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A Multi-Site Assessment of the ACSCOT Field Triage Decision Scheme for Identifying Seriously Injured Children and Adults

Craig D Newgard, MD, MPH[1], **Dana Zive, MPH**[1], **James F Holmes, MD, MPH**[2], **Eileen M Bulger, MD, FACS**[3], **Kristan Staudenmayer, MD, FACS**[4], **Michael Liao, MD**[5], **Thomas Rea, MD, MPH**[6], **Renee Y Hsia, MD, MSc**[7], **N Ewen Wang, MD**[8], **Ross Fleischman, MD, MCR**[1], **Jonathan Jui, MD, MPH**[1], **N Clay Mann, PhD, MS**[9], **Jason S Haukoos, MD, MSc**[5], **Karl A Sporer, MD**[7], **K Dean Gubler, DO, MPH, FACS**[10], **Jerris R Hedges, MD, MS, MMM**[11], and **the WESTRN investigators**

[1]Center for Policy and Research in Emergency Medicine, Department of Emergency Medicine, Oregon Health & Science University, Portland, OR

[2]Department of Emergency Medicine, University of California at Davis, Sacramento, CA

[3]Department of Surgery, University of Washington, Seattle, WA

[4]Department of Surgery, Stanford University, Palo Alto, CA

[5]Department of Emergency Medicine, Denver Health Medical Center, Denver, CO, Department of Epidemiology, Colorado School of Public Health, University of Colorado School of Medicine, Aurora, CO

[6]Department of Medicine, University of Washington, Seattle, WA

[7]Department of Emergency Medicine, University of California San Francisco, San Francisco General Hospital, San Francisco, CA

[8]Division of Emergency Medicine, Department of Surgery, Stanford University, Palo Alto, CA

[9]Intermountain Injury Control Research Center, University of Utah School of Medicine, Salt Lake City, UT

[10]Legacy Emanuel Trauma Program, Portland, OR

[11]Department of Medicine, John A. Burns School of Medicine, University of Hawaii-Manoa, Honolulu, HI

Abstract

Background—ACSCOT has developed and updated field trauma triage protocols for decades, yet the ability to identify major trauma patients remains unclear. We estimate the diagnostic value

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Correspondence address: Craig D. Newgard, MD, MPH, Department of Emergency Medicine, Center for Policy and Research in Emergency Medicine, Oregon Health & Science University, 3181 SW Sam Jackson Park Road, mailcode CR-114, Portland, Oregon 97239-3098, Phone (503) 494-1668, Fax (503) 494-4640, newgardc@ohsu.edu.

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of the Field Triage Decision Scheme for identifying major trauma patients (Injury Severity Score [ISS] ≥ 16) in a large and diverse multi-site cohort.

Study Design—This was a retrospective cohort study of injured children and adults transported by 94 EMS agencies to 122 hospitals in 7 regions of the Western U.S. from 2006 through 2008. Patients who met any of the field trauma triage criteria (per EMS personnel) were considered triage positive. Hospital outcome measures were probabilistically linked to EMS records through trauma registries, state discharge data and emergency department data. The primary outcome defining a "major trauma patient" was ISS ≥ 16.

Results—122,345 injured patients were evaluated and transported by EMS over the 3-year period, of who 34.5% met at least one triage criterion and 5.8% had ISS ≥ 16. The overall sensitivity and specificity of the criteria for identifying major trauma patients were 85.8% (95% CI 85.0 – 86.6%) and 68.7% (95% CI 68.4 – 68.9%). Triage sensitivity and specificity differed by age: 84.1% and 66.4% (0 – 17 years); 89.5% and 64.3% (18 – 54 years); and 79.9% and 75.4% (≥ 55 years). Evaluating the diagnostic value of triage by hospital destination (transport to Level I/II trauma centers) did not substantially improve these findings.

Conclusions—The sensitivity of the Field Triage Decision Scheme for identifying major trauma patients is lower and specificity higher than previously described, particularly among elders.

INTRODUCTION

The process of triaging injured patients in the out-of-hospital setting is a critically important aspect of concentrating those with serious injuries in high-resource hospitals (i.e., major trauma centers), while conserving limited trauma resources. Such regionalized trauma care has been shown to improve outcomes among seriously injured adults[1–8] and children.[9–13] Several additional studies also suggest that patients triaged directly to a trauma center may have improved outcomes when compared to those initially transported to a non-trauma hospital.[3,14,15] Because the majority of seriously injured patients access acute care through 9-1-1 emergency medical services (EMS), an accurate and effective out-of-hospital mechanism for appropriately matching patients to hospital resources is a vital aspect of trauma systems.

