are more occult (or less predictable) injuries. Although the TS metric evaluates the percentages of all patients with a particular injury that require transfer, the TS_{MAIS} metric eliminates patients with co-injuries of higher AIS severity level from the calculation before evaluating the proportion of patients with a particular injury that require transfer. The TS_{MAIS} metric can serve as a better estimate of the true predictability of an individual injury because it is not affected by more severe concomitant injuries. The TS and TS_{MAIS} developed will be used as part of a larger effort for incorporation in a pediatric AACN algorithm to detect less-predictable injuries in MVCs requiring prompt treatment at a TC. The TS and TS_{MAIS} metrics can also be useful for on-scene injury severity prediction algorithms that could be integrated into emergency medical services software platforms to use data obtainable at the MVC scene to improve occupant triage.[30,31]

The TS and TS_{MAIS} were stratified by age, AIS severity, body region, and injury type. Overall results demonstrated that injuries showed higher TS when occurring in younger age groups as opposed to older age groups, when involving injuries to the head, thorax, or spine and when involving hemorrhagic or internal contusive and concussive injuries. The TS_{MAIS} values also tended to increase with increasing AIS severity.

The greater TS and TS_{MAIS} values in the youngest subsets point to the fact that identification of injuries in the prehospital setting might be more difficult among younger children. Particularly within 0- to 4-year-olds, children might not be able to verbally express their symptoms. Alternatively, providers at referring centers might be less comfortable caring for younger children than providers at large tertiary centers with pediatric subspecialists available. Although these referring centers might be comfortable providing definitive treatment to older children who are more similar to adults, they might be more likely to defer treatment of the youngest of children to tertiary referral centers.

Injuries to the spine and head, regardless of age, had the highest propensity for transfer. Spine injuries might not be recognized in the field because field assessment does not typically involve a full neurologic exam. In addition, children might not be capable of cooperating with a full neurologic exam. Both spinal injuries and head injuries can be

Table 1. Number of Patients and Injuries (Unique Abbreviated Injury Scale Codes), and Median and Interquartile Range of Co-Injury Adjusted Transfer Score Stratified by Abbreviated Injury Scale Severity

			TS_{MAIS}	
Severity	**n**	**No. of injuries**	**Median**	**Interquartile range**
AIS 2	8,623	33	0.15	0.08–0.21
AIS 3	24,161	38	0.20	0.08–0.38
AIS 4	7,769	8	0.49	0.32–0.61
AIS 5	3,990	14	0.70	0.48–0.79

AIS, Abbreviated Injury Scale; TS_{MAIS}, co-injury adjusted transfer score to account for maximum AIS (MAIS).
Data source: National Inpatient Sample, years 1998 to 2007.

accompanied by a lack of external symptoms. In addition, head injuries can present with an initial lucid period or it might be difficult to distinguish altered mental status from baseline in a very young or frightened child. In addition, head injuries are often triaged to the nearest hospital regardless of TC designation for maintenance of cerebral perfusion pressure and oxygenation, only to later require transfer.

The TS_{MAIS} of injuries to the abdomen and thorax were highest in the youngest age group than in the older age groups. High rates of transfer among young children with thoracic injuries might reflect the fact that the chest walls of younger children are more pliable than those of older children.[32,33] This allows for internal and initially occult injuries to the thoracic viscera without more obvious overlying chest wall deformities or fractures. Higher rates of transfer among young children with abdominal injuries might reflect a younger child's inability to relay symptoms of abdominal pain. It might also reflect the fact that younger children exhibit stronger compensatory mechanisms than adults and might not manifest hemodynamic evidence of intra-abdominal hemorrhage until after they have been triaged.[34]

The higher TS_{MAIS} values among higher-severity AIS groupings make sense because severe injuries are likely to require transfer to a TC if initially triaged to a non-TC, and lower-severity injuries are not. However, one would expect TS_{MAIS} values to be 1 for the most severe AIS 5 and 6 injuries, or that almost all injuries would be transferred, as it is unlikely that non-TCs have the staff and equipment to care for such injuries. One possible explanation for this value not being 1 is that injuries of very high severity that are undertriaged can result in patient death before transfer can occur, lowering the TS_{MAIS} values of those injuries.

