DOES MECHANISM OF INJURY PREDICT TRAUMA CENTER NEED?

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ABSTRACT

Objective. To determine the predictive value of the mechanism-of-injury step of the American College of Surgeons Field Triage Decision Scheme for determining trauma center need. **Methods.** Emergency medical services (EMS) providers caring for injured adult patients transported to the regional trauma center in three midsized communities over two years were interviewed upon emergency department (ED) arrival. Included was any injured patient, regardless of injury severity. The interview collected patient physiologic condition, apparent anatomic injury, and mechanism of injury. Using the 1999 Scheme, patients who met the physiologic or anatomic steps were excluded. Patients were considered to need a trauma center if they had nonorthopedic surgery within 24 hours, had intensive care unit admission, or died prior to hospital discharge. Data were analyzed by calculating positive likelihood ratios (+LRs) and 95% confidence intervals (CIs) for each mechanism-of-injury criterion. **Results.** A total of 11,892 provider interviews were conducted. Of those, one was excluded because outcome data were not available, and 2,408 were excluded because they met the other steps of the Field Triage Decision Scheme. Of the remaining 9,483 cases, 2,363 met one of the mechanism-of-injury criteria, 204 (9%) of whom needed the resources of a trauma center. Criteria with a +LR ≥5 were death of another occupant in the same vehicle (6.8; CI: 2.7–16.7), fall >20 feet (5.3; CI: 2.4–11.4), and motor vehicle crash (MVC) extrication time >20 minutes (5.1; CI: 3.2–8.1). Criteria with a +LR between >2 and <5 were intrusion >12 inches (4.2; CI: 2.9–5.9), ejection (3.2; CI: 1.3–8.2), and deformity >20 inches (2.5; CI: 1.9–3.2). The criteria with a +LR ≤2 were MVC speed >40 mph (2.0; CI: 1.7–2.4), pedestrian/bicyclist struck at a speed >5 mph (1.2; CI:1.1–1.4), bicyclist/pedestrian thrown or run over (1.2; CI: 0.9–1.6), motorcycle crash at a speed >20 mph (1.2; CI: 1.1–1.4), rider separated from motorcycle (1.0; CI: 0.9–1.2), and MVC rollover (1.0; CI: 0.7–1.5). **Conclusion.** Death of another occupant, fall distance, and extrication time were good predictors of trauma center need when a patient did not meet the anatomic or physiologic conditions. Intrusion, ejection, and vehicle deformity were moderate predictors. **Key words:** wounds and injury; triage; emergency medical services; emergency medical technicians; predictors; mechanism of injury; trauma center

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INTRODUCTION

Traumatic injury is the leading cause of death for Americans aged 1 to 44 years.[1] Compared with the number of patients who sustain traumatic injuries, those who die from their injuries represent just a small proportion (<1%).[2] Injured patients account for approximately 40% of all emergency medical services (EMS) transports.[3] EMS field providers must ensure that the injured patients they transport are taken to the most appropriate hospital that has the necessary resources to manage the patients' injuries. Failure to appropriately triage these patients can result in a significant increase in mortality risk.[4]

The Field Triage Decision Scheme, established by the American College of Surgeons Committee on

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Trauma in 1987, has helped guide EMS providers in making appropriate triage decisions for injured patients.[5] These guidelines describe a four-step process for identifying patients with potentially severe traumatic injuries that require treatment at a trauma center, which they defined as a patient with an Injury Severity Score (ISS) greater than 15. Patients who meet the physiologic or anatomic components of the Decision Scheme are identified in the first two steps. Patients who fail to meet the conditions under either of these components are then evaluated using the mechanism-of-injury component, which evaluates patients for mechanisms that are likely to cause injury even if one is not apparent to the EMS provider.