The Field Triage Decision Scheme was developed by the American College of Surgeons Committee on Trauma (ACSCOT) more than 20 years ago[16–19] and has been periodically revised and updated. In 2006, the Centers for Disease Control and ACSCOT partnered to bring a broad group of stakeholders together for the most recent revision of the decision scheme.[20] These guidelines have been widely promoted and integrated into most EMS and trauma systems throughout the U.S. The guidelines represent a combination of science and expert opinion, built largely from research evaluating individual criteria or portions of the triage algorithm. Several studies show the decision scheme to be highly sensitivity (≥ 95%) for identifying seriously injured patients,[21,22] though more recent research suggests the sensitivity may be much lower,[23–25] particularly among elder patients.[23,25,26] Due to inherent limitations in previous triage research (e.g., study design, patient sampling restrictions, single hospital, single EMS agency, single mechanism of injury, trauma registry patients, variable outcome measures) and the resulting biases, the true diagnostic value of the Field Triage Decision Scheme remains uncertain.

In this project, we sought to estimate the diagnostic value (e.g., sensitivity, specificity) of the Field Triage Decision Scheme for identifying major trauma patients (Injury Severity Score [ISS] ≥16) among a large and diverse population of injured patients evaluated by EMS providers across multiple sites. We conducted secondary analyses to assess the decision scheme by age group and hospital destination.

METHODS

Study Design

This investigation was a multi-site retrospective cohort study. Sixteen Institutional Review Boards at 7 sites approved this protocol and waived the requirement for informed consent.

Study Setting

The study included injured children and adults evaluated and transported by 94 EMS agencies to 122 hospitals (including 15 Level I, 8 Level II, 3 Level III, 4 Level IV, 1 Level V and 91 community/private/federal hospitals) in 7 sites across the Western U.S over a 3-year period (January 1, 2006 through December 31, 2008). The 7 sites included: Portland, OR/Vancouver, WA (4 counties); King County, WA; Sacramento, CA (2 counties); San Francisco, CA; Santa Clara, CA (2 counties); Salt Lake City, UT (4 counties), and Denver County, CO. These sites are part of the Western Emergency Services Translational Research Network (WESTRN), a consortium of geographic regions, EMS agencies and hospitals linked through Clinical and Translational Science Award centers. Each site represents a pre-defined geographic "footprint," typically consisting of a central metropolitan area and surrounding region, defined by EMS agency service areas. The majority of sites are urban and suburban, though some outlying rural areas are also included. All sites have established trauma systems with designated Level I/II trauma centers and standardized trauma triage protocols to guide selection of transport destinations and trauma care by EMS personnel (Table 1).[27]

For injured patients evaluated by EMS providers at these sites, there is an initial field triage decision of whether an injured patient meets field trauma triage criteria and warrants transport to a major (i.e., Level I or II) trauma center. The triage processes in all sites use standardized triage protocols[27] based on the ACSCOT Field Triage Decision Scheme (Figure 1),[19] though there is variability in local figureimplementation and retention of criteria from older versions of the scheme. The presence of one or more trauma triage criteria typically triggers transport to a Level I or II trauma center, but may result in transport to a lower level trauma center (e.g., Level III or IV hospitals) depending on proximity and established protocols in each system.

Patient Population

The study sample included all patients (children and adults) for whom the 9-1-1 EMS system was activated within the 7 predefined geographic regions, the EMS provider(s) recorded a primary impression of "injury" or "trauma," the patient was transported to an acute care hospital (trauma centers and non-trauma centers) and a matched hospital record was available. Specifying the sample in this manner allowed for an out-of-hospital injury cohort of patients with both minor and serious injuries, as perceived by EMS providers (i.e., the denominator to whom the Field Triage Decision Scheme is applied). This sampling strategy is distinct from previous triage research and was designed to minimize bias in generating estimates for triage performance. Interhospital transfers without an initial presentation involving EMS were excluded from the sample, though injured patients evaluated and transported by EMS with subsequent transfer to another hospital were included. EMS runs listed as "cancelled," "no patient found," "stand by" (i.e., calls without patient contact), and patients that were not transported (e.g., deaths in the field, refusals of transport) were excluded from the sample.

Variables

The primary "exposure" variable of interest was whether the patient met any of the criteria listed in the ACSCOT Field Triage Decision Scheme (Figure 1),[19] as determined by EMS providers. Because relying exclusively on recorded trauma triage criteria in EMS records may underestimate the sensitivity of the triage guidelines (due to missing data for triage criteria), we took several steps to ensure comprehensive identification of all patients determined by EMS to meet field triage criteria. The presence of trauma triage criteria was determined as follows: trauma triage criteria specified in the EMS chart; EMS provider documented “trauma system entry” (or similar charting, depending on local terminology); EMS-recorded trauma identification number (used at some sites as a mechanism for tracking injured patients entered into the trauma system); a matched record from the local trauma registry specifying “scene” origin (i.e., EMS-identified trauma patient); or other surrogate EMS charting markers used in local EMS electronic health records to denote triage-positive patients. All other patients were considered triage negative. The presence or absence of triage criteria was considered independent of transport destination (type of hospital to which the patient was initially transported). We recorded all individual triage criteria cited by EMS personnel (up to five per patient), including any of the 24 criteria listed in current Field Triage Decision Scheme[19] and any additional criteria cited from previous versions (e.g., rollover motor vehicle crash).[16]