In a recent evaluation of TS values among adult patients, Schoell and colleagues[9] found that the majority of the TS_{MAIS} for the most commonly occurring MVC-induced injuries had values close to 0.5. The authors found this troubling, as they posited that injuries requiring transfer to a TC should consistently require transfer regardless of location and, therefore, have a TS_{MAIS} score of close to 1. Conversely, injuries not requiring care at a TC should never be transferred and should have TS_{MAIS} values close to 0. They provided several explanations for the discrepancy between hypothesized and real-world data, including the differences in the capabilities of different non-TCs, differences in regionalized prehospital protocols, the effects of additive injuries and the fact that the TS_{MAIS} does not account for patient comorbidities.[9]

Similar to the findings of Schoell and colleagues[9] about the transfer practices among adult MVC occupants, our data revealed that few injuries had TS_{MAIS} values of 0 or 1. This indicates great variability in the transfer practices for particular injuries. Certainly, some of the reasons posited by Schoell and colleagues apply to the pediatric population. However, several other factors unique to this population might apply. Goldstein and colleagues[35] evaluated overall transfer practices among patients aged 15 years and younger and defined secondary overtriage, or the transfer of patients without need for treatment at a PTC from a non-PTC to a PTC. Patients without need for treatment at a PTC were defined as those with an Injury Severity Score of <9 who did not require surgical intervention or critical care admission and who had a total hospital stay of less than 24 hours. Using this definition, 22% of patients in their study were unnecessarily transferred to a PTC. The authors suggest that a lack of national guidelines or the fear of litigation among physicians when treating children might be to blame.[35] The variability in injury-specific TS in the current study could be attributable to not only primary undertriage (or failure to recognize an occult injury in the field), but also secondary overtriage (or the unnecessary inter-facility transfer of a patient with mild injuries). Additional investigations into subsequent treatment and outcomes among the transferred and nontransferred subsets of patients with particular injuries could help to answer this question in the future.

There are several limitations to these analyses. First, this is a retrospective review of a large national dataset. Quality-control measures within the facilities that contribute this information can vary. Second, the database used to generate the most commonly occurring MVC-induced injuries occurring in pediatric subsets uses AIS codes and the NIS database uses ICD-9 codes, and mappings between the 2 lexicons can be imperfect. However, this mapping was rigorously created and validated. Final mapping results were reviewed by experienced clinicians to determine their accuracy. Third, although 10 years of NIS data were used, age-specific subanalysis reduced this sample size, particularly for injuries that occur infrequently. Data-driven metrics require large sample sizes to ensure the accurate calculation of transfer proportions, and the TS of injuries with small sample sizes might be skewed. However, similar injuries were grouped to determine these TS metrics and this resulted in improved sample sizes. Additionally, use of the top 95% most frequently occurring injuries among pediatric MVC occupants served to eliminate many exceedingly rare injuries with small sample sizes from the analysis. Fourth, the number of comparisons made in this article could result in apparent significance for some injury and age group pairs that is the result of chance. However, due to the descriptive nature of this article, such occurrences are not considered highly informative. Fifth, analyses focused on an older AIS version (AIS98) because injuries were coded in this lexicon in all the years of NASS-CDS analyzed. Additional work might be needed to translate findings to more recent AIS versions.

CONCLUSIONS

The TS and TS_{MAIS} values help us to better understand transfer practices for children with particular injuries. This information can inform guidelines for prehospital staff to prevent initial undertriage with subsequent inter-facility transfer, as well as guidelines for non-TCs to prevent secondary overtriage. Perhaps of greatest significance, this information can be useful in AACN and on-scene injury severity prediction algorithms to identify and alert first responders to the possibility of an occult, or highly transferred, injury. This can improve initial triage decisions to reduce undertriage of missed injuries. Conversely, one could postulate that even with guidelines to reduce secondary overtriage, the fear experienced by many providers in caring for the pediatric trauma patient with certain injuries will result in transfers, even when not indicated by the guidelines. With this attitude, AACN or on-scene injury severity prediction algorithms could be designed to urge first responders to transport pediatric patients with highly transferred injuries to TCs, even when such injuries are not severe, as ultimate treatment there might be inevitable.

Author Contributions

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Analysis and interpretation of data: Doud, Schoell, Talton, Weaver

Drafting of manuscript: Doud, Schoell, Talton, Weaver

Critical revision: Doud, Schoell, Talton, Barnard, Petty, Meredith, Martin, Stitzel, Weaver

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eTable 1. Abbreviated Injury Scale-International Classification of Diseases Maps for Top 95% Injuries, Number of Age Group Lists that the Injury Appears on, Injury Groupings, and Injury Characteristics

