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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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0001-4575/

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

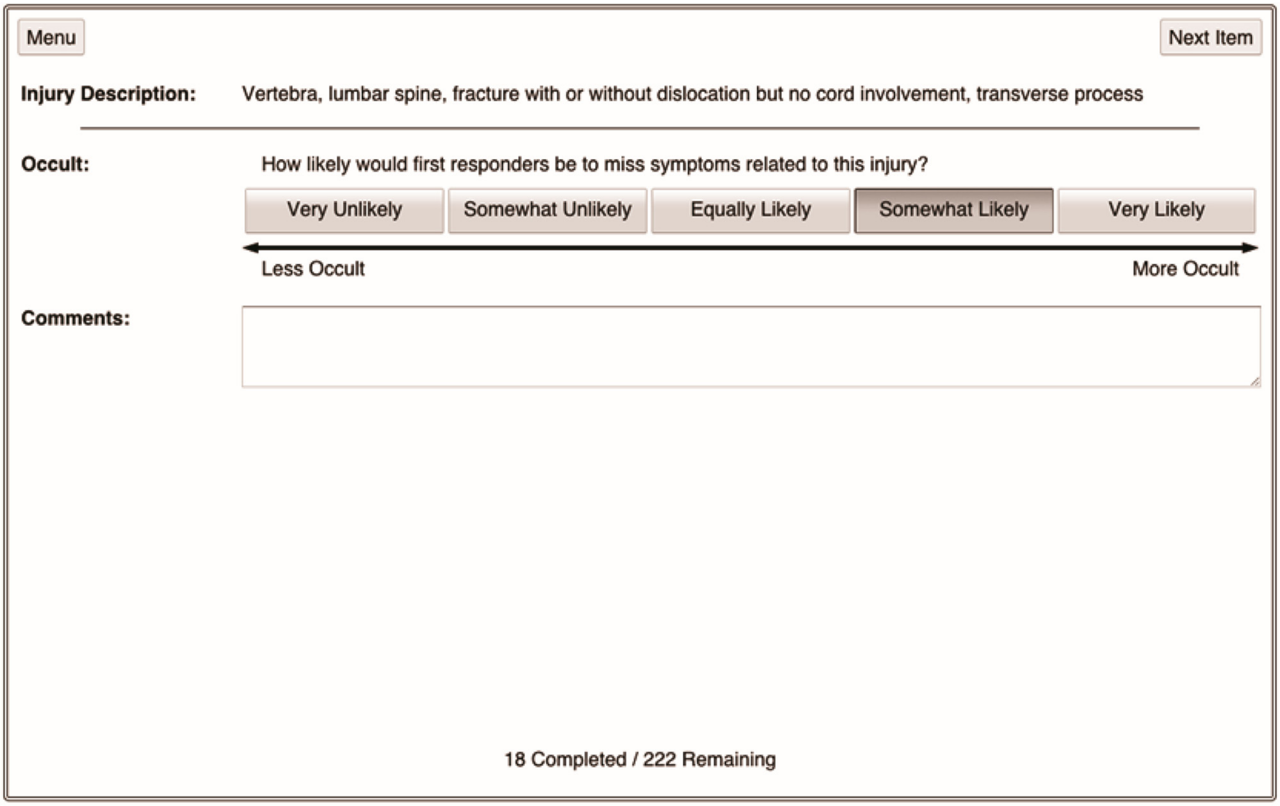

Fig. 1. Example survey question for Occult Survey.

published study (Schoell et al., 2015a), which aimed to quantify the urgency and treatment location for each injury on the Top 95% List. The order of the injuries presented to the participants was randomized subject to the uniform distribution sampling method. The sampling methodology ensured equal distribution of the questions dedicated for each injury. The survey was deployed from December 2013 through May 2014. The survey was electronic and any participant with the emailed link could take it on a computer, tablet, or mobile device. The participant could start and stop the survey at any point with all the responses being saved. The first 500 participants who answered at least 100 questions were emailed a $5 coffee shop gift card.

Each survey question presented a single injury from the Top 95% List and the participant was asked how likely a first responder would be to miss symptoms related to this injury (Fig. 1). An occult value was assigned on a 5-point Likert scale, with 1 being very unlikely to miss symptoms and 5 being very likely to miss symptoms. A value of 1 corresponds to a less occult or more predictable injury while a value of 5 corresponds to a more occult or more unpredictable injury.

