Abstract—Background: Selective cervical spine immobilization performed by Emergency Medical Services (EMS) is being utilized with increasing frequency. These protocols, although very sensitive, still include subjective data such as “mild cervical discomfort.” The aim of this study is to create an objective clinical decision rule that would enhance the selective approach for cervical spine immobilization in patients aged 16–60 years. Study Objective: It is hypothesized that, in a motor vehicle crash, the integrity of the involved vehicle’s glass window and airbag status is an excellent objective measure for the amount of energy a vehicle occupant has experienced during the crash. GLass intact Assures Safe Spine (GLASS) is an easy and objective method for evaluation of the need for prehospital cervical spine immobilization. Methods: A retrospective cohort study was performed with sample motor vehicle crash cases to evaluate the performance of the GLASS rule. The National Accident Sampling System-Crashworthiness Data System (NASS-CDS) was utilized to investigate tow-away motor vehicle crashes, including their glass damage characteristics and occupant injury outcomes, over an 11-year period (1998–2008). Sample occupant cases selected for this study were patients aged 16–60 years, who were belt-restrained front seat occupants involved in a crash with no airbag deployment, and no glass damage before the crash. Results: A total of 14,191 occupants involved in motor vehicle crashes were evaluated in this analysis. The results showed that the sensitivity of the GLASS rule was 95.20% (95% confidence interval [CI] 91.45–98.95%), the specificity was 54.27% (95% CI 53.44–55.09%), and the negative predictive value was 99.92% (95% CI 99.86–99.98%). Conclusion: The GLASS rule presents the possibility of a novel, more objective tool for cervical spine clearance. Prospective evaluation is required to further evaluate the validity of this clinical decision rule. © 2013 Elsevier Inc.

Keywords—cervical spine clearance; trauma; prehospital

INTRODUCTION

More than 13 million trauma patients at risk for cervical spine (C-spine) injury are treated annually in Emergency Departments (EDs) in the United States and Canada. Less than 2% of these patients have clinically important C-spine injuries and less than 1% have neurological deficits (1). Current Advanced Trauma Life Support protocol mandates that all trauma patients be presumed to have a C-spine injury. Standard prehospital practices include spinal immobilization of blunt trauma patients, often based solely on the mechanism of injury (2). This is typically achieved with use of a C-spine collar, a backboard, and head immobilization.

Due to the morbidity associated with C-spine injuries, the need for prehospital C-spine immobilization has garnered a significant amount of attention. Although significant injuries are relatively rare, a very conservative approach has been accepted based on the idea that C-spine immobilization will halt the progression of an occult unstable fracture that might progress to spinal cord injury. However, this benefit has never been conclusively demonstrated in the literature (3).
(4–13). Risks of spine immobilization include physiologic alterations to the patient as well as Emergency Medical Services (EMS) procedural delays. The physiological changes range from minor symptoms such as pain and discomfort to side effects like respiratory compromise, that occur when certain strapping systems are utilized, as well as increased intracranial pressure that could potentially lead to worsening of a patient’s condition (8,12,13).

Clinical decision guidelines such as the NEXUS criteria and Canadian C-spine Rules have been validated in robust landmark studies. These rules are reliably able to identify patients at low risk of C-spine injury (1,4,14). These clinical guidelines are routinely incorporated in the ED setting. Recently, studies have investigated the potential for selective C-spine immobilization in the prehospital setting (15–17).

Currently, all the clinical guidelines including the NEXUS criteria and Canadian C-Spine Rules provide symptomatic and physiologic guidelines. Many patients, however, may still complain of neck pain after low speed crashes, requiring immobilization and radiological imaging.

Our study seeks to assess the ability of a simple and objective field test to exclude unstable C-spine injuries in the setting of a motor vehicle crash. It is hypothesized that if a patient involved in a motor vehicle crash meets the following criteria: age 16–60 years, no damage to any of the vehicle’s windows, no airbags were deployed, and the patient was a front seat occupant restrained by a lap and shoulder belt, the patient does not have an unstable C-spine fracture. This is the GLass intact Assures Safe Spine (GLASS) rule.

**METHODS**

**Study Design**

A retrospective cohort study was conducted to evaluate the association between the vehicle glass damage involved in a traffic collision and the likelihood of the vehicle occupant sustaining an unstable C-spine injury that requires surgical intervention or prolonged immobilization. The Institutional Review Board approved this as an exempted study.

**Setting**

Data from the U.S. National Highway Traffic Safety Administration National Automotive Sampling System Crashworthiness Data System (NASS CDS) were used to enroll cases for the cohort study (18). The NASS CDS database provides nationally representative data regarding motor vehicle crashes based on a weighted annual sample of approximately 5000 police-reported collisions (19). To be recorded in the database, at least one of the vehicles involved in the crash must be damaged enough to require it to be towed from the scene. NASS CDS includes researcher-determined detailed information for each individual crash, including vehicle properties, damage to the vehicle, crash conditions, occupant characteristics, and the injury outcome sustained by each vehicle occupant. A NASS field investigator measures over 200 different data points on every vehicle that is enrolled in the database. This includes investigating and documenting the status of all the glass on a vehicle, including all windows and mirrors, as well as the status of the airbag deployment. The injury severity assessment for each NASS CDS case is done based on the Abbreviated Injury Scale (AIS) scoring system and, in addition, an injury description, severity rating, and identification of injury source is performed based on medical records and field investigation (20).