A literature review of the Decision Scheme and its components demonstrated that little scientific evidence exists to support them, particularly for the mechanism-of-injury component that is used to guide field triage decisions when the physiologic and anatomic components are not met.[6] In 2006, the Centers for Disease Control and Prevention (CDC) hosted a National Expert Panel on Field Triage, which evaluated the Field Triage Decision Scheme and came to consensus on changes that should be made to update the Scheme.[7] The majority of these changes were to the mechanism-of-injury criteria, many of which were removed. The objectives of this study were to determine the predictive value of specific mechanisms of injury for determining trauma center need for injured adult patients who do not meet the anatomic or physiologic steps of the Field Triage Scheme. A secondary objective was to identify thresholds for the measurable mechanism-of-injury criteria (e.g., speed) that are the best predictors of trauma center need.

Methods

A two-year prospective observational study was conducted from March 2007 to March 2009 at three large tertiary care hospitals that were also state-designated level 1 regional trauma centers in Milwaukee, Wisconsin; Rochester, New York; and Royal Oak, Michigan. These hospitals were the primary receiving hospitals for their regions and treated numerous injured patients transported by EMS who were not considered to have severe injures as well as those patients who were identified as needing a trauma center. The emergency department (ED) in Wisconsin had approximately 61,500 visits annually, the ED in New York, 95,000 visits, and the ED in Michigan, 115,000 visits.

To be included in the study, subjects had to be adults (aged $\geq$18 years) presenting to a participating ED with a traumatic mechanism of injury (including the full spectrum of severities, from ankle sprain to major trauma) transported by an EMS provider (by either ground ambulance or helicopter) from the scene of the injury. For the purposes of this study, traumatic mechanisms of injury included assault (including gunshot and stabbing), motor vehicle crash, motorcycle crash, fall, and pedestrian or bicyclist struck. Subjects were excluded if the patient was transported by means other than a ground or air ambulance, transferred from another receiving facility, or transported by multiple EMS agencies where the final providers who accompanied the patient to the ED had not observed the scene of injury.

Study interviewers staffed each of the study EDs seven days a week for a set number of hours. The coverage varied by day and site, and did not include overnight hours. The interviewers identified any patient who met the study inclusion/exclusion criteria and interviewed the EMS provider who was in charge of the patient's care immediately after the EMS provider transferred care of the patient to ED staff. The interviewer reviewed each of the Field Triage Decision Scheme conditions with the EMS provider and asked which (if any) of the conditions the patient met. This included the anatomic and physiologic components of the Decision Scheme as well as specific details regarding the patient's mechanism of injury. The EMS providers were asked to estimate the value for any measurable mechanism-of-injury criteria (e.g., vehicle speed or intrusion distance). When an interviewer was not present in the ED, a paper version of the interview was available for EMS providers to complete on their own.

When the patient was discharged, a research coordinator reviewed the hospital medical record and obtained outcome information. This information was used to determine in retrospect whether the patient needed the resources of a trauma center. In the literature, need for a trauma center has been defined in a variety of ways. In several studies it has been defined as a composite measure of whether the patient had urgent nonorthopedic surgery within 24 hours, admission to an intensive care unit (ICU), and/or death prior to hospital discharge.[6] Others have used an ISS greater than 15 as a surrogate indicator of need for a trauma center.[8] We used both definitions, since there is no consensus definition, but considered the composite measure to be our primary outcome. The ISS was calculated based on the patient's *International Classification of Diseases, Ninth Revision* (ICD-9) discharge codes using ICDMAP-90 software (Tri-Analytics, Inc., Bel Air, MD).[9,10]

The medical record review was conducted by a site research coordinator using a structured data-collection instrument. To ensure consistency in the data abstraction, the research coordinator and a physician site investigator independently reviewed the same 10 charts. The abstraction was reviewed and, if there were any discrepancies, an additional five charts were reviewed. The research coordinator could not independently review charts until there was 100% agreement on the data abstraction between the research coordinator and the physician site investigator on at least five consecutive charts. The physician was available for questions throughout the study, and monthly conference calls were held with all of the investigators and coordinators to discuss data abstraction.