2.1.2. Occult score

An Occult Score based on the survey data was computed. For each injury, the mean of the occult values (1, 2, 3, 4, and 5) was computed and termed the "Non-Normalized Occult Score". To normalize the Occult Score on a 0 to 1 scale, the minimum value was subtracted from the calculated Non-Normalized Occult Score and then divided by the range of the distribution (Eq. (1)). The normalization of the Occult Score was completed for future inclusion into an AACN algorithm. The Occult Score is combined with other injury-based metrics including a Severity Score and Time Sensitivity Score to define a list of injuries necessitating treatment at a Level I/II trauma center. Each metric is normalized on a 0 to 1 scale for ease of combining metrics and for interpretability, with scores closer to 1 being more severe, more time sensitive, and less predictable injuries. More information regarding the combination of the injury-based metrics and inclusion into the AACN algorithm can be found in the paper published by Stitzel et al. (Stitzel et al., 2016).

$$\mathit{Occult\ Score} = \frac{\mathit{Non-Normalized\ Occult\ Score} - 1.11}{2.95} \tag{1}$$

The Occult Score is a continuous metric that ranges from 0 to 1, where 0 is a non-occult (highly apparent on initial presentation) injury and 1 is an occult (not apparent on initial presentation) injury. Analysis of the Occult Score for the injuries on the Top 95% List was completed by stratifying the metric by AIS severity, body region, and injury type. Injury type was manually coded based on the AIS injury description to characterize the injury as internal versus external, fracture, laceration, contusion, hemorrhage or hematoma, or intracranial injuries including loss of consciousness. One-way ANOVA models were used to examine the overall relationship between the Occult Score and injury severity as well as body region. Pairwise comparisons between body regions and injury severity on the Occult Score were examined using Tukey-Kramer HSD. In addition, the Occult Scores for AIS 3+ head, thoracic, and abdominal injuries were compared to the dichotomous classification from the OID study (Blatt and Bellis, 2004). All statistical analyses were performed using SAS 9.3 (SAS Institute, Cary, NC) and JMP Pro 11.0.0 (SAS institute, Cary, NC) and p-values of less than 0.05 were considered statistically significant.

3. Results

Overall, 110,671 survey responses were collected from 1,125 individuals with an average of 461 responses for each of the 240 injuries on the Top 95% List. The median and interquartile range for the number of injuries classified by each respondent was 75

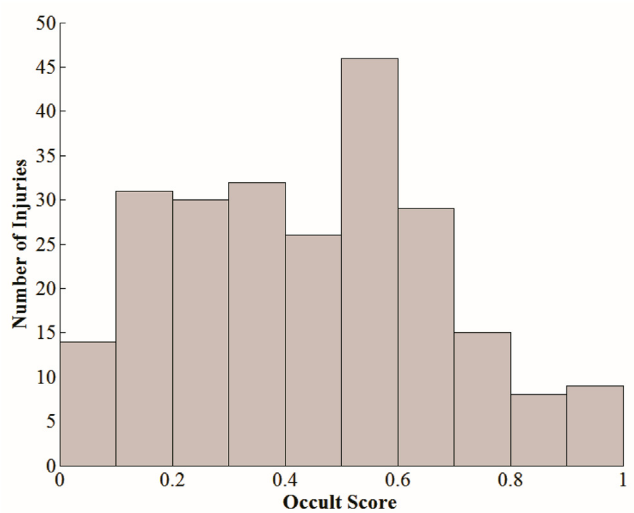

Fig. 2. Histogram for the Occult Scores from survey data for all injuries on the Top 95% List.

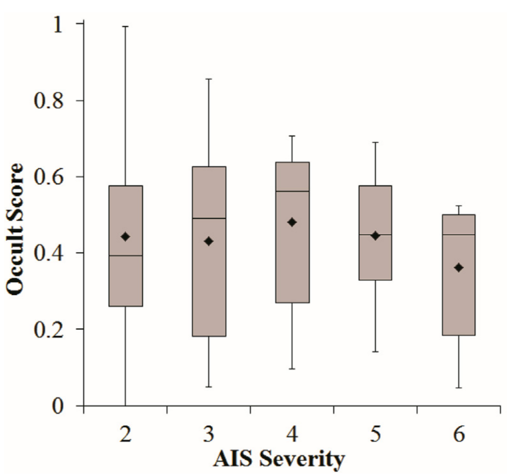

Fig. 3. Box-and-whisker plots of the Occult Scores by AIS severity. The whiskers correspond to the minimum and maximum scores. The mean Occult Score value is designated by the ♦ symbol.