In addition, we tracked patient demographics (age, gender), out-of-hospital physiology (systolic blood pressure [SBP], Glasgow Coma Scale [GCS] score, respiratory rate), EMS procedures (intubation attempt, intravenous line placement), transport mode (air versus ground), hospital destination (including hospital type), interhospital transfers, injury severity (Injury Severity Score [ISS], Abbreviated Injury Scale [AIS] score), major non-orthopedic surgical procedures (brain, spine, neck, thorax, abdomen, vascular or interventional radiology), orthopedic surgery and in-hospital mortality. Acute care hospitals were categorized as tertiary trauma centers (Level I or II trauma facilities) or non-trauma centers based on their American College of Surgeons accreditation status and state-level designations.

Outcomes

The primary outcome for this study was Injury Severity Score (ISS) ≥ 16, which we use to define a “major trauma patient.” While many definitions of serious injury have been used in previous triage studies, an ISS ≥ 16 is the threshold used by ACSCOT to define under- and over-triage,[19] allows comparison to results from multiple previous triage studies, and defines the subset of patients most likely to benefit from trauma center care.[1,2,4,7,8,10]

Data Sources, Data capture & Processing

EMS and hospital outcome data were collected and transmitted electronically to the WESTRN Data Coordinating Center (Portland, OR). Probabilistic linkage (LinkSolv v8.2, Strategic Matching, Inc., Morrisonville, NY) [28–30] was used to match EMS records to hospital outcomes from local trauma registries, state discharge databases and state emergency department (ED) data. Three sites did not have statewide ED data available. The same probabilistic linkage methodology has been used to link EMS data to hospital records in previous studies[30] and has been validated for matching ambulance records to trauma registry data.[31] In regions where multiple EMS agencies care for the same patient (and therefore generate multiple EMS records for a single patient), we also used probabilistic linkage to combine EMS records. All hospital data sources had standardized processes to ensure consistent and reliable data collection. Because AIS and ISS are not collected in state discharge or ED databases, we used ICD9 codes and a mapping function (Stata v. 11, StataCorp, College Station, TX) to generate consistent AIS and ISS measures for patients in all sites. ICD9 procedure codes, CPT codes, and abstracted data on surgical procedures (e.g., from trauma registries) were compiled to track surgical interventions.

Data Analysis

We used descriptive statistics to characterize the sample, outcomes and diagnostic metrics for the triage guidelines. We designed the primary analysis to validate the ability of the Field Triage Decision Scheme to identify patients with ISS ≥ 16, regardless of the type of hospital to which they were initially transported. Sensitivity was calculated as the proportion of seriously injured patients identified by field triage criteria and specificity as the proportion of non-seriously injured patients that did not meet triage criteria. Under-triage (the proportion of major trauma patients missed by the triage criteria) was calculated from 1 - sensitivity and over-triage (the proportion of minimally injured patients meeting triage criteria) as 1 – specificity. Additional diagnostic metrics included positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (+LR), negative likelihood ratio (−LR) and area under the curve (AUC). Stratified analyses were conducted by age group for children (0 – 17 years), adults (18 – 54 years), and elders (≥ 55 years) based on previous research demonstrating an age-dependent benefit of trauma center care.[1] Because triage can be defined using different perspectives, we recalculated the diagnostic metrics based on transport destination (i.e., to a Level I/II hospital versus non-trauma or lower level trauma hospitals) as the exposure variable, regardless of the presence or absence of triage criteria. All analyses were conducted using SAS (v 9.2, SAS Institute, Cary, NC).

Missing values were handled using multiple imputation to minimize bias and preserve study power.[32] We have previously demonstrated the validity of multiple imputation for imputing missing out-of-hospital values and trauma data under a variety of conditions.[33,34] We used flexible chains regression models for multiple imputation (IVEware, Survey Methodology Program, Survey Research Center, Institute for Social Research, University of Michigan, MI)[35] with generation of 10 multiply imputed datasets, each analyzed independently and combined using Rubin’s rules to appropriately account for variance within- and between-datasets.[32] Missing data were imputed for: age (< 1%), gender (5%), mechanism of injury (28%), field intubation (1%), field IV (6%), SBP (9%), GCS (14%), heart rate (6%), respiratory rate (8%), triage step (10%), hospital destination (< 1%), ISS (< 1%) and maximum AIS (< 1%).