**Sample Selection**

Motor vehicle occupants between the ages of 16 and 60 years who were involved in a crash and were recorded in the NASS CDS database during the years 1998–2008 were selected as sample cases in the study. The selection criteria further required that the occupant must be seated in the front driver or passenger position, be lap and shoulder belt restrained, and the vehicle must be equipped with functional frontal driver and passenger airbags that did not deploy during the event of the crash. The vehicle types considered in the study were limited to passenger cars, sport utility vehicles, light trucks, and vans. To adequately evaluate post-crash window integrity as an exposure measure, vehicles were pre-screened to include only those that had intact windows and all adjustable windows were in the completely closed position (windows up) before the crash. Cases of vehicle fire, water submersion, and other non-representative cases (sample weighting factors in excess of one million) were excluded from the study.

**Exposure and Outcome Measures**

The exposure measure used in this analysis was the post-crash integrity of the vehicle windows. For each case selected in the sample, it was determined whether or not a window (whether windshield, door window, or rear window) was damaged as a result of the crash impact. The cause of window damage might be either from occupant contact or from contact with external sources in the crash environment. The outcome measure of the analysis was the incidence of a clinically important C-spine injury with an AIS severity score magnitude of 2 or higher.
(AIS 2+) as reported in the NASS CDS. Clinically important C-spine injuries, as defined in this study, include cord contusion, cord laceration, and cervical body injury, which may include fracture, herniation, or dislocation (refer to Appendix 1 for further details on C-spine injury definition).

Data Analysis

The measure of association between the post-crash integrity of the vehicle windows and the outcome event of an occupant in the vehicle sustaining an AIS score of 2+ severe C-spine injury was analyzed using a 2×2 Contingency Table. In the analysis, chi-squared statistic was computed to compare the probability of sustaining a C-spine injury for the two exposure groups considered in the study, and the association measure was reported in terms of relative risk with 95% confidence intervals (CI). The performance characteristic of a rule stating that post-crash integrity of vehicle windows is indicative of the absence of C-spine injuries was evaluated with 95% CI for sensitivity, specificity, and negative predictive value. All of the analysis was performed with SAS statistical software, version 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

A total of 14,191 occupant cases were examined that, when weighted, represented over 10 million front seat occupants involved in crashes during calendar years 1998–2008. The vehicles involved were mostly passenger cars (62%), followed by SUVs (sport utility vehicles) (22%) and vans (7%). These occupants of motor vehicles involved in a crash had a mean age of 34 years, 54% were female, and 81% of them were seated in the driver position (Table 1). There were 7639 crash victims with intact windows; only six of them sustained C-spine injuries with AIS score of 2 or more. Table 2 details the injury outcome of the six subjects with a C-spine injury: two cases of cervical disc herniation without cord involvement, two cases of pedicle and facet fractures, and two cases of cervical body fracture without cord involvement. In the exposure-outcome analysis, there were a total of 6552 cases (46%) with window damage. Of those cases with window damage, 119 occupants sustained a C-spine injury with AIS score of 2 or more. The proposed GLASS rule was found to have a specificity of 95.20% (95% CI 91.45–98.95%), specificity of 54.27% (95% CI 53.44–55.09%), and a negative predictive value of 99.92% (95% CI 99.86–99.98%). In essence, utilizing the GLASS rule, 8 out of 10,000 motor vehicle crash victims who, after the crash had intact windows, would sustain an AIS score of 2 or higher for C-spine injury.

DISCUSSION

In the past, it was thought that EMS providers could not differentiate those patients with C-spine injuries from those without. This conventional thought led to EMS field protocols that incorporated a conservative, non-selective approach to spine immobilization. Recent studies have demonstrated the potential for a more selective approach to prehospital C-spine immobilization. Vaillancourt et al. found a sensitivity of 100% when paramedics applied the Canadian C-Spine rule for prehospital clinical clearance (21). Stroh and Braude also reported a 99% sensitivity when clearing patients using the Fresno County EMS protocol (16). These studies demonstrate that EMS personnel are capable of clearing C-spines in the prehospital setting, and that a more selective immobilization approach does not significantly place patients at increased risk of injury.

Subjective measures such as cervical pain and tenderness are included in all C-spine protocol algorithms, both prehospital and in the ED, when attempting to clear a patient’s C-spine. These rules are more complex than the GLASS approach, which takes into account only objective data. Patients in low speed crashes with cervical strain will likely complain of some neck pain or pain with palpation. Also, patients who have been immobilized in a collar for a prolonged period of time may
complain of neck pain and tenderness, leading to unnecessary testing (8). In addition, current protocols exclude intoxicated patients from being cleared, but such patients would not be excluded utilizing the GLASS approach.