(15–175). The EMS professionals consisted of 81 EMRs, 964 EMTs, and 80 paramedics with a median and interquartile range of 6 (2–15) years of experience. The response rate of the survey was 4% and it was deemed sufficient as our sample of 93% EMRs/EMTs and 7% paramedics is comparable on a national level (Federal Interagency Committee on Emergency Medical Services, 2011). Thus, the participants are a representative sample of the larger population.

Occult Scores for the 240 injuries on the Top 95% List are provided in the Appendix A. A histogram for the Occult Scores for all 240 injuries derived from the survey data is provided in Fig. 2. The Occult Score mean, median, and standard deviation were 0.443, 0.450, and 0.233, respectively.

3.1. Occult score and AIS comparison

The Occult Score for each injury on the Top 95% List was compared to its corresponding AIS severity (Fig. 3). Overall, there was no relationship between the Occult Score and AIS severity ($p = 0.8216$). As measured by the minimum and maximum values in Table 1, there are large variations in the Occult Score for a given AIS severity. The variation was the greatest for AIS 2 severity injuries with

Table 1
Occult Score summary statistics stratified by AIS severity.

Severity	# Injuries	Mean	Median	Min	Max
AIS 2	123	0.444	0.393	0.000	1.000
AIS 3	68	0.431	0.491	0.050	0.864
AIS 4	28	0.481	0.561	0.096	0.701
AIS 5	16	0.446	0.449	0.141	0.681
AIS 6	5	0.363	0.448	0.048	0.518

Table 2
Highest and lowest Occult Scores for injuries on the Top 95% List.

Rank	AIS Code	Summarized AIS Description	Occult Score
1	541612.2	Kidney contusion	1.000
2	540610.2	Bladder contusion	0.978
3	541812.2	Liver contusion	0.973
4	541410.2	Jejunum-ileum contusion	0.952
5	541622.2	Kidney laceration	0.951
236	752604.3	Humerus fracture	0.050
237	113000.6	Crush head injury	0.048
238	210604.2	Facial laceration	0.040
239	110604.2	Scalp laceration	0.017
240	752402.2	Finger amputation	0.000

the variation decreasing for increasing AIS severity. The overall variability manifests that AIS severity alone does not fully capture important aspects of injury, such as the occultness.

3.2. Occult score, body region, and injury type comparison

The Occult Score for each injury on the Top 95% List was compared with its corresponding body region and injury type as shown in Fig. 4. There were large variations in the Occult Score for injuries to the same body region and of the same injury type. The head, thorax, and lower extremity had the largest variations among all the body regions. AIS 2–4 abdominal and AIS 3–4 head injuries tended to be the most often perceived to be missed. Pairwise comparisons demonstrated statistically significant differences between each body region when compared to the abdominal region ($p < 0.0001$). Significant differences also existed when comparing the head and spine to the face, thorax, and upper and lower extremity regions ($p < 0.0001$). In terms of injury type, internal, laceration, and hemorrhage had the largest variations. AIS 2–3 injuries involving laceration, contusion, and hemorrhage were the most occult.

3.3. Select injury examples

The highest and lowest Occult Scores for injuries on the Top 95% List are listed in Table 2. The five injuries with the highest Occult Scores all were AIS 2 abdominal injuries with Occult Scores ranging from 0.951 to 1.000 (541612.2, kidney contusion; 540610.2, bladder contusion; 541812.2, liver contusion; 541410.2, jejunum-ileum contusion; 541622.2, kidney laceration). The majority of the injuries were contusions. The five injuries with the lowest Occult Scores ranged from AIS 2 to AIS 6 injuries to the head, face, and upper extremity with Occult Scores ranging from 0.000 to 0.050 (752604.3, humerus fracture; 113000.6, crush head injury; 210604.2, facial laceration; 110604.2, scalp laceration; 752402.2, finger amputation). All the injuries with the lowest Occult Scores would result in external symptoms that could be identified on scene immediately.

