THE SCENESCORE FOR IMPROVED PRE-HOSPITAL TRIAGE
OF MOTOR-VEHICLE CRASH VICTIMS

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ABSTRACT

The SceneScore is a simple mechanism of injury scoring system designed to facilitate the appropriate triage of crash victims. It comprises 7 variables including age, collision type, impact location, airbag deployment, steering wheel deformity, intrusion, and restraint use. A cutoff value of 7 or 8 provides the maximum balance between sensitivity and specificity, with sensitivities of 75% to 83% and specificities of 29% to 46%. For cases triaged to the trauma center based only on high suspicion of injury, the SceneScore reduces the overtriage rate by almost half. Proper application of the SceneScore may lead to improved triage and enhanced communication of mechanism of injury criteria.

There is currently a problem with the overtriage of a large proportion of trauma patients. This is perhaps most accentuated with victims of motor-vehicle related crashes. The pre-hospital criteria used to determine who needs to be triaged to a trauma center after a motor-vehicle crash are poor predictors of injury. As many as 50% of blunt trauma patients initially thought to be seriously injured and transported to a trauma center are not admitted or are discharged from the hospital within 24 hours (Norwood, McAuley, Berne et al. 2002; Kohn, Hammel, Bretz et al. 2004). Better triage of these patients will lead to better resource utilization and cost savings.
Using the definition of the American College of Surgeons (ACS), "overtriage" is a decision that incorrectly classifies a patient as needing trauma center care (ACS 2006). This may be reflected by the number of patients with an ISS of 1 to 9 admitted to level I trauma centers. "Undertriage" refers to patients with an ISS greater than or equal to 15 admitted to non-trauma hospitals (ACS 2006). Undertriage is a potential cause of severe morbidity and mortality if life-threatening injuries are not promptly recognized and treated in an appropriate trauma center. Therefore, current systems and practices have been designed to minimize the undertriage rate. Since our analysis is based on AIS scores, we defined any patient with a maximal AIS score of $\geq 3$ as being properly triaged to the trauma center. Those patients transported to the trauma center with a maximal AIS $< 2$ were considered overtriaged, as the overwhelming majority of these patients can likely be treated at a non-trauma hospital. Since we are only assessing those patients who were transported to the trauma center, we cannot assess undertriage.

Field triage criteria have been established by the American College of Surgeons and include physiologic, anatomic, and mechanism of injury criteria to justify transport directly to a trauma center. Since no criteria will capture all severely injured patients, most trauma systems, including ours, also relies on “paramedic judgement” or “high suspicion of injury.” The trauma criteria used in our Trauma System can be seen in Table 1. This means even in the absence of defined trauma triage criteria, the first responder can use his/her judgement to upgrade the patient to a trauma alert. This is also reflected in the fact that an overtriage rate of 25-50% is considered acceptable by the ACS in order to ensure that all severely injured trauma patients are seen at a trauma center (ACS 2006).

### Table 1 State of Florida Trauma Criteria

<table>
<thead>
<tr>
<th>Category</th>
<th>Category 1 (Any 1 meets TTC)</th>
<th>Category 2 (Any 2 meet TTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Age $\geq 55$ years old</td>
<td></td>
</tr>
<tr>
<td>Airway</td>
<td>Active assistance</td>
<td>Respiratory rate $\geq 30$</td>
</tr>
<tr>
<td>Consciousness</td>
<td>BMR $&lt; 4$, Paralysis, GCS $\leq 12$</td>
<td>BMR 5</td>
</tr>
<tr>
<td>Circulation</td>
<td>HR $&gt; 120$, SBP $&lt; 90$</td>
<td>Sustained HR $\geq 120$</td>
</tr>
<tr>
<td>Fracture</td>
<td>$\geq 2$ long bone fractures</td>
<td>Any long bone fracture in MVC or fall $\geq 10$ feet</td>
</tr>
<tr>
<td>Cutaneous</td>
<td>$2^{nd}$ or $3^{rd}$ degree burns $&gt; 15%$ TBSA, amputation, penetrating injury to head, neck or torso</td>
<td>Major degloving, flap avulsion $&gt; 5$ inches or GSW to extremities</td>
</tr>
<tr>
<td>Mechanism of Injury</td>
<td>Ejection from motor vehicle, or steering wheel deformity</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>High index of suspicion, paramedic judgement</td>
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</tr>
</tbody>
</table>
Adult trauma patients meeting any one of the parameters in Category 1, or any 2 parameters in Category 2, are considered trauma alert patients and should be transported to the nearest State Approved Trauma Center.