AIS code	ICD code	No. of lists	Injury grouping	Injury characteristic
1106042	873.0	2	AIS 2 Head, other	Internal contusion/concussion
1130006	800.25	1	AIS 6 Head, crush	Other
1210025	900	1	AIS 3-5 Head, hemorrhage	Hemorrhage
1316042	951.4	1	AIS 2 Head, other	Fracture/joint dislocation
1402025	348.4	4	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1402045	851.4	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1402105	853	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1402126	851.6	2	AIS 6 Head, brainstem laceration	Internal contusion/concussion
1402186	851.65	1	AIS 6 Head, brainstem laceration	Internal contusion/concussion
1404033	851	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1404304	853	1	AIS 3-5 Head, hemorrhage	Hemorrhage
1404384	852.25	1	AIS 3-5 Head, hemorrhage	Hemorrhage
1404663	852	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1406043	851	2	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406063	851.01	4	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406113	851	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406123	851	2	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406143	851.02	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406203	800.65	4	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406223	851.02	4	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406244	851.05	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406265	851	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406285	854	4	AIS 3-5 Head, other	Internal contusion/concussion
1406294	853	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1406304	852.4	1	AIS 3-5 Head, hemorrhage	Hemorrhage
1406324	852.4	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406345	852.2	2	AIS 3-5 Head, hemorrhage	Hemorrhage
1406384	431	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1406404	853.01	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406424	853	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1406465	853.05	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1406504	852.2	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406524	852.2	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406545	852.2	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406565	852.25	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1406603	854	4	AIS 3-5 Head, other	Internal contusion/concussion
1406623	348.5	4	AIS 3-5 Head, other	Internal contusion/concussion
1406644	348.5	4	AIS 3-5 Head, other	Internal contusion/concussion
1406665	854	4	AIS 3-5 Head, other	Internal contusion/concussion
1406763	851	1	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1406784	853	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406823	854.02	4	AIS 3-5 Head, other	Internal contusion/concussion
1406843	852	4	AIS 3-5 Head, hemorrhage	Hemorrhage
1406884	851.2	4	AIS 3-5 Brain contusion/laceration/infarction	Internal contusion/concussion
1502003	801	4	AIS 3/4 Head, fracture	Fracture/joint dislocation
1502023	801	4	AIS 3/4 Head, fracture	Fracture/joint dislocation
1502064	801.65	4	AIS 3/4 Head, fracture	Fracture/joint dislocation

(Continued)

eTable 1. Continued

AIS code	ICD code	No. of lists	Injury grouping	Injury characteristic
1504002	800.2	4	AIS 2 Head, fracture	Fracture/joint dislocation
1504022	800.01	4	AIS 2 Head, fracture	Fracture/joint dislocation
1504043	800	4	AIS 3/4 Head, fracture	Fracture/joint dislocation
1504064	800.9	4	AIS 3/4 Head, fracture	Fracture/joint dislocation
1602022	850.1	4	AIS 2/3 Head, concussion	Internal contusion/concussion
1604062	850.1	4	AIS 2/3 Head, concussion	Internal contusion/concussion
1604102	850.1	4	AIS 2/3 Head, concussion	Internal contusion/concussion
1604142	850.1	4	AIS 2/3 Head, concussion	Internal contusion/concussion
1606022	850.0	4	AIS 2/3 Head, concussion	Internal contusion/concussion
1606043	850	1	AIS 2/3 Head, concussion	Hemorrhage
1606062	850.5	2	AIS 2/3 Head, concussion	Internal contusion/concussion
1606102	850.1	4	AIS 2/3 Head, concussion	Internal contusion/concussion
1606992	850.0	3	AIS 2/3 Head, concussion	Internal contusion/concussion
1608023	850.3	2	AIS 3-5 Head, hemorrhage	Hemorrhage
1608063	850.3	3	AIS 3-5 Head, hemorrhage	Hemorrhage
1608084	850.2	1	AIS 4/5 Head, concussion	Internal contusion/concussion
1608204	850.2	3	AIS 4/5 Head, concussion	Internal contusion/concussion
1608225	850.2	1	AIS 4/5 Head, concussion	Internal contusion/concussion
1608245	850.4	4	AIS 3-5 Head, other	Internal contusion/concussion
1608993	850.5	1	AIS 3-5 Head, hemorrhage	Hemorrhage
1610002	850.1	4	AIS 2/3 Head, concussion	Internal contusion/concussion
2106042	873.42	3	AIS 2 Face, soft tissue laceration	Other
2434042	873.64	1	AIS 2 Face, soft tissue laceration	Other
2502002	802.27	4	AIS 2/3 Face, fracture	Fracture/joint dislocation
2506082	802.22	2	AIS 2/3 Face, fracture	Fracture/joint dislocation
2506102	802.3	1	AIS 2/3 Face, fracture	Fracture/joint dislocation
2506122	802.33	1	AIS 2/3 Face, fracture	Fracture/joint dislocation
2506142	802.36	1	AIS 2/3 Face, fracture	Fracture/joint dislocation
2506162	802.34	1	AIS 2/3 Face, fracture	Fracture/joint dislocation
2508002	802.4	4	AIS 2/3 Face, fracture	Fracture/joint dislocation
2508022	802.4	1	AIS 2/3 Face, fracture	Fracture/joint dislocation
2508042	802.4	2	AIS 2/3 Face, fracture	Fracture/joint dislocation
2508062	802.4	1	AIS 2/3 Face, fracture	Fracture/joint dislocation
2508083	802.4	2	AIS 2/3 Face, fracture	Fracture/joint dislocation
2510042	802.1	4	AIS 2/3 Face, fracture	Fracture/joint dislocation
2512002	802.6	4	AIS 2/3 Face, fracture	Fracture/joint dislocation
2512022	802.6	4	AIS 2/3 Face, fracture	Fracture/joint dislocation
2512043	802.6	4	AIS 2/3 Face, fracture	Fracture/joint dislocation
2516042	830.0	1	AIS 2 Face, joint dislocation	Other
2518002	802.4	2	AIS 2/3 Face, fracture	Fracture/joint dislocation
4202105	901	1	AIS 5 Thoracic, aortic laceration	Hemorrhage
4406064	862	2	AIS 4 Thorax diaphragm rupture	Internal contusion/concussion
4414023	861.21	3	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4414063	861.21	4	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4414104	861.21	4	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4414303	861.22	1	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4422023	860	4	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4422043	862.29	2	AIS 3 Thorax, other	Other