To compare the metric derived with an existing objective measure, the Occult Scores for AIS 3+ head, thoracic, and abdominal injuries were compared to the dichotomous classification from the OID study (Blatt and Bellis, 2004). Of the 240 injuries on the Top 95% List, 120 of those injuries are AIS 3+ head, thoracic, and abdominal injuries. Of the 54 identified occult injuries from the OID study, the

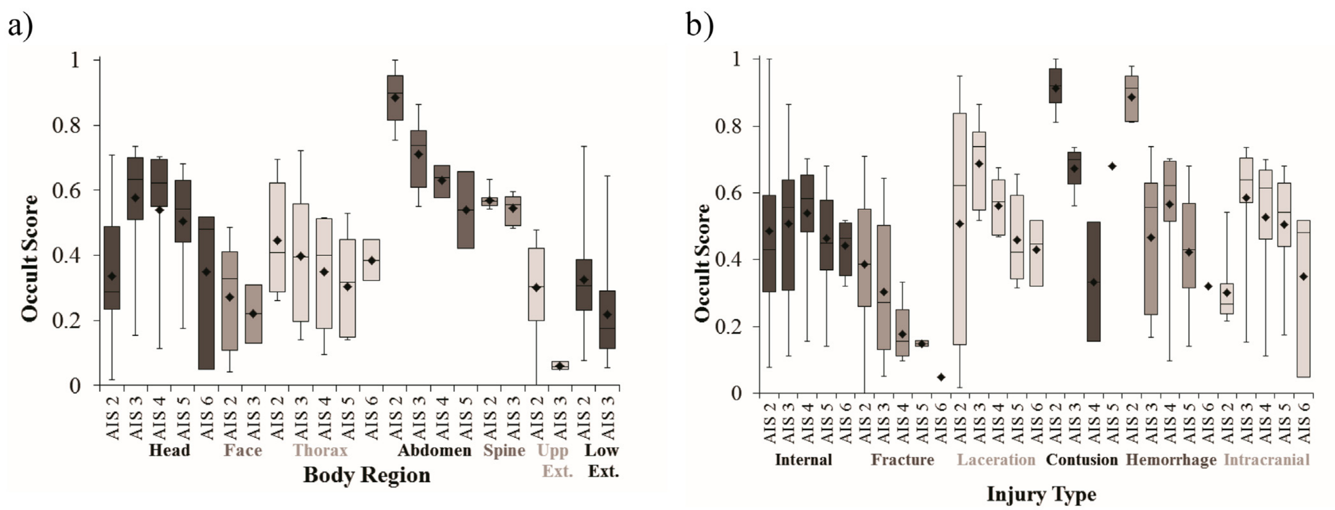

Fig. 4. Box-and-whisker plots of the Occult Scores by a) body region and AIS severity and b) injury type and AIS severity. The whiskers correspond to the minimum and maximum scores.

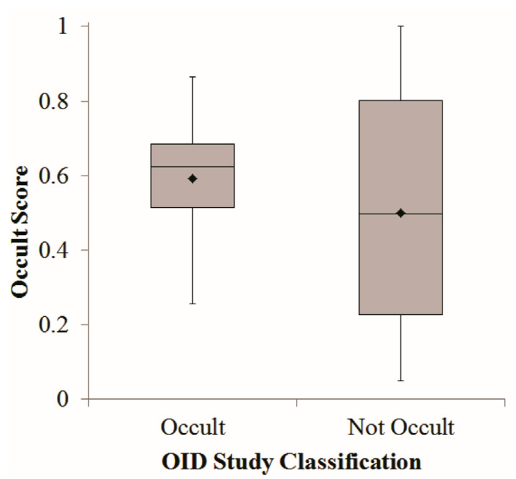

Fig. 5. Distribution of the Occult Score within each Occult Injury Database (OID) study classification.

Occult Score ranged from 0.256 to 0.864 with a mean of 0.593. Of the 66 identified non-occult injuries in the OID study, the Occult Score ranged from 0.048 to 1.000 with a mean of 0.500. As seen by the large variations in Fig. 5, especially within the non-occult injuries from the OID study, the continuous nature of the Occult Score better captures the occult nature of injury in comparison to the dichotomous outcome as recorded in the OID study. In addition, the Occult Score highlights the extent to which an injury may be missed. For example, an AIS 3 colon laceration (540824.3) and an AIS 5 spleen laceration (544228.5) were both classified as occult injuries by the OID study. The Occult Score for the AIS 3 colon laceration was 0.864 and for the AIS 5 spleen laceration was 0.421. As a result, the AIS 3 colon laceration is more occult and more likely to be missed than the AIS 5 spleen laceration even though both are considered occult injuries.

