ORIGINAL SCIENTIFIC ARTICLE

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

Andrea N Doud, MD, Samantha L Schoell, PhD, Jennifer W Talton, MS, Ryan T Barnard, MS, John K Petty, MD, J Wayne Meredith, MD, FACS, R Shayn Martin, MD, FACS, Joel D Stitzel, PhD, Ashley A Weaver, PhD

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 2017;■:1−10. © 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

---

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

---

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