(Continued)

eTable 1. Continued

AIS code	ICD code	No. of lists	Injury grouping	Injury characteristic
4502102	807.09	3	AIS 2/3 Chest wall fracture	Fracture/joint dislocation
4502113	807.09	1	AIS 2/3 Chest wall fracture	Fracture/joint dislocation
4502143	860	1	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4502202	807.02	3	AIS 2/3 Chest wall fracture	Fracture/joint dislocation
4502223	860	3	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4502303	807.05	3	AIS 2/3 Chest wall fracture	Fracture/joint dislocation
4502324	860	2	AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	Internal contusion/concussion
4502524	807.08	1	AIS 4 Thorax, fracture with lung injury or hemo/pneumothorax	Fracture/joint dislocation
4502644	807.4	1	AIS 4 Thorax, fracture with lung injury or hemo/pneumothorax	Fracture/joint dislocation
4508042	807.2	2	AIS 2/3 Chest wall fracture	Fracture/joint dislocation
5202085	902	1	AIS 5 Abdomen, aortic laceration	Hemorrhage
5206043	902.53	1	AIS 3 Abdomen, internal arterial laceration	Hemorrhage
5214063	902.89	1	AIS 3 Abdomen, internal arterial laceration	Hemorrhage
5404243	879.6	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5406102	867.0	2	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5406244	867.1	1	AIS 4 Abdomen hollow organ or mesenteric laceration	Internal contusion/concussion
5406992	867.0	1	AIS 2 Abdominal, other	Other
5408102	863.41	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5408222	863.44	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5408243	863.44	2	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5408264	863.5	2	AIS 4 Abdomen hollow organ or mesenteric laceration	Internal contusion/concussion
5410102	863.21	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5414102	863.29	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5414202	863.29	2	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5414222	863.2	2	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5414243	863.29	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5414264	863.3	2	AIS 4 Abdomen hollow organ or mesenteric laceration	Internal contusion/concussion
5416102	866.01	4	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5416122	866.01	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5416202	866.02	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5416222	866.02	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5418102	864.01	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5418122	864.01	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5418202	864.02	4	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5418222	864.02	4	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5418243	864.03	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5418264	864.04	2	AIS 4/5 Abdomen, solid organ laceration	Hemorrhage
5420102	863.29	4	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5420202	863.89	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5420222	863.2	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5420243	863.29	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5428122	863.82	1	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5428243	863.81	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5432242	878.8	1	AIS 2 Abdomen, perineal laceration	Other
5436102	863.4	1	AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	Internal contusion/concussion
5442102	865.01	2	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5442122	865.01	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5442202	865.02	2	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion

(Continued)

eTable 1. Continued

AIS code	ICD code	No. of lists	Injury grouping	Injury characteristic
5442222	865.02	4	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5442243	865.03	3	AIS 2/3 Abdomen, solid organ contusion/laceration	Internal contusion/concussion
5442264	865.04	2	AIS 4/5 Abdomen, solid organ laceration	Hemorrhage
5442285	865.04	2	AIS 4/5 Abdomen, solid organ laceration	Hemorrhage
5454242	878.6	1	AIS 2 Abdomen, perineal laceration	Other
5456242	878.4	1	AIS 2 Abdomen, perineal laceration	Other
5920122	942.2	1	AIS 2 Abdominal, other	Other
6402063	805.08	1	AIS 3 Cervical spine cord contusion	Internal contusion/concussion
6402366	952.01	1	AIS 6 Cervical spine contusion/compression/laceration with complete cord syndrome	Internal contusion/concussion
6402746	952.01	1	AIS 6 Cervical spine contusion/compression/laceration with complete cord syndrome	Internal contusion/concussion
6402766	806.01	2	AIS 6 Cervical spine contusion/compression/laceration with complete cord syndrome	Internal contusion/concussion
6502042	839	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502063	839.02	1	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502082	839.01	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502162	805.01	4	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502182	805.06	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502202	805.07	1	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502223	805.07	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502243	805.06	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502263	805.02	3	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502283	805.02	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502302	805.02	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502322	805.02	2	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6502992	805	1	AIS 2/3 Cervical spine fracture/dislocation	Fracture/joint dislocation
6504162	805.2	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504182	805.2	2	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504202	805.2	3	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504223	805.2	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504243	805.2	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504302	805.2	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504322	805.2	3	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6504343	805.2	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506182	805.4	2	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506202	805.4	3	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506243	805.4	2	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506263	805.4	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506302	805.4	1	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506322	805.4	3	AIS 2/3 Thoracic/lumbar spine fracture	Fracture/joint dislocation
6506343	805.4	1	AIS 2/3 thoracic/lumbar spine fracture	Fracture/joint dislocation
7110003	887.3	1	AIS 3 Upper extremity amputation	Other
7130003	927.2	1	AIS 3 Upper extremity crush	Other
7206022	903.1	1	AIS 2 Upper extremity arterial laceration	Hemorrhage
7404002	884.0	2	AIS 2 Upper extremity laceration	Other
7406002	842.12	1	AIS 2 Upper extremity laceration	Other
7502302	831.04	2	AIS 2 Shoulder dislocation	Fracture/joint dislocation

(Continued)

eTable 1. Continued

AIS code	ICD code	No. of lists	Injury grouping	Injury characteristic
7510302	831.01	2	AIS 2 Shoulder dislocation	Fracture/joint dislocation
7514302	833.02	2	AIS 2 Wrist dislocation	Fracture/joint dislocation
7516002	811.01	1	AIS 2 Scapula fracture	Fracture/joint dislocation
7518002	813.83	4	AIS 2/3 Humerus fracture	Fracture/joint dislocation
7519002	813.8	4	AIS 2 Forearm fracture	Fracture/joint dislocation
7520022	815.03	4	AIS 2 Hand/wrist fracture	Fracture/joint dislocation
7522002	810.02	4	AIS 2 Clavicle fracture	Fracture/joint dislocation
7526002	812.2	4	AIS 2/3 Humerus fracture	Fracture/joint dislocation
7526022	812.21	4	AIS 2/3 Humerus fracture	Fracture/joint dislocation
7526043	812.3	4	AIS 2/3 Humerus fracture	Fracture/joint dislocation
7528002	813	4	AIS 2 Forearm fracture	Fracture/joint dislocation
7528022	813.42	4	AIS 2 Forearm fracture	Fracture/joint dislocation
7528043	813.44	3	AIS 3 Forearm fracture	Fracture/joint dislocation
7530002	811.09	3	AIS 2 Scapula fracture	Fracture/joint dislocation
7532002	813	3	AIS 2 Forearm fracture	Fracture/joint dislocation
7532022	813.43	4	AIS 2 Forearm fracture	Fracture/joint dislocation
7532043	813.23	2	AIS 3 Forearm fracture	Fracture/joint dislocation
7940063	882.2	2	AIS 3 Hand degloving	Other
8404022	845.01	1	AIS 2 Lower extremity muscle or ligament tear	Other
8404042	844.2	2	AIS 2 Lower extremity muscle or ligament tear	Other
8406002	845.09	1	AIS 2 Lower extremity muscle or ligament tear	Other
8408022	845.09	1	AIS 2 Lower extremity muscle or ligament tear	Other
8410022	891.2	1	AIS 2 Lower extremity muscle or ligament tear	Other
8502102	837	1	AIS 2 Ankle dislocation	Fracture/joint dislocation
8502142	837	2	AIS 2 Ankle dislocation	Fracture/joint dislocation
8506102	835.01	1	AIS 2 Hip dislocation	Fracture/joint dislocation
8506142	835.01	2	AIS 2 Hip dislocation	Fracture/joint dislocation
8508062	836.3	1	AIS 2 Knee dislocation/sprain	Fracture/joint dislocation
8508262	844.1	3	AIS 2 Knee dislocation/sprain	Fracture/joint dislocation
8514002	825	1	AIS 2 Ankle or foot fracture	Fracture/joint dislocation
8516052	823.81	3	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8516062	823.21	4	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8516082	824.2	2	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8516102	824.3	1	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8516122	824.4	2	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8516143	824.5	1	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8518003	821.01	4	AIS 3 Femur fracture	Fracture/joint dislocation
8518013	821.1	2	AIS 3 Femur fracture	Fracture/joint dislocation
8518043	821.21	1	AIS 3 Femur fracture	Fracture/joint dislocation
8518083	820.09	1	AIS 3 Femur fracture	Fracture/joint dislocation
8518103	820.21	2	AIS 3 Femur fracture	Fracture/joint dislocation
8518123	820.03	3	AIS 3 Femur fracture	Fracture/joint dislocation
8518143	821.01	4	AIS 3 Femur fracture	Fracture/joint dislocation
8518183	820.22	1	AIS 3 Femur fracture	Fracture/joint dislocation
8518223	821.23	1	AIS 3 Femur fracture	Fracture/joint dislocation
8520002	825.22	2	AIS 2 Ankle or foot fracture	Fracture/joint dislocation
8520022	824.8	4	AIS 2 Lower extremity fracture, other	Fracture/joint dislocation
8522002	825.25	4	AIS 2 Ankle or foot fracture	Fracture/joint dislocation

