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Characterization of the occult nature of injury for frequently occurring motor vehicle crash injuries

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ABSTRACT

Background: Occult injuries are not easily detected and can be potentially life-threatening. The purpose of this study was to quantify the perceived occultness of the most frequent motor vehicle crash injuries according to emergency medical services (EMS) professionals.
Study design: An electronic survey was distributed to 1,125 EMS professionals who were asked to quantify the likelihood that first responders would miss symptoms related to a particular injury on a 5-point Likert scale. The Occult Score for each injury was computed from the average of all the survey responses and normalized to be a continuous metric ranging from 0 to 1 where 0 is a non-occult (highly apparent on initial presentation) injury and 1 is an occult (unapparent on initial presentation) injury.
Results: Overall, 110,671 survey responses were collected. The Occult Score ranged from 0 to 1 with a mean, median, and standard deviation of 0.443, 0.450, and 0.233, respectively. When comparing the Occult Score of an injury to its corresponding AIS severity, there was no relationship between the metrics. When stratifying by body region, injury type, and AIS severity, it was evident that AIS 2–4 abdominal injuries with lacerations, hemorrhage, or contusions were perceived as the most occult injuries.
Conclusions: Timely triage is key to reduce the morbidity and mortality associated with occult injuries. The Occult Score developed in this study to describe the predictability of an injury in a motor vehicle crash will be used as part of a larger effort, including incorporation into an advanced automatic crash notification (AACN) algorithm to detect crash conditions associated with a patient's need for prompt treatment at a trauma center.

1. Introduction

Detection and prompt treatment of motor vehicle crash (MVC) injuries is crucial in reducing morbidity and mortality. The goal of the pre-hospital trauma system is to appropriately triage patients such that they receive the "right treatment" at the "right place" and at the "right time". For severely injured patients, several studies have demonstrated the benefit of being managed at a Level I/II trauma center (TC) versus a non-trauma center (non-TC). The National Study on the Costs and Outcomes of Trauma (NSCOT) identified a 25% reduction in mortality for severely injured patients who received care at a Level I TC rather than at a non-TC (MacKenzie et al., 2006; Centers for Disease Control and Prevention, 2008). Accurate, appropriate, and efficient triage remains difficult as the process of identifying seriously injured occupants is challenging based upon the limited physical examination and initial assessment at the scene of the trauma by emergency medical services (EMS) professionals.

Advanced Automatic Crash Notification (AACN) algorithms have the ability to improve the trauma triage process. By predicting occupant injury severity in combination with vehicle telemetry data such as delta-v, belt use, airbag deployment, and multiple impacts, AACN systems can inform emergency personnel of a recommended triage decision for an occupant. The development of such AACN systems has the potential to reduce response times, increase triage efficiency, and improve overall patient outcomes (Champion et al., 2005; Malliaris and Digges, 1997; Bahouth et al., 2004, 2012; Verma

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et al., 2007; Rauscher et al., 2009; Kononen et al., 2011; Augenstein et al., 2005). Current AACN systems define severely injured occupants using Abbreviated Injury Scale (AIS) metrics. AIS is the most advanced trauma-specific, anatomically-based coding lexicon and was conceived as a system to define the type and severity of injuries arising from MVCs. Although AIS-based metrics are most commonly used, other methods of injury scoring have been developed to better discriminate severely injured patients. To improve the prediction of severely injured occupants, an injury-based approach was developed to quantity three facets of injury including the severity, time sensitivity, and predictability (Weaver et al., 2013; Schoell et al., 2015a,b). Severity is associated with injuries with a high mortality and high threat-to-life and was quantified based on mortality risk ratios (MRRs) obtained from the National Trauma Data Bank (NTDB) (Weaver et al., 2013). Time sensitivity is associated with injuries that require prompt treatment for the patient to avoid death and was quantified using expert physician survey data which incorporated the recommended treatment location and a rank of urgency for treatment (Schoell et al., 2015a). Predictability, the focus of this study, defines the extent to which injuries are identifiable by emergency medical personnel upon arrival at the scene. Predictability was scored using two components: an Occult Score and a Transfer Score. The Occult Score, highlighted in this paper, is a measure of the likelihood that an injury is missed upon initial assessment. The Transfer Score is a measure of the likelihood that an injury is present in patients that require transfer from a non-TC to a Level I/II TC using the NIS database (Schoell et al., 2015b). The quantification of these three facets generates a list of injuries necessitating treatment at a Level I/II TC. This list is incorporated into an AACN algorithm that predicts the risk of an occupant sustaining any injury on the list using vehicle telemetry data to ultimately recommend a triage decision.