4. Discussion

An occult injury may pose a threat to one's life if the injury is not detected and treated in a timely manner. Detection of occult injuries can be made more difficult due to the effects of sustaining multiple injuries which can mask the pain or symptoms of other serious injuries. In order to reduce morbidity and mortality associated with these injuries, timely triage is important. AACN systems can be useful in predicting occult injuries that are less likely to be detected by first responders. Current AACN algorithms rely on AIS-based metrics to distinguish patients requiring trauma center treatment. In order to better predict an occupant's need for treatment at a trauma center, however, the quantification of the severity, time sensitivity, and predictability provides more information about the patient condition in order to execute proper triage.

The Occult Score developed in this study is a component of the predictability metric and describes the propensity of an injury to be missed by first responders. Information on the occultness of injury is difficult to derive from data available in source databases due to the retrospective nature and therefore it cannot be directly measured. As a result, the occultness of injury was derived from expert survey data from EMS professionals. The Occult Score provides a consensus derived continuous metric to indicate the perceived likelihood of an injury being undetected. Injuries with higher Occult Scores are more likely to be missed on initial assessment and it is crucial that detection of these injuries be made promptly in order to triage the patient to the correct location.

The Occult Scores of the 240 most frequently occurring AIS 2+ MVC-induced injuries were stratified by AIS severity, body region, and injury type. When comparing the Occult Score of an injury to its corresponding AIS severity, there was no relationship between these metrics. This emphasizes the limitation of AIS as a tool for guiding patient management. 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. Other AACN algorithms use AIS-based metrics to define severely injured occupants which affects the triage decisions of these algorithms. Characterization of an injury's severity, time sensitivity, and predictability may provide better estimates to understand injuries that require TC-level treatment and result in better triaging of patients. When stratifying by body region, injury type, and AIS severity, it is evident that AIS 2–4 abdominal injuries with lacerations, hemorrhage, or contusions were perceived as less predictable, more occult injuries.

The comparison of the Occult Score to the OID study revealed large variations in the Occult Score in comparison to the dichotomous outcome as derived from the OID study (Blatt and Bellis, 2004). While both studies are consensus-based, the methods used to derive the dichotomous outcome were subjective and not clearly defined. The survey-based method allowed for a more-focused derivation of the occultness of an injury. In comparison to the OID study, this study characterized the occultness for a larger sample of injuries which included the top 95% most frequently occurring AIS 2+ MVC injuries. The results of the study are consistent with previous studies that identified head, spine, and abdominal regions as being more at risk for missed injuries (Houshian et al., 2002; Chen et al., 2011). In addition, AIS 2–3 injuries were also more likely to be missed (Houshian et al., 2002).

Injuries to the abdomen often affect internal organs and may not have overt external signs or symptoms. Such injuries may result in abdominal pain or hypotension. However, hypotension can result from a multitude of causes and might only result from an abdominal injury if the injury is very severe. Additionally, abdominal pain may be masked by other distracting injuries that cause pain or by head injuries that cause altered levels of consciousness. Thus, abdominal injuries of mild to moderate severity may be easily missed by first responders. Similarly, injuries to the head often result in an altered level of consciousness. However, many trauma patients are either intoxicated or using other drugs at the time of injury. Such substances can result in an altered level of consciousness, thus masking the effects of head injuries (Stuke et al., 2007; Center for Substance Abuse Treatment, 1995). Hypotension, which is also common after injury, may decrease perfusion to the brain, again, altering consciousness, and masking the effects of head injuries.

The overall goal of quantifying the Occult Score involves incorporation into an AACN algorithm to predict the risk of an occupant sustaining a serious injury and to aid emergency personnel in making a recommended triage decision for an occupant. Current AACN algorithm performance is measured using undertriage (UT) and overtriage (OT) rates with the goal of producing UT rates <5% and OT rates <50% as recommended by the American College of Surgeons (ACS) (American College of Surgeons Committee on Trauma, 2006). UT correlates to the proportion of seriously injured occupants that are not transported to a Level I/II TC and is computed using the false-negative rate (Simmons et al., 1995; Wuerz et al., 1996; Cox et al., 2012; Lossius et al., 2012). OT correlates to the proportion of mildly injured occupants that are transported to a Level I/II TC and is computed using the false-positive rate (Simmons et al., 1995; Wuerz et al., 1996; Cox et al., 2012). Existing AACN algorithms include OnStar and URGENCY (Bahouth et al., 2004, 2012; Rauscher et al., 2009; Kononen et al., 2011; Augenstein et al., 2003, 2002). UT rates for OnStar range from 28 to 85% and for URGENCY range from 6 to 71%. OT rates for OnStar range from 0 to 11% and for URGENCY range from 2 to 46%. The AACN algorithm associated with this study resulted in UT rates ranging from 6 to 12% and OT rates ranging from 25 to 50% (Stitzel et al., 2016). Using the injury-based approach, the developed AACN algorithm which incorporates the Occult Score developed in this study resulted in improved UT rates compared with other AACN algorithms in the literature and OT rates meeting ACS recommendations.