(Continued)

eTable 1. Continued

AIS code	ICD code	No. of lists	Injury grouping	Injury characteristic
8524002	822	2	AIS 2 Lower extremity fracture, other	Fracture/joint dislocation
8526002	808	4	AIS 2/3 Pelvic fracture	Fracture/joint dislocation
8526022	808.8	4	AIS 2/3 Pelvic fracture	Fracture/joint dislocation
8526043	808	3	AIS 2/3 Pelvic fracture	Fracture/joint dislocation
8528003	805.6	2	AIS 2/3 Pelvic fracture	Fracture/joint dislocation
8530003	821.0	3	AIS 3 Femur fracture	Fracture/joint dislocation
8532002	825.21	1	AIS 2 Ankle or foot fracture	Fracture/joint dislocation
8534042	823.8	4	AIS 2/3 Tibia and/or fibulafractrue	Fracture/joint dislocation
8534053	823.9	1	AIS 2/3 Tibia and/or fibulafractrue	Fracture/joint dislocation
8534062	823	2	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8534083	823.1	1	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8534102	823	1	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8534122	824	2	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8534142	824.1	2	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8534202	823.2	3	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
8534223	823.32	4	AIS 2/3 Tibia and/or fibula fractrue	Fracture/joint dislocation
9192023	986	1	Inhalation injury	Other

AIS, Abbreviated Injury Scale.

eTable 2. Normalized Transfer Score and Normalized Co-Injury Adjusted Transfer Score Values for Each Injury Grouping by Age Group, Sorted by Increasing Abbreviated Injury Scale Severity