TTC=Trauma Transfer Criteria, BMR=Best Motor Response of the Glasgow Coma Scale (GCS), HR=Heat Rate, SBP=Systolic Blood Pressure, TBSA=Total Body Surface Area, GSW=Gun Shot Wound

As early as 1985, the use of field triage scoring systems were studied to help predict severity of injury in the pre-hospital setting. Using the Trauma Score and the CRAMS scale, it was found that either score failed to identify two out of three patients needing immediate surgery and that paramedic judgement was better (Ornato, Mlinek, Craren et al. 1985). West and colleagues found that adding anatomic and mechanism of injury criteria reduced trauma deaths in nondesignated trauma hospitals but doubled the overtriage rate (West, Murdock, Baldwin et al. 1986). In 1986, review of a single trauma center’s experience found that death of another occupant in the same vehicle and extrication time longer than 20 minutes were useful triage criteria (Long, Bachulis and Hynes 1986). Others found structural intrusion, extrication difficulties, and passenger ejection to be useful, but still there was an overtriage rate of 14 to 43 percent (Lowe, Oh, Neely et al. 1986). Many authors have also noted the increased undertriage rate of older motor-vehicle occupants due to their blunted response to injury in some cases (Miltner and Salwender 1995; Scheetz 2003)

Data from our group previously demonstrated that occult abdominal injuries were occurring even with airbag deployment, and these may be unrecognized at the scene. It was particularly noted that steering wheel deformity is an indicator of increased likelihood of internal injury (Augenstein, Digges, Lombardo et al. 1995). More recently, creation of the Urgency algorithm included vehicle crush, restraint usage, age, gender, severe pole crashes, multiple impact crashes and close-in occupants to accurately predict AIS 3+ injuries (Augenstein, Digges, Ogata et al. 2001). This was, however, with the addition of variables such as delta V, not currently available to pre-hospital personnel.

A recent analysis using the National Automotive Sampling System (NASS) by Newgard and colleagues demonstrated a significant increase in the risk of injury for each 5 cm of steering wheel deformity, near-side impacts and ejection (Newgard, Lewis and Kraus 2005). Nirula and colleagues used a similar analysis of NASS to find that age, ejection, restraints, near-side impact and rollover were all associated with increased injury (Nirula, Talmor and Brasel 2005). Fox and colleagues
evaluated 500 patients presenting to a Level 1 trauma center and noted that seatbelt use was protective, while dashboard intrusion, steering wheel deformity, windshield violation, and irreparable vehicles correlated with significant injuries (Fox, Fabian, Croce et al. 1991). In another crash investigation study, Seigel and colleagues noted that restraint use, intrusion, and steering wheel deformity were associated with certain injuries, but that the injury patterns differed with respect to impact location (Siegel, Mason-Gonzalez, Dischinger et al. 1993). It has also been shown that the more areas of intrusion or deformation there are, the higher the incidence of serious injury (Stefanopoulos, Vagianos, Stavropoulos et al. 2003).

Despite this wealth of data on specific mechanism of injury characteristics, there remains no simple, standardized criteria for pre-hospital personnel to be able to effectively communicate the severity of the injury mechanism. Furthermore, the predictive value of such a score has not been well validated. Although mechanism of injury is part of the American College of Surgeons (ACS) trauma triage criteria, the exact mechanistic parameters to be utilized remains controversial. In addition, the use of mechanism of injury in the pre-hospital setting is not uniformly applied. Burstein and colleagues performed a prospective study of the use of mechanism of injury as a field triage criteria and found that standard EMS documentation underreports ACS trauma triage mechanism criteria, biasing outcome analysis in the direction of a worse outcome and more resource utilization. They suggested use of a standardized data instrument would improve the reporting of mechanism of injury criteria (Burstein, Henry, Alicandro et al. 1996).