All study data were entered into a research database. To ensure accurate data entry, all forms were verified using a double-entry system. Data were analyzed using descriptive statistics, including sensitivity, specificity, and positive likelihood ratios (+LRs), as well as 95% confidence intervals. Patients who met the anatomic or physiologic criteria were excluded from the analysis and each mechanism of injury was analyzed separately. We defined a good predictor as one having a +LR of 5 or greater, a moderate predictor as one having a +LR between 2 and less than 5, and a poor predictor as one having a +LR of 2 or less.[11] For measurable mechanisms of injury, receiver-operating characteristic (ROC) curves were examined and tables were generated to assist in finding optimal cutpoints.

The study was approved by all three institutions' institutional review boards.

RESULTS

During the study period, we identified 20,542 patients who met the study's inclusion/exclusion criteria at the three study hospitals. A total of 11,892 (58%) were enrolled in the study and EMS provider interviews were conducted. The eligible patients who were not enrolled were missed because no interviewer was on duty, no interviewer was available to complete the interview before EMS left the ED, or the EMS provider refused to complete the survey. Basic characteristics between the missed and included patients were similar (Table 1). Outcome information for the included patients was available for 11,891 (99.99%) subjects.

Based on the information obtained from EMS provider interviews, 2,408 subjects met the physiologic (1,262) or anatomic (1,146) steps of the 1999 Field Triage Decision Scheme.[7] Therefore, 9,483 subjects were included in the mechanism-of-injury analysis. Of those, 2,363 met one of the mechanism-of-injury criteria of the Field Triage Decision Scheme. Nine percent of the subjects who met any of the mechanism-of-injury criteria were found to have actually needed the resources of a trauma center (Table 2). Of the patients who did not meet the mechanism-of-injury criteria, 4% were found to have needed the resources of a trauma center and would have been undertriaged. When we used an ISS greater than 15 as the definition for trauma center need, 9% of the subjects who met the mechanism-of-injury criteria needed the resources of a trauma center, whereas 6% of the patients who did not meet the mechanism-of-injury criteria needed the resources of a trauma center.

The sensitivity, specificity, and +LR for each of the mechanism-of-injury criteria in the 1999 Field Triage Decision Scheme for determining trauma center need are shown in Table 3. Death of another occupant, fall distance, and extrication time were found to be good predictors of trauma center need, as defined by a +LR of 5 or greater. Intrusion, ejection, and vehicle deformity were moderate predictors as defined by a +LR greater than 2 and less than 5.

When ISS greater than 15 was used as the outcome variable instead of the composite measure, the results for the individual mechanism-of-injury criteria changed (Table 4). However, the mechanism-of-injury criteria that were considered poor predictors (i.e., a +LR of 2 or less) remained poor predictors regardless of which outcome was used.

Changing the cutpoints from the 1999 values might improve the ability of some of the criteria to identify patients who needed a trauma center (Tables 5 through 12). For example, patients who fell from a height of 35

TABLE 1. Comparison of Patients Included in the Study with Those for Whom an EMS Interview Was Not Conducted

	Included (n = 11,892)	Missed (n = 8,650)
Gender—male	51%	52%
Age—mean	48 years	47 years
Admitted	36%	33%
Died	2%	1%
Mechanism of injury		
Assault	11%	18%
Fall	38%	40%
Motor vehicle crash	39%	35%
Motorcycle crash	5%	3%
Pedestrian/bicyclist struck	5%	3%
Other	2%	1%

TABLE 2. Comparison of Those Who Met the Mechanism-of-Injury Criteria from the 1999 Field Triage Decision Scheme and Their Need for a Trauma Center

	Met Any Mechanism-of-Injury Criteria	Met None of the Mechanism-of-Injury Criteria
Needed the resources of a trauma center*	204	310†
Did not need the resources of a trauma center	2,159‡	6,810

Sensitivity = 39.7%; 95% confidence interval 35.6%–44.0%. Specificity = 75.9%; 95% confidence interval 75.0%–76.8%.
Positive likelihood ratio = 1.65; 95% confidence interval 1.47–1.85.
*Trauma center need was defined as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†Patients who would have been undertriaged using the first three steps of the Field Triage Decision Scheme.
‡Patients who would have been overtriaged using the first three steps of the Field Triage Decision Scheme.