	Age group											
	0 to 4 years old			5 to 9 years old			10 to 14 years old			15 to 18 years old		
Injury grouping	TC	Non-TC	TS	TC	Non-TC	TS	TC	Non-TC	TS	TC	Non-TC	TS
AIS 2 Abdomen, perineal laceration	—	—	—	1	12	0.00	—	—	—	—	—	—
AIS 2 abdominal, other	—	—	—	—	—	—	2	12	0.14	—	—	—
AIS 2 Ankle dislocation	—	—	—	—	—	—	—	—	—	0	13	0.00
AIS 2 Ankle or foot fracture	2	9	0.00	3	10	0.26	12	48	0.24	41	270	0.23
AIS 2 Clavicle fracture	8	7	0.62	15	22	0.56	23	78	0.29	28	205	0.21
AIS 2 Face, soft tissue laceration	—	—	—	38	87	0.39	39	164	0.22	70	571	0.19
AIS 2 Forearm fracture	—	—	—	7	30	0.19	21	159	0.09	23	229	0.16
AIS 2 Hand/wrist fracture	—	—	—	—	—	—	—	—	—	5	25	0.29
AIS 2 Head, fracture	14	31	0.23	15	18	0.64	8	15	0.50	5	19	0.36
AIS 2 Head, other	28	43	0.37	—	—	—	—	—	—	70	597	0.18
AIS 2 Hip dislocation	—	—	—	—	—	—	—	—	—	3	70	0.07
AIS 2 Knee dislocation/sprain	—	—	—	—	—	—	3	8	0.37	3	23	0.20
AIS 2 Lower extremity fracture, other	7	21	0.12	16	86	0.14	24	298	0.01	35	299	0.18
AIS 2 Lower extremity muscle or ligament tear	—	—	—	—	—	—	2	12	0.14	17	114	0.23
AIS 2 Scapula fracture	—	—	—	—	—	—	4	20	0.18	5	34	0.22
AIS 2 Shoulder dislocation	—	—	—	—	—	—	3	12	0.24	11	72	0.23
AIS 2 Upper extremity laceration	—	—	—	—	—	—				3	52	0.10
AIS 2/3 Humerus fracture	13	12	0.60	17	43	0.35	16	95	0.14	25	166	0.23
AIS 2/3 Abdomen, solid organ contusion/laceration	28	27	0.58	20	58	0.30	80	337	0.22	115	666	0.26
AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	—	—	—	18	53	0.30	3	26	0.07	—	—	—
AIS 2/3 Chest wall fracture	—	—	—	5	11	0.40	15	35	0.41	46	279	0.25
AIS 2/3 Cervical spine fracture/dislocation	9	3	1.00	—	—	—	12	7	1.00	77	156	0.58
AIS 2/3 Face, fracture	8	9	0.51	17	31	0.47	40	133	0.29	107	309	0.45
AIS 2/3 Head, concussion	22	70	0.10	17	95	0.13	24	221	0.06	15	428	0.06
AIS 2/3 Pelvic fracture	—	—	—	—	—	—	39	103	0.37	151	442	0.45
AIS 2/3 Thoracic/lumbar spine fracture	—	—	—	—	—	—	—	—	—	174	650	0.37
AIS 2/3 Tibia and/or fibula fracture	10	32	0.10	15	62	0.20	56	371	0.12	64	743	0.14
AIS 3 Femur fracture	35	123	0.07	90	355	0.21	103	368	0.27	106	721	0.22
AIS 3 Forearm fracture	—	—	—	10	84	0.05	22	311	0.00	26	279	0.15
AIS 3 Hand degloving	—	—	—	—	—	—	—	—	—	3	21	0.22
AIS 3 Thorax, other	—	—	—	8	4	1.00	—	—	—	9	21	0.52
AIS 3/4 Head, fracture	5	6	0.48	12	6	1.00	6	15	0.39	12	31	0.49
AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	53	55	0.54	73	103	0.57	124	229	0.50	207	1017	0.30
AIS 3-5 Brain contusion/laceration/infarction	—	—	—	—	—	—	9	11	0.68	15	15	0.87
AIS 3-5 Head, hemorrhage	19	9	0.87	35	51	0.56	19	21	0.72	32	86	0.47
AIS 3-5 Head, other	15	15	0.56	22	25	0.66	27	28	0.75	76	114	0.70
AIS 4 Thorax diaphragm rupture	—	—	—	—	—	—	—	—	—	3	7	0.52
AIS 4 Thorax, fracture with lung injury or hemo-/pneumothorax	—	—	—	—	—	—	—	—	—	3	18	0.25
AIS 4/5 Abdomen, solid organ laceration	4	6	0.38	—	—	—	15	19	0.66	27	188	0.22
AIS 5 Thoracic, aortic laceration	—	—	—	—	—	—	—	—	—	12	9	1.00

non-TC, number of patients managed at a nontrauma center; TC, number of patients transferred to a trauma center; TS, normalized transfer score.

eTable 3. Normalized Co-Injury Adjusted Transfer Score Values for Each Injury Grouping by Age Group, Sorted by Increasing Abbreviated Injury Scale Severity