We now present the development of the SceneScore field triage tool. Its purpose is to aid the pre-hospital provider in their efforts to properly triage motor-vehicle crash victims to the trauma center. It is meant to be used as an adjunct to the already defined trauma triage criteria and to provide some objectivity to the use of “paramedic judgment” as a criteria. In addition, its use may serve to improve communication about mechanism of injury between the pre-hospital and hospital providers. We will describe the creation of the SceneScore instrument and how it performs compared to a large series of motor-vehicle related crashes. The main objective of the SceneScore is to improve the accuracy of triage for motor-vehicle related crashes. In particular, the SceneScore may reduce the overtriage of patients when mechanism of injury alone is the sole criteria for trauma team activation.
METHODS

A computerized crash database was used that contains cases from the Crash Injury Research and Engineering Network (CIREN) as well as other crash investigations during the years 1994-2006. All cases contain information from the police report, medical records, and official crash investigation including scene and vehicle inspections. All cases were reviewed by the crash investigation team for completeness and accuracy.

A comprehensive literature search was used to identify mechanism of injury variables shown to be associated with motor-vehicle crashes. The computerized crash database was also used to identify variables suitable for a motor-vehicle crash scoring system. Those variables felt to be easily observed and reported by first responders were considered for inclusion. These included 7 variables: Age, Collision Type, Impact Location, Airbag Deployment, Steering Wheel Deformity, Intrusion (reduction of the interior compartment of the vehicle), and Restraint Use. Other variables that were considered but not used in the final model included gender, weight (BMI), principle direction of force, and crush deformity. All of these variables were excluded due to lack of predictive ability in the model, except for crush, which was predictive. Since crush and intrusion have some collinearity, and intrusion was a better predictor, intrusion alone was retained in the final model.

Logistic regression was used to determine the utility and impact of each variable. Each variable was initially assigned an individual score ranging from 0 to 5 based on the magnitude of each variable’s effect in the logistic regression and its effect on providing optimal sensitivity and specificity of correct triage. The scenescore was then calculated for the entire cohort using higher and lower values (1 to 5) for each of the variables. These models were then tested for sensitivity and specificity with each value change. The lowest value that maintained an acceptable sensitivity and specificity was chosen. The maximum number of points that can be attained in the final SceneScore model is 17. The predictive value of the SceneScore was then compared to the trauma alert criteria (Table 1), particularly in cases where the only trauma alert criteria was "paramedic judgement," indicating the patient did not meet any physiological criteria for trauma team activation.

RESULTS

Creation of the SceneScore

118 cases with AIS < 3 and 419 cases with AIS 3+ were used in the analysis. The seven variables selected were analyzed by logistic regression for their potential influence in predicting injury severity.
Variables were dichotomized or categorized to maximize their discriminant ability. The results of these analyses are presented in Table 2.

Table 2: Analysis of Predictor Variables

<table>
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<tr>
<th></th>
<th>Odds Ratio (95% CI)</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td>Age &gt; 60</td>
<td>1.76 (0.96-3.24)</td>
<td>0.07</td>
</tr>
<tr>
<td>Airbag Deployed</td>
<td>1.21 (0.63-2.35)</td>
<td>0.39</td>
</tr>
<tr>
<td>Collision Type (Vehicle vs Narrow Object, Pole or Tree)</td>
<td>1.83 (1.05-3.20)</td>
<td>0.03</td>
</tr>
<tr>
<td>Impact Type (Frontal vs Nearsise)</td>
<td>2.26 (1.29-4.59)</td>
<td>0.006</td>
</tr>
<tr>
<td>Intrusion &gt; 6 inches</td>
<td>2.65 (1.75-4.05)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>No Restraint Use</td>
<td>2.2 (1.39-3.40)</td>
<td>0.006</td>
</tr>
<tr>
<td>Steering Wheel Deformity &gt; 2 inches</td>
<td>2.0 (1.16-3.47)</td>
<td>0.01</td>
</tr>
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</table>