Table 3. Sensitivity, Specificity, Positive Likelihood Ratio of Each Triage Criterion for Determining Trauma Center Need**

Mechanism of Injury	Triage Criteria	Number that met the Criteria	Sensitivity*	Specificity*	+LR*
Motor Vehicle Crash	Death of another occupant	25	3% (0.7%–5.9%)	99.5% (99.3%–99.7%)	6.8 (2.7–16.7)
	Extrication >20 min	105	11% (6.6%–15.8%)	98% (97.3%–98.3%)	5.1 (3.2–8.1)
	Intrusion >12″	202	19% (13.0%–25.4%)	95% (94.7%–96.1%)	4.2 (2.9–5.9)
	Ejection	38	3% (0.4%–5.1%)	99% (98.9% – 99.4%)	3.2 (1.3–8.2)
	Deformity >20″	457	27% (20.4%–34.2%)	89% (87.9%–89.9%)	2.5 (1.9–3.2)
	Speed >40 mph	969	47% (39.6%–54.9%)	76% (75.0%–77.7%)	2.0 (1.7–2.4)
	Rollover	523	13% (8.2%–18.0%)	87% (86.2%–88.3%)	1.0 (0.7–1.5)
Fall	Fall >20 ft	36	4% (1.4%–7.2%)	99% (98.9%–99.5%)	5.3 (2.4–11.4)
Pedestrian/bicyclist struck by a car	thrown or run over	251	65% (48.6%–80.8%)	46% (41.8%–51.2%)	1.2 (0.9–1.6)
	Struck at speed >5 mph	314	93% (84.4%–100%)	24% (20.0%–28.7%)	1.2 (1.1–1.4)
Motorcycle crash	Speed >20 mph	297	87% (77.2%–96.7%)	29% (23.9%–33.3%)	1.2 (1.1–1.4)
	Rider separated from motorcycle	350	83% (72.4%–93.0%)	19% (14.8%–22.7%)	1.0 (0.9–1.2)

*95% Confidence Interval shown in parenthesis.
**Trauma Center Need defined as death, admitted to ICU, or non-orthopedic surgery within 24 hours of arrival.

feet or greater (+LR = 12.3) had a higher +LR than those who fell from a height of 5 feet or greater (+LR = 2.1). For patients whose mechanism was pedestrian or bicyclist struck, a striking vehicle speed of 55 mph or greater (+LR = 30.6) had a higher +LR than a cutpoint of 10 mph or greater (+LR = 1.0). These tables might be useful in defining more sensitive or, alternatively, more specific triage criteria, depending on regional trauma system needs and resources.

Discussion

This study found that the mechanism-of-injury criteria used in the 1999 Field Triage Decision Scheme may not be the most efficient for identifying patients who need the resources of a trauma center. Specifically, 91% of those who met the criteria would have been overtriaged, whereas 4% of those who did not meet the criteria would have been undertriaged. While there are no universally accepted rates for under- and overtriage, the American College of Surgeons Resources for Optimal Care of the Injured Patient 2006 suggests that a 5% rate of undertriage and a 25% to 50% overtriage rate may be acceptable.[8] A previous study that applied the 2006 Field Triage Decision Scheme to the same data set found that using the physiologic, anatomic, and mechanism-of-injury criteria resulted in 28% undertriage and 22% overtriage.[12] A separate analysis of the National Trauma Databank found that the anatomic and physiologic steps alone resulted in 51% undertriage and 22% overtriage.[13] Therefore, including mechanism of injury in the decision scheme clearly improves undertriage.