	Age group											
	0 to 4 years old			5 to 9 years old			10 to 14 years old			15 to 18 years old		
Injury grouping	**TC**	**Non-TC**	**TS_{MAIS}**	**TC**	**Non-TC**	**TS_{MAIS}**	**TC**	**Non-TC**	**TS_{MAIS}**	**TC**	**Non-TC**	**TS_{MAIS}**
AIS 2 Abdominal, other	—	—	—	—	—	—	0	10	0.00	—	—	—
AIS 2 Ankle dislocation	—	—	—	—	—	—	—	—	—	0	11	0.00
AIS 2 Ankle or foot fracture	—	—	—	1	9	0.01	5	41	0.19	16	185	0.14
AIS 2 Clavicle fracture	—	—	—	3	15	0.12	9	48	0.27	7	96	0.12
AIS 2 Face, soft tissue laceration	—	—	—	25	66	0.29	16	110	0.22	36	310	0.18
AIS 2 Forearm fracture	—	—	—	3	24	0.03	13	130	0.16	6	167	0.06
AIS 2 Hand/wrist fracture	—	—	—	—	—	—	—	—	—	1	13	0.12
AIS 2 Head, fracture	12	27	0.29	12	14	0.58	7	15	0.55	2	15	0.21
AIS 2 Head, other	12	33	0.21	—	—	—	—	—	—	33	310	0.17
AIS 2 Hip dislocation	—	—	—	—	—	—	—	—	—	0	39	0.00
AIS 2 Knee dislocation/sprain	—	—	—	—	—	—	—	—	—	2	13	0.23
AIS 2 Lower extremity fracture, other	4	16	0.08	9	80	0.02	14	272	0.08	15	243	0.10
AIS 2 Lower extremity muscle or ligament tear	—	—	—	—	—	—	1	10	0.16	8	84	0.15
AIS 2 Scapula fracture	—	—	—	—	—	—	—	—	—	1	11	0.15
AIS 2 Shoulder dislocation	—	—	—	—	—	—	2	8	0.34	4	46	0.14
AIS 2 Upper extremity laceration	—	—	—	—	—	—	—	—	—	1	25	0.07
AIS 2/3 Humerus fracture	6	9	0.47	6	37	0.08	4	79	0.08	6	123	0.08
AIS 2/3 Abdomen, solid organ contusion/laceration	18	16	0.71	12	43	0.20	47	255	0.27	52	408	0.20
AIS 2/3 Abdominal, hollow organ/mesenteric contusion/laceration	—	—	—	9	41	0.14	2	25	0.13	—	—	—
AIS 2/3 Chest wall fracture	—	—	—	—	—	—	4	11	0.46	19	96	0.29
AIS 2/3 Cervical spine fracture/dislocation	—	—	—	—	—	—	7	5	1.00	55	109	0.59
AIS 2/3 Face, fracture	7	7	0.66	14	29	0.37	32	121	0.36	79	251	0.42
AIS 2/3 Head, concussion	20	68	0.14	12	82	0.06	20	192	0.16	11	337	0.06
AIS 2/3 Pelvic fracture	—	—	—	—	—	—	27	87	0.41	110	351	0.42
AIS 2/3 Thoracic/lumbar spine fracture	—	—	—	—	—	—	—	—	—	133	545	0.34
AIS 2/3 Tibia and/or fibula fracture	5	27	0.00	10	59	0.08	44	340	0.20	32	630	0.08
AIS 3 Femur fracture	25	118	0.04	77	347	0.14	83	348	0.33	78	657	0.19
AIS 3 Forearm fracture	—	—	—	8	80	0.00	19	306	0.10	21	263	0.13
AIS 3 Hand degloving	—	—	—	—	—	—	—	—	—	3	19	0.24
AIS 3 Thorax, other	—	—	—	—	—	—	—	—	—	4	16	0.35
AIS 3/4 Head, fracture	—	—	—	11	4	1.00	5	15	0.43	11	29	0.48
AIS 3/4 Thorax with lung injury or hemo-/pneumothorax	49	54	0.61	67	94	0.51	115	217	0.59	184	964	0.28
AIS 3-5 Brain contusion/laceration/infarction	—	—	—	—	—	—	7	9	0.75	13	14	0.84
AIS 3-5 Head, hemorrhage	19	9	1.00	32	48	0.48	17	21	0.77	30	82	0.47
AIS 3-5 Head, other	12	13	0.62	21	24	0.58	22	28	0.75	68	103	0.70
AIS 4 Thorax, fracture with lung injury or hemo-/pneumothorax	—	—	—	—	—	—	—	—	—	3	17	0.26
AIS 4/5 Abdomen, solid organ laceration	4	6	0.47	—	—	—	13	19	0.70	25	188	0.21
AIS 5 Thoracic, aortic laceration	—	—	—	—	—	—	—	—	—	12	9	1.00

non-TC, number of patients managed at a non- trauma center; TC, number of patients transferred to a trauma center; TS_{MAIS}, normalized co-injury adjusted transfer score to account for maximum Abbreviated Injury Scale (MAIS).