Although not statistically significant, age and airbag deployment were retained in the model due to literature that suggests they may be markers of severe injury and due to the known limitations of the database. The values assigned to the elements of the SceneScore are shown in Table 3. The values chosen for each variable were based on their magnitude of effect in the logistic regression and their effect on the sensitivity and specificity of the overall SceneScore. For example, age and airbag deployment were given the lowest scores since they were the weakest predictors in the model. In contrast, intrusion was given a high score since it had the greatest odds ratio in the model. Each change in a variable’s value was also analyzed for its effect on the sensitivity and specificity of the SceneScore to accurately triage patients to the trauma center. If a higher value did not improve the predictive value of the SceneScore, it was not used. As can be seen in Table 3, intrusion and restraint use had the greatest effect at the higher value of 5, whereas impact type and steering wheel deformity had more modest effects and maximized their discriminant ability at a value of 3.
Using the entire cohort regardless of the trauma criteria originally used in the field, the sensitivity and specificity for the SceneScore with various cutoff values is presented in Table 4. The sensitivity was defined as the ability of the SceneScore to correctly triage patients with an AIS 3+ to the trauma center. The specificity is defined as the ability of the SceneScore to correctly identify patients with an AIS of 2 or less, who may not have needed transfer to the trauma center. Since all patients in this cohort were transferred to the trauma center based on trauma alert criteria or paramedic judgement, the specificity value indicates the percent of patients that the SceneScore correctly identified as having less severe injuries (AIS $\leq 2$), and whom were possibly overtriaged. It appears that a cutoff value of 7 or 8 provides the maximum balance between sensitivity and specificity, with sensitivities of 75% to 83% and specificities of 29% to 46%, respectfully.

<table>
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<tr>
<th>SceneScore Cutoff Value</th>
<th>Sensitivity</th>
<th>Specificity</th>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>85%</td>
<td>26%</td>
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<tr>
<td>7</td>
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<td>29%</td>
</tr>
<tr>
<td>8</td>
<td>76%</td>
<td>46%</td>
</tr>
<tr>
<td>9</td>
<td>64%</td>
<td>52%</td>
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</table>
Comparison with Paramedic Judgment

The trauma criteria for each patient arriving at the trauma center is recorded on arrival and later verified in the crash database. These may be physiologic or mechanism of injury criteria as outlined in Table 1, or may fall into the category of paramedic judgment. For comparison with those cases in which paramedic judgment was the sole trauma criteria, the Scenescore was used to determine whether the crash was less severe (non-trauma alert) or it is was very severe (trauma alert). Once again, different cut-off values were used to determine the best possible discriminant ability of the scenescore in these cases.

Paramedic judgement as a trauma criteria overtriaged 49% of the AIS < 3 injuries. Using the newly devised SceneScore with a cutoff of 7 reduced this overtriage rate by 14%, for a 29% relative reduction in the overtriage rate. Using the SceneScore with a cutoff of 8 reduces the overtriage rate by almost half, or 23%, which is a 46% relative reduction in the overtriage rate. This increased cutoff value only reduces the overall sensitivity of the SceneScore by 7%, from 83% to 76%. The overall performance of the SceneScore compared to paramedic judgement is shown in Table 5.

Table 5: SceneScore vs Paramedic Judgment (n=180)

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DISCUSSION

Pre-hospital triage may be improved in many ways. In addition to modification of existing triage criteria, improved education and training of first responders may be beneficial. Attempts have been made in the past to improve pre-hospital triage using mechanism of injury criteria. Bond and colleagues combined the prehospital index (a score comprised of systolic blood pressure, pulse, respirations and level of consiousness) with mechanism of injury criteria including death or serious injury to another occupant, steering wheel deformity or intrusion greater than 20 inches. They found the combination of prehospital index and mechanism injury increased the triage sensitivity while maintaining similar specificities (Bond, Kortbeek and Preshaw 1997).

The current pre-hospital triage of motor-vehicle crash victims relies on certain pre-defined physiologic criteria. To account for injuries that do not manifest overtly, we rely on paramedic judgment to assess the
scene and suspect serious injury based on the crash mechanism and crash characteristics. Unfortunately, this has led to a large overtriage rate, worsened by the increasingly novice workforce of paramedics. The SceneScore provides objective criteria by which a paramedic can quickly assess the crash scene and augment their judgment. The reduction in overtriage using the SceneScore could save enormous resources and costs in the care of crash victims.

Of course, mechanism of injury should never be used by itself. Knopp and colleagues looked at the positive predictive value of crash characteristics such as extrication time > 30 minutes (40% PPV), ejection (22.4% PPV), fatality in the same vehicle (21.4% PPV), and intrusion > 12 inches (19% PPV), but the best balance of undertriage and overtriage was achieved when these were coupled with physiologic criteria (Knopp, Yanagi, Kallsen et al. 1988). A prospective study trying to determine the efficacy of mechanism of injury alone found that by itself, mechanism of injury had a positive predictive value of just 6.9%, and should be augmented by anatomic and physiologic criteria (Cooper, Yarbrough, Zone-Smith et al. 1995). Similarly, Norcross and colleagues found that adding mechanism of injury to physiologic and anatomic triage criteria increased sensitivity but further reduced the positive predictive value (Norcross, Ford, Cooper et al. 1995). The SceneScore appears to improve upon these significantly, with a positive predictive value of 84% for a cutoff value of 7, but still should never be the sole triage criteria.