Undertriage rates should be minimized since undertriage significantly increases mortality by depriving patients of trauma center care.[4] While overtriage has no direct effect on an individual patient's outcome, it can have significant negative effects on the emergency care system and trauma system, as well as indirect patient effects. Bringing extra patients to the trauma center may unnecessarily contribute to ED crowding and increase hospital turnaround times, while having ambulances bypass closer non–trauma centers can increase EMS transport times, making the EMS system less efficient for all patients. Ambulances' bypassing non–trauma hospitals can have negative economic consequences for those hospitals and threaten their survival, while transport methods used to reduce the

Table 4. Comparison of Positive Likelihood Ratio's by Outcome Definition

Mechanism of Injury	Criteria	Composite Outcome** +LR*	ISS>15 +LR*
Motor Vehicle Crash	Death of another occupant	6.8 (2.7–16.7)	5.5 (2.2–13.6)
	Extrication > 20 min	5.1 (3.2–8.1)	3.7 (2.2–6.0)
	Intrusion > 12″	4.2 (2.9–5.9)	3.2 (2.2–4.6)
	Ejection	3.2 (1.3–8.2)	7.1 (3.6–14.1)
	Deformity > 20″	2.5 (1.9–3.2)	2.2 (1.7–2.8)
	Speed > 40 mph	2.0 (1.7–2.4)	1.8 (1.5–2.1)
	Rollover	1.0 (0.7–1.5)	1.2 (0.9–1.7)
Fall	Fall > 20 ft	5.3 (2.4–11.4)	2.1 (0.8–5.4)
Pedestrian/bicyclist	Thrown or run over	1.2 (0.9–1.6)	1.3 (0.99–1.6)
	Struck at speed > 5 mph	1.2 (1.1–1.4)	1.2 (1.0–1.3)
Motorcycle crash	Speed > 20 mph	1.2 (1.1–1.4)	1.2 (1.1–1.4)
	Rider separated from motorcycle	1.0 (0.9–1.2)	1.1 (1.0–1.2)

*95% Confidence Interval shown in parenthesis.
**Composite Outcome defined trauma center need as death, admitted to ICU, or non-orthopedic surgery within 24 hours of arrival.

Table 5. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Fall Height to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥5 ft	32%	85%	82%	2.1
≥10 ft	21%	92%	88%	2.6
≥15 ft	11%	96%	92%	3.2
≥20 ft	7%	98%	93%	3.8
≥25 ft	3%	99%	94%	4.4
≥30 ft	3%	100%	95%	8.5
≥35 ft†	2%	100%	95%	12.3
≥ 40 ft	1%	100%	95%	7.4
≥ 45 ft	1%	100%	95%	4.6

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

Table 7. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Estimated Motorcycle Speed Prior to the Crash to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥5 mph	98%	3%	14%	1.0
≥20 mph	93%	22%	30%	1.2
≥30 mph	85%	39%	44%	1.4
≥40 mph	52%	72%	70%	1.9
≥50 mph	26%	87%	80%	2.0
≥60 mph	15%	94%	85%	2.4
≥80 mph†	11%	99%	89%	19.6

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

time to the trauma center (i.e., helicopter transport and ground transport with emergency lights and sirens) can increase the risk of additional injury[14–16] and cost.

The key difference between this and previous studies of the mechanism-of-injury criteria is that we identified and excluded those patients who met the anatomic or physiologic components of the Field Triage Decision Scheme. This likely explains the difference between our findings and those of a recent study by Isenberg and colleagues, which found that intrusion was 58% sensitive and 92% specific.[17] Further, because we interviewed the EMS provider to specifically obtain the various criteria of the Decision Scheme, we were not subject to as many of the documentation errors and missed data found in retrospective studies. We believe studies must evaluate the mechanism-of-injury criteria as they are meant to be used by EMS providers—specifically, after identifying those critically ill patients who meet the anatomic or physiologic criteria. This study did not evaluate whether changing the order of the current steps of the Decision Scheme would improve the accuracy of the Scheme. Future research should be conducted to evaluate the order of the steps to maximize accuracy.