4.1. Limitations

A potential limitation of the AIS is that it may be overly-specific from the perspective of EMS in terms of providing specific AIS code descriptions. Future studies involve grouping injuries into similar AIS severity levels or injury types that are utilized by EMS in the field. For the application of the Occult Score into the AACN algorithm, the score needed to be quantified at an injury level to maintain specificity used for classification of other facets of injury including severity and time sensitivity. A limitation of the study design involves the information gathered from the survey. Since the occultness of injury cannot be directly measured from existing databases, the survey provides information on the perceived occultness of injury based on EMS professional opinions. Future work includes further validation of the Occult Scores with a more objective measure using real-world hospital data. A comprehensive dataset from both the prehospital/EMS setting and the hospital facility would be required to compare the initial assessment at the scene by EMS to the clinically diagnosed outcomes at the hospital to accurately capture missed injuries. The validation would involve collecting a sample of trauma hospital records that include EMS records. Each case would be examined to determine when each injury was first diagnosed whether it was by EMS, in the initial physical examination by the emergency physician, following diagnostic radiology, or during diagnostic or corrective surgery. Injuries missed along this process would be noted and compared to their corresponding Occult Score. Such a study would be possible with the full implementation of the ESO Health Data Exchange. The goal of the ESO Health Data Exchange is to link EMS electronic patient care reports (ePCRs) using the National EMS Information System (NEMSIS) data standard to hospital electronic medical records (EMRs). With the data linked, EMS will directly receive patient outcome information and will be able to quantify and improve the quality of care. Hospitals will be able to view ePCRs directly within the EMRs to also improve the quality of end-to-end care. Having this information available would allow for the collaboration between the hospitals and EMS to track a patient throughout their care process (ESO Health Data Exchange, 2013).

5. Conclusion

An Occult Score for the top 95% most frequently occurring AIS 2+ injuries in MVCs was derived using EMS professional survey data to determine the perception that first responders would miss symptoms of each particular injury. The Occult Score is a portion of an injury-based approach to improve the prediction of severely injured occupants using facets of injury including severity, time sensitivity, and predictability. This injury-based approach serves as the foundation to a developed AACN algorithm in order to improve the prediction of injury for allocation of emergency response resources and triage decision-making. The overall goal of implementation of such an AACN algorithm is to reduce response times, increase triage efficiency, and improve overall patient outcome.

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Appendix A.

Occult Scores for the AIS codes on the Top 95% List. Injuries are sorted by ascending AIS severity and then by ascending AIS pre-dot code.