Kreis and colleagues found mechanism of injury had the highest rate of overtriage yet had a low sensitivity, with 74% of patients triaged to the trauma center for this mechanism discharged directly from the emergency department (Kreis, Fine, Gomez et al. 1988). Similarly, Knudson and colleagues found that a “motor vehicle accident over 40 mph” had a sensitivity of 24% and specificity of 72% (Knudson, Frecceri and DeLateur 1988). Intrusion was found to have an accurate triage rate of only 20% to 56% (Long et al. 1986; Kreis et al. 1988). The SceneScore, when compared only to paramedic judgement, has a sensitivity of 76-83% and a specificity of 29-46%, which is better but still leaves plenty of room for improvement. This specificity of 46% means that the SceneScore correctly identified 46% of patients as not needing transfer to the trauma center (the false positives). This does mean that the current system inherently has a large number of false positives, and the SceneScore is more specific by identifying a large percentage of these false positives. Perhaps future technological improvements such as crash kinetics from onboard sensors available to pre-hospital personnel will add the final critical piece to the puzzle.

There are several limitations to the present study. First, the selection of cases to be included in the crash database were based on many different criteria over the various years and phases of the study. It is possible that the variables and their values would be different if a
different database was used. The study includes many older model vehicles before the implementation of the latest safety designs and features. This includes vehicles not equipped with driver side airbags and these were included in the analysis and placed in the same category as if airbags were not deployed. The sample size is moderate, although for many specific crash types such as rollovers there were very few cases included in the analysis. The crash database focused mostly on frontal and side impact crashes. Lastly, the accuracy of the use of specific trauma triage criteria versus paramedic judgment is subject to all the flaws inherent in a retrospective analysis.

While the SceneScore is an attempt to improve the pre-hospital triage of victims of motor-vehicle crashes, there are several other important aspects to implementing this type of pre-hospital scoring system. First, it encourages the communication of crash severity to the hospital personnel, which is often lost in the hand-off at the hospital. This, in turn, should stimulate hospital providers to think about and include mechanism of injury parameters in their initial management and workup of the injured patient. Hunt and others studied the feasibility and utility of using pictures of the vehicle and crash scene to improve communication about crash mechanism and severity (Hunt, Whitley, Allison et al. 1997; Newgard, Martens and Lyons 2002). Using photographs or scoring systems such as the SceneScore may help to mitigate the difference in experience between pre-hospital providers in rural versus urban settings, and with differing years of experience. In addition, the mere implementation of such a scoring system would lead to increased education and training of pre-hospital personnel regarding the importance of certain mechanism of injury criteria.

It does appear, however, based on the sensitivity and specificity of the SceneScore, that it may be better in preventing overtriage than in reducing undertriage at certain cut-off values. Clearly it cannot be used as a stand alone instrument, but in cases where there are no other hard signs of injury (such as in paramedic judgement), it may be a useful adjunct. Since this study was limited by only including patients transported to the trauma center, and was retrospective in nature, prospective validation in real world situations is necessary. Its use combined with traditional triage tools and protocols must be further evaluated.

In conclusion, this analysis of our crash database has yielded a new field triage tool called the SceneScore. It is simple and easy to use, with no added equipment, and can be implemented with minimal additional training of pre-hospital personnel. While its performance metrics are fairly good, it must be considered with other established anatomic and physiologic triage criteria to minimize the undertriage rate. It may prove most useful when none of the other criteria are satisfied and the pre-hospital personnel are left with mechanism of injury as the sole
reason for transport to the trauma center. In this situation, it may aide in reducing the overtriage that occurs and lead to significant cost savings and more efficient resource utilization. Clearly, prospective validation of this decision tool is required.

REFERENCES


Newgard CD, Martens KA and Lyons EM. "Crash scene photography in motor vehicle crashes without air bag deployment." Acad Emerg Med 9(9): 924-9;2002.