We used the 1999 Field Triage Decision Scheme in this study instead of the 2006 Scheme because the 2006 Scheme excluded many of the mechanism-of-injury criteria. Specifically, deformity, extrication time, initial speed, and rollover were removed from the mechanism-of-injury criteria in the 2006 update. Our data support the removal of rollover, since it was shown to be a poor predictor regardless of the number of turns the vehicle sustained. Although vehicles that roll over have been shown to be associated with a large proportion of motor vehicle deaths,[18] our contrasting finding is likely to be because those studies did not exclude patients who met the physiologic and/or anatomic criteria. That is, it is likely that rollover is not a significant predictor because most injured rollover victims are identified by the physiologic or anatomic criteria, and those who are not identified by the first two criteria apparently do not need the resources of a trauma center. Our findings also support the removal of initial speed greater than 40 mph from the Field Triage Decision Scheme. This is probably because estimated initial speed does not correlate with change in velocity at the time of the crash.[19] However, we did find that when the cutpoint was increased

Table 6. Results of the Receiver-Operating Characteristic Curve Analysis, for Pedestrians or Bicyclists Struck, of the Ability of Striking Vehicle Speed to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥10 mph	100%	4%	12%	1.0
≥20 mph	86%	40%	44%	1.4
≥30 mph	75%	66%	67%	2.2
≥40 mph	39%	89%	85%	3.6
≥50 mph	11%	99%	91%	10.2
≥55 mph†	11%	100%	92%	30.6

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

Table 8. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Patient's Extrication Time Following a Motor Vehicle Crash to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥5 min	44%	82%	80%	2.4
≥10 min	38%	88%	85%	3.1
≥20 min	17%	96%	93%	4.4
≥30 min	9%	98%	94%	5.3
≥40 min	4%	99%	95%	6.9
≥80 min†	1%	100%	96%	43.2
≥90 min	1%	100%	96%	21.6

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

Table 9. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Estimated Maximum Intrusion in the Patient's Vehicle to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥2 inches	56%	79%	78%	2.7
≥12 inches	33%	90%	88%	3.4
≥24 inches	9%	98%	95%	4.7
≥36 inches	3%	100%	96%	7.0
≥66 inches†	1%	100%	96%	12.0

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

above 50 mph, the +LR increased to make it a moderate predictor. It is possible that increasing the cutpoint may make this variable a better predictor. Perhaps surprisingly, our data show that extrication time and deformity were good to moderate predictors of trauma center need. The importance of these variables should be reevaluated and considered for inclusion in future revisions of the Field Triage Decision Scheme.

It is also important to note that while this study evaluated patients seen at the trauma center, it did not limit its analysis to those patients identified by EMS as needing the trauma center. Previous studies only used a population of patients identified by EMS as severe trauma patients.[6] Those studies would have had a limited ability to evaluate undertriage (inappropriate transport to a non–trauma center), since patients who were not recognized as having sustained severe trauma were not included in the study. While our study was not population-based, we did have the full range of injury severity and thus were able to consider both under- and overtriage while at the same time ensuring that hospital-based care and decisions were as close to standardized as possible, since all patients were treated in a state-designated level 1 trauma center.

Table 10. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Estimated Maximum Deformity of the Patient's Vehicle to Identify Trauma Center Need*

Cutp oint	Sensitivity	Specificity	Correctly Classified	+LR
≥10 inches	76%	54%	55%	1.7
≥20 inches	32%	87%	85%	2.4
≥30 inches	13%	95%	92%	2.7
≥40 inches	4%	98%	94%	2.3
≥50 inches	2%	99%	95%	3.3
≥66 inches†	2%	100%	96%	5.3
≥72 inches	1%	100%	96%	4.2