Previous work related to identifying occult MVC injuries involves the development of an Occult Injury Database (OID) by the Center for Transportation Injury Research (CenTIR). The OID was developed based on the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) 1997–2001 to analyze crash-related occult injuries (Blatt and Bellis, 2004). The OID identified potentially occult injuries in the head, thorax, and abdomen based on the following criteria: 1) injuries in which patient signs and symptoms may not be evident in the pre-hospital/emergency department (ED) setting, 2) injuries which pose a significant threat to life (AIS $\geq$ 3), and 3) injuries which may be suspected when crash scene information is utilized. This criteria was applied subjectively using expert opinion, so it is not known to what extent different experts would weight criteria #1, #2, and #3 in their assessments and therefore bias is likely. A dichotomous outcome for each injury was recorded as 'occult' or 'not occult' based on opinion and some basic analysis of the data collected. The database also contains the frequency of occurrence of injuries and the frequency a particular injury was cited as a cause of death. NASS-CDS permits the specification of up to three causes of death for each fatality using the variable Cause of Death 1, 2, and 3. Based on the data for the years 1997 to 2001, approximately 29,118 injuries per year were cited as a cause of death. Of those injuries, approximately 18,888 were identified as potentially occult which results in almost 65 percent of all fatal injuries per year being due to potentially occult injuries. Limitations associated with this study include the inclusion of only AIS 3+ head, thoracic, and abdominal injuries. In addition, the consensus-derived occult classification is limited to a dichotomous outcome. Injuries can have varying levels of mortality risk, and as such, injuries can have varying levels of occultness (Weaver et al., 2013; Meredith et al., 2002; Sacco et al., 1999).

Thus, a more robust metric of injury occultness is needed. Data on the occultness of injury is difficult to derive from data available in source databases due to the retrospective nature as well as the difficulty to follow a patient from the scene of the accident to hospital disposition. As such, the objective of this study was to quantify the perceived occultness of the most frequent motor vehicle crash injuries according to EMS professionals. Similar to the previous OID study, a consensus-derived classification of the occultness was derived. However, this study derives a continuous metric of the occultness for the top 95% most frequent AIS 2+ MVC injuries to the head, face, thorax, abdomen, spine, and upper and lower extremities.

2. Materials and methods

2.1. Top 95% AIS 2+ NASS-CDS injuries

The analysis was focused on the top 95% most frequently occurring AIS 2+ MVC injuries in NASS-CDS 2000–2011, which were identified using the AIS 98 coding lexicon (AAAM, 2001). NASS-CDS is a database which is a detailed sample of a representative, random sample of thousands of minor, serious, and fatal tow-away MVCs in the United States. A national estimate of the number of MVCs in the United States can be determined by applying weighting factors to the NASS-CDS data. AIS 1 injuries, which are mostly minor abrasions and contusions, were excluded to capture the most prominent MVC injuries. NASS-CDS 2009–2011 cases with model year vehicles greater than 10 years old were excluded from the analysis due to missing occupant and injury information. As a result, the NASS-CDS 2000–2011 dataset contained 54,703 crashes, 94,283 vehicles, 115,159 occupants, and 303,230 injuries. For each injury in NASS-CDS, the weighting factors were used to determine the total weighted injury count and cumulative percent. The list was determined on an injury-basis. Therefore, if the occupant sustained the same injury multiple times, the injury was counted multiple times.

The top 95% most frequently occurring AIS 2+ MVC injuries (termed the "Top 95% List") included 240 unique AIS codes with injuries to the head, face, thorax, abdomen, spine, and upper and lower extremities. The severity, time sensitivity, and likelihood of transfer of these 240 injuries have been previously characterized (Weaver et al., 2013; Schoell et al., 2015a, 2015b).

2.1.1. Occult survey

To characterize the perceived occult nature of injuries on the Top 95% List, an electronic survey was deployed to certified EMS professionals. Institutional Review Board approval was obtained to administer the survey. In addition, approval from the North Carolina Office of EMS (NCOEMS) was obtained to administer the survey to EMS providers in the state of North Carolina. All EMS personnel in the state of North Carolina were recruited through the EMS Performance Improvement Center's (EMSPIC) email distribution list. For each survey participant, their institution, specialty, level of expertise, and years of experience at their current level of expertise were collected.

The types of EMS professionals targeted for the study included emergency medical responders (EMRs), emergency medical technicians (EMTs) (basic and intermediate), and paramedics. In the state of North Carolina, there is a feedback loop in place to follow up with EMS on the injuries of severely injured patients. Feedback is provided through the regional trauma advisory council, the ED nurse liaison, the local medical director, or through the EMS personnel's day-to-day contact with the staff in the emergency room in order to provide outcome information on the patients that were treated. Based on this feedback loop, training, and experience, the EMS professionals targeted in this study were deemed suitable to provide expert opinion.

The underlying architecture and basic structure of the survey was almost identical to a predecessor that was used in a previous