AIS Code	Occult Score	AIS Code	Occult Score	AIS Code	Occult Score	AIS Code	Occult Score	AIS Code	Occult Score	AIS Code	Occult Score
110604.2	0.017	542020.2	0.755	815000.2	0.306	150200.3	0.533	851810.3	0.288	140656.5	0.449
150400.2	0.607	542022.2	0.837	840402.2	0.340	150202.3	0.626	851812.3	0.249	140666.5	0.449
150402.2	0.709	542810.2	0.913	840404.2	0.290	150404.3	0.451	851814.3	0.110	160824.5	0.174
160202.2	0.267	544210.2	0.811	840600.2	0.306	160802.3	0.196	851818.3	0.264	420210.5	0.316
160406.2	0.324	544212.2	0.815	840802.2	0.409	160806.3	0.154	851822.3	0.266	420216.5	0.370
160410.2	0.330	544220.2	0.769	841002.2	0.345	250808.3	0.309	852604.3	0.117	441012.5	0.528
160414.2	0.306	544222.2	0.857	850210.2	0.257	251204.3	0.130	852800.3	0.644	450242.5	0.141
160602.2	0.245	650200.2	0.632	850214.2	0.322	440604.3	0.613	853000.3	0.174	450266.5	0.157
160606.2	0.248	650204.2	0.543	850218.2	0.268	441402.3	0.721	853405.3	0.147	541828.5	0.657
160610.2	0.215	650208.2	0.601	850610.2	0.226	441406.3	0.560	853408.3	0.111	544228.5	0.421
160699.2	0.232	650209.2	0.574	850614.2	0.270	441430.3	0.517	853422.3	0.054	113000.6	0.048
161000.2	0.541	650216.2	0.542	850806.2	0.163	441499.3	0.551	140410.4	0.632	140212.6	0.518
210604.2	0.040	650218.2	0.552	850818.2	0.163	442202.3	0.256	140629.4	0.607	140218.6	0.482
241202.2	0.171	650220.2	0.561	850822.2	0.735	442204.3	0.459	140630.4	0.588	420218.6	0.321
243404.2	0.094	650230.2	0.541	850826.2	0.526	450211.3	0.177	140632.4	0.696	441016.6	0.448
250200.2	0.318	650232.2	0.552	851400.2	0.602	450214.3	0.329	140638.4	0.635		
250608.2	0.393	650416.2	0.561	851605.2	0.329	450222.3	0.167	140640.4	0.701		
250610.2	0.113	650418.2	0.574	851606.2	0.233	450230.3	0.276	140642.4	0.701		
250612.2	0.129	650420.2	0.581	851608.2	0.329	450250.3	0.140	140650.4	0.622		
250616.2	0.105	650430.2	0.577	851610.2	0.093	521604.3	0.550	140652.4	0.700		
250800.2	0.354	650432.2	0.574	851612.2	0.329	540824.3	0.864	140664.4	0.549		
250802.2	0.465	650616.2	0.559	852000.2	0.358	541424.3	0.783	140678.4	0.658		
250806.2	0.339	650618.2	0.583	852002.2	0.210	541824.3	0.738	140688.4	0.573		
251004.2	0.084	650620.2	0.566	852200.2	0.508	544214.3	0.610	150206.4	0.112		
251200.2	0.417	650630.2	0.576	852400.2	0.387	544224.3	0.752	150406.4	0.119		
251202.2	0.485	650632.2	0.554	852600.2	0.303	544240.3	0.669	160820.4	0.199		
251604.2	0.353	740400.2	0.264	852602.2	0.399	650222.3	0.484	420206.4	0.473		
251800.2	0.470	750230.2	0.417	853200.2	0.669	650224.3	0.493	420208.4	0.515		
441602.2	0.551	751030.2	0.146	853404.2	0.261	650226.3	0.488	440606.4	0.514		
441800.2	0.695	751230.2	0.430	853406.2	0.387	650228.3	0.584	441410.4	0.512		
450210.2	0.260	751430.2	0.201	853412.2	0.287	650234.3	0.562	441450.4	0.469		
450220.2	0.313	751800.2	0.198	853414.2	0.102	650424.3	0.555	450232.4	0.251		
450804.2	0.409	751900.2	0.183	853420.2	0.227	650426.3	0.596	450240.4	0.332		
540610.2	0.978	752002.2	0.444	140466.3	0.626	650434.3	0.557	450252.4	0.096		
540810.2	0.920	752200.2	0.313	140602.3	0.728	650624.3	0.546	450260.4	0.180		
541410.2	0.952	752402.2	0.000	140604.3	0.693	650634.3	0.578	450264.4	0.155		
541610.2	0.921	752500.2	0.476	140606.3	0.735	752604.3	0.050	541626.4	0.676		
541612.2	1.000	752600.2	0.250	140612.3	0.644	752804.3	0.057	541826.4	0.577		
541620.2	0.844	752602.2	0.292	140614.3	0.704	753204.3	0.073	544226.4	0.638		
541622.2	0.951	752800.2	0.260	140620.3	0.634	840406.3	0.342	140202.5	0.578		
541810.2	0.897	752802.2	0.359	140622.3	0.704	851614.3	0.131	140204.5	0.680		
541812.2	0.973	753000.2	0.438	140660.3	0.597	851800.3	0.161	140210.5	0.431		
541820.2	0.799	753200.2	0.346	140662.3	0.640	851801.3	0.057	140628.5	0.541		
541822.2	0.938	753202.2	0.420	140682.3	0.488	851804.3	0.293	140646.5	0.681		
542010.2	0.871	810604.2	0.077	140684.3	0.638	851808.3	0.290	140654.5	0.568		

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