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

Table 11. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Estimated Speed of the Patient's Vehicle Prior to the Crash to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥5 mph	96%	14%	17%	1.1
≥20 mph	85%	29%	31%	1.2
≥40 mph	59%	66%	66%	1.7
≥50 mph	36%	83%	81%	2.1
≥60 mph	15%	93%	90%	2.1
≥70 mph	6%	98%	94%	2.6
≥80 mph	1%	100%	96%	2.3
≥90 mph	1%	100%	96%	4.6
≥100 mph†	1%	100%	96%	5.8

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

We used death, ICU admission, or nonorthopedic surgery as our primary measure for trauma center need. We also conducted a secondary analysis using ISS as a secondary outcome measure. This change in outcome affected the mechanism-of-injury criteria that were identified as good or moderate predictors (Table 4), but did not affect the poor predictors. We made the composite measure our primary outcome because we were able to collect the patients' actual resource use at the trauma center and felt that ISS has been used as a proxy measure when that level of information was not available. However, for research in field triage decision making to progress, an accepted "gold standard" that establishes need for a trauma center is necessary. It is important to note that the National Study on Costs and Outcomes of Trauma (NSCOT) study, which found improved survival among patients treated at a level 1 trauma center, used an ISS greater than 15 to identify severe trauma patients.[4]

Analysis of the ROC curve data will assist those considering changes to the Field Triage Decision Scheme by allowing them to explore the effect of using different cutpoints. However, it is important to emphasize that the measurements analyzed were

Table 12. Results of the Receiver-Operating Characteristic Curve Analysis of the Ability of Estimated Number of Quarter Turns the Patient's Vehicle Turned to Identify Trauma Center Need*

Cutpoint	Sensitivity	Specificity	Correctly Classified	+LR
≥1	100%	0%	4%	1.0
≥2	82%	21%	23%	1.0
≥4	59%	56%	56%	1.3
≥8†	29%	83%	81%	1.7
≥16	6%	95%	92%	1.1

*Composite outcome defined trauma center need as death, admission to an intensive care unit, or nonorthopedic surgery within 24 hours after arrival.
†The cutpoint with the highest +LR in the analysis.
+LR = positive likelihood ratio.

estimates made by EMS field providers while they were treating the patient and without any additional training in how to make those estimates. As such, we do not know if these estimates were accurate. For example, EMS providers were asked "How long do you estimate it took to extricate the patient from the vehicle?" Therefore, we evaluated the ability of real-world EMS estimations to identify trauma center need, but cannot determine whether actual measures are predictive of trauma center need. Future research might consider whether measurement training would improve estimation accuracy and, if so, whether it would improve triage accuracy. All of the communities that contributed data to this study used a locally modified version of the Field Triage Decision Scheme for their trauma protocols and expected their providers to determine the patient's mechanism of injury.

LIMITATIONS

This study was limited by its use of a convenience sample. We were able to gather basic data on the eligible patients who were not included in the study, and we found the two populations to be similar (Table 1). The benefit of this sampling scheme was that we were able to conduct direct provider interviews and thus have gathered complete information on the Field Triage Decision Scheme criteria. This would not have been possible with a medical record review, and it was not possible to obtain the resources that would have been needed to interview EMS providers for all patients.

This was not a population-based study. Patients with minor injuries could have been transported to our participating hospitals or to other hospitals within the study communities. This might have created some bias in our study. Further, while we were able to assess overtriage by examining the full range of patients who were brought to the study hospitals, our patient populations may not be representative of injured patients who were transported to other facilities. However, the three hospitals that participated in this study are large and treat a large percentage of the injured patients in their communities, and it seems unlikely that there was a systematic difference between the field presentations of patients transported to the study facilities compared with those transported to other facilities in the communities.

The advantage of only studying patients seen at these facilities was that they all had access to the same resources and level of provider training. This means that our outcome was likely to be consistent across all sites, but since long-term follow up after patient discharge was not conducted to confirm the patient's final status, we would not have identified patients who were misclassified because of a missed diagnosis.