Our study is the first to attempt selective C-spine immobilization of patients aged 16–60 years based completely on objective criteria. Our data suggest that patients who meet the following criteria: lap and shoulder belt restrained front seat passengers, intact (non-deployed) airbags, no glass on the vehicle is broken, and all windows were in the up position; do not need to be immobilized regardless of cervical pain. According to this GLASS rule, these patients would not require C-spine imaging if they are transported to a hospital for further evaluation.

The authors did not choose patients in the extreme age groups for the initial derivation. The goal of this investigation was to find a simple, objective rule that is easy to remember (i.e., ages 16–60 years, no broken glass, belt worn without airbag deployment). Also, it was felt that younger children and elderly patients might not be fairly represented within the database. Thus, the database might inaccurately represent the patients at the extreme ages because it only includes accidents that were potentially more severe (tow away). For this reason and to simplify the initial derivation, patients aged 16–60 years were chosen. Further evaluation of the elderly population would be prudent in a validation study.

Limitations

A primary limitation of the study is that a retrospective cohort analysis was performed utilizing a national database. A prospective study would further clarify some of the injuries we found in our study group that we suspect were inaccurately reported in the database. It is important to realize that the analysis performed to evaluate the performance of the GLASS rule is not population based but, rather, includes a random selection of police-reported cases involving tow-away crashes. This may have resulted in the slightly lower sensitivity being recorded for GLASS, when compared to Nexus and Canadian C-Spine, because it does not capture occupants involved in crashes in which neither vehicle required towing. Although the NASS CDS includes weighting information to extrapolate the risk measures at the national level, inaccuracies associated with the weighting scheme to appropriately address specific injury outcomes and glass damage exposure may lead to misleading results.

CONCLUSION

The GLASS rule holds promise as a novel, objective approach to C-spine clearance of patients involved in
low-speed motor vehicle crashes. Given the results of this derivation, a prospectively conducted study is needed to further clarify the actual characteristics of the rule with regard to sensitivity and specificity, as well as ease of implementation and potential cost savings.

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REFERENCES

ARTICLE SUMMARY

1. Why is this topic important?
   Cervical spine injuries, although rare, are devastating when they occur, which has led to a very conservative approach to prehospital immobilization. There are still a large number of patients who receive unnecessary cervical spine immobilization. Our goal was to create an objective decision rule that would further stratify patients who would not require immobilization.

2. What does this study attempt to show?
   The patients who meet the GLass intact Assures Safe Spine (GLASS) criteria, although they may still have neck soreness and tenderness, do not require cervical spine immobilization.

3. What are the key findings?
   The clinical decision rule had a sensitivity of 95% and a negative predictive value of 99.9%.

4. How is patient care impacted?
   With the use of the GLASS rule, a greater number of patients would not require cervical spine immobilization, and even if they complain of some tenderness, would not require any radiographic imaging.
### APPENDIX

#### SUMMARY OF CERVICAL SPINE INJURIES CONSIDERED CLINICALLY IMPORTANT IN THIS STUDY

<table>
<thead>
<tr>
<th>Description of Cervical Spine Injury</th>
<th>AIS 90 Code(s)</th>
<th>Valid AIS Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cord contusion</td>
<td>640200-01</td>
<td>3</td>
</tr>
<tr>
<td>Cord contusion with transient neurological signs (with or without fracture or dislocation)</td>
<td>640201-08</td>
<td>3</td>
</tr>
<tr>
<td>Incomplete cord syndrome (with or without fracture of dislocation)</td>
<td>640210-18</td>
<td>4</td>
</tr>
<tr>
<td>Complete cord syndrome (quadriplegia or paraplegia with no sensation)</td>
<td>640220</td>
<td>5</td>
</tr>
<tr>
<td>Complete cord syndrome for C-4 and lower (with or without fracture or dislocation)</td>
<td>640221-28</td>
<td>5</td>
</tr>
<tr>
<td>Complete cord syndrome for C-3 and lower (with or without fracture or dislocation)</td>
<td>640229-36</td>
<td>6</td>
</tr>
<tr>
<td>Cord laceration (includes transection and cuts)</td>
<td>640240</td>
<td>5</td>
</tr>
<tr>
<td>Incomplete cord laceration (with or without fracture or dislocation)</td>
<td>640242-50</td>
<td>5</td>
</tr>
<tr>
<td>Cord laceration and complete cord syndrome</td>
<td>640260</td>
<td>5</td>
</tr>
<tr>
<td>Cord laceration and complete cord syndrome for C-4 and lower (with fracture dislocation)</td>
<td>640261-68</td>
<td>5</td>
</tr>
<tr>
<td>Cord laceration and complete cord syndrome for C-4 and lower (with fracture dislocation)</td>
<td>640269-76</td>
<td>6</td>
</tr>
<tr>
<td>Disc herniation with or without nerve root damage</td>
<td>650200-03</td>
<td>2, 3</td>
</tr>
<tr>
<td>Disc dislocation without fracture, cord contusion or cord laceration</td>
<td>650204-12</td>
<td>2, 3</td>
</tr>
<tr>
<td>Cervical body fracture without cord contusion or laceration with or without dislocation</td>
<td>650216-34</td>
<td>2, 3</td>
</tr>
</tbody>
</table>

AIS = Abbreviated Injury Scale.