CONCLUSIONS

The mechanism-of-injury criteria used in the 1999 version of the Field Triage Decision Scheme resulted in significant overtriage. Death of another occupant, fall distance, and extrication time were found to be good predictors of trauma center need when a patient does not meet the anatomic or physiologic criteria. Intrusion, ejection, and vehicle deformity were found to be moderate predictors. The remaining mechanism-of-injury criteria were found to be poor predictors: motor vehicle crash speed, rollover, pedestrian or bicyclist thrown or run over, pedestrian or bicyclist striking vehicle speed, motorcycle crash speed, and separation of a rider from a motorcycle.

References

1. Office of Statistics and Programming, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. 10 Leading causes of death, United States. 2002. Available at: http://webappa.cdc.gov/sasweb/ncipc/leadcaus10.html. Accessed January 26, 2006.
2. Office of Statistics and Programming, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. Overall all injury causes: nonfatal injuries and rates per 100,000. 2002. Available at: http://webappa.cdc.gov/sasweb/ncipc/nfirates2001.html. Accessed January 26, 2006.
3. National Center for Health Statistics. National Hospital Ambulatory Medical Care Survey (NHAMCS) data files. 2006. Available at: ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHAMCS/. Accessed January 12, 2006.
4. Mackenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med. 2006;354:366–74.
5. Mackersie RC. History of trauma field triage development and the American College of Surgeons criteria. Prehosp Emerg Care. 2006;10:287–94.
6. Lerner EB. Studies evaluating current field triage: 1966–2005. Prehosp Emerg Care. 2006;10:303–6.
7. Sasser SM, Hunt RC, Sullivent EE, et al. Guidelines for field triage of injured patients. Recommendations of the National Expert Panel on Field Triage. MMWR Recomm Rep. 2009;58(RR-1):1–35.
8. Committee on Trauma, American College of Surgeons. Resources for Optimal Care of the Injured Patient 2006. Chicago, IL: American College of Surgeons, 2006.
9. MacKenzie EJ, Steinwachs DM, Shankar B. Classifying trauma severity based on hospital discharge diagnoses. Validation of an ICD-9CM to AIS-85 conversion table. Med Care. 1989;27:412–22.
10. Rutledge R. Injury severity and probability of survival assessment in trauma patients using a predictive hierarchical network model derived from ICD-9 codes. J Trauma. 1995;38:590–7; discussion 597–601.
11. McGee S. Simplifying likelihood ratios. J Gen Intern Med. 2002;17:646–9.
12. Lerner EB, Shah MN, Swor RA, et al. Comparison of the 1999 and 2006 trauma triage guidelines: where do patients go? Prehosp Emerg Care. 2011;15:12–7.
13. Brown JB, Stassen NA, Bankey PE, Sangosanya AT, Cheng JD, Gestring ML. Mechanism of injury and special consideration criteria still matter: an evaluation of the National Trauma Triage Protocol. J Trauma. 2011;70:38–44; discussion 44–35.

14. Kahn CA, Pirrallo RG, Kuhn EM. Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective analysis. Prehosp Emerg Care. 2001;5:261–9.
15. Rhee KJ, Holmes EM 3rd, Moecke HP, Thomas FO. A comparison of emergency medical helicopter accident rates in the United States and the Federal Republic of Germany. Aviat Space Environ Med. 1990;61:750–2.
16. Saunders CE, Heye CJ. Ambulance collisions in an urban environment. Prehosp Disaster Med. 1994;9:118–24.
17. Isenberg D, Cone DC, Vaca FE. Motor vehicle intrusion alone does not predict trauma center admission or use of trauma center resources. Prehosp Emerg Care. 2011;15:203–7.
18. Champion HR, Lombardo LV, Shair EK. The importance of vehicle rollover as a field triage criterion. J Trauma. 2009;67: 350–7.
19. Lerner E, Cushman J, Blatt A, et al. EMS provider assessment of vehicle damage compared with assessment by a professional crash reconstructionist. Prehosp Emerg Care. 2011;15(in press).