RESULTS

There were 122,345 injured patients evaluated by 94 EMS agencies and transported to 122 hospitals over the 3-year period, of whom 42,207 (34.5%) met at least one trauma triage criterion. The proportion of patients at each site meeting at least one triage criterion ranged from 18.2 – 50.7%. Of the study sample, 7,100 (5.8%) patients had ISS ≥16. Characteristics of the study sample, separated by the presence or absence of field trauma triage criteria, are demonstrated in Table 2.

Field triage diagnostic measures (for individual sites and overall) are demonstrated in Table 3. The overall sensitivity and specificity of the Field Triage Decision Scheme for identifying major trauma patients were 85.8% (95% CI 85.0 – 86.6%) and 68.7% (95% CI 68.4 – 68.9%), respectively. Assessment of the triage diagnostic value by initial transport to a Level I or II trauma center demonstrated a sensitivity of 73.4% (95% CI 72.4 – 74.4%) and a specificity of 63.9% (95% CI 63.6 – 64.2%) (Table 4). For final transport to a Level I or II trauma center (combined primary and secondary triage processes), the sensitivity for identifying major trauma patients was 82.6% (95% CI 81.7 – 83.5%) with specificity 53.2% (95% CI 52.9 – 53.5%) (Table 5). There was inter-site variability in all diagnostic metrics and some intra-site variability based on how triage accuracy was defined (i.e., by triage criteria versus transport destination). Under-triaged patients tended to be older, suffering falls or motor vehicle crashes, and frequently required operative intervention (both non-orthopedic and orthopedic) with elevated mortality (Table 5) compared to the full sample and triage-positive patients (Table 2). Even after combining primary and secondary triage processes, a substantive portion of under-triaged patients were not cared for in major trauma centers (Table 5, Table 6). Triage sensitivity was highest among adults and lowest among elders, with specificity highest among elders (Table 7).

Diagnostic measures for each step of the Field Triage Decision Scheme (cumulative and independent) and the accompanying receiver operating characteristic (ROC) curve are depicted in Figure 2. The physiologic and anatomic criteria (steps 1 and 2) were highly specific, but insensitive for identifying major trauma patients, while mechanism and special considerations criteria (steps 3 and 4) increased sensitivity of the guidelines with modest reductions in specificity.

DISCUSSION

The findings in this multisite cohort study of injured patients triaged by EMS suggest that the sensitivity of the Field Triage Decision Scheme is lower than previously described, supporting several studies showing that a substantive percentage of patients with serious injuries are cared for in non-trauma hospitals.[23–25] Further, only a minority of major trauma patients were identified by triage steps 1 and 2 (physiologic and anatomic criteria), with steps 3 and 4 (mechanism of injury and special considerations) serving to identify a larger portion of such patients with a modest decrement in specificity. Calculating diagnostic test measures based on triage criteria versus hospital destination also impacted values for triage accuracy at most sites. While trauma systems remain the model for regionalized healthcare, our results suggest that the ability to fully concentrate all major trauma patients in Level I or II trauma centers is not yet optimized. However, these results also raise questions regarding realistic goals for primary (field) trauma triage, the practical ability to fully concentrate seriously injured patients in high-resource hospitals through EMS and the potential role for secondary (hospital-based) triage.

According to ACSCOT, the target for under-triage in a trauma system is less than 5%.[19] Under-triage can be defined either based on the ability of field triage criteria to correctly identify seriously injured patients (regardless of transport destination) or based on transport to a major trauma center (regardless of triage criteria). We calculated estimates using both of these perspectives, with generally similar findings. However, changing the definition did impact the apparent accuracy of trauma triage within individual sites. These findings are in contrast to previous trauma triage research suggesting under-triage rates of $\leq 5\%$ for the ACSCOT criteria identifying patients with ISS ≥ 16,[21,22] though variability in the triage criteria used, outcome definitions, patient sampling and study designs hamper direct comparisons with many previous studies. Closer examination of under-triaged patients reveal this group to be older, often suffering falls (and to a lesser extent motor vehicle crashes) with little physiologic derangement and relatively high rates of surgical intervention. The regions represented in this study have established trauma systems with demonstrated redistribution of seriously injured patients and improved survival.[2,4,10] Therefore, these estimates approximate primary triage accuracy among well-developed trauma systems. It is possible that less established trauma and EMS systems may have different diagnostic accuracy for field triage.

While the accuracy of triage criteria among different age groups continues to be debated, our findings support results from other studies suggesting that under-triage is substantially worse among elders[23,25,26] and to a lesser extent among children.[24] Whether triage criteria are less sensitive or are applied more selectively to different age groups remains unclear. There are unique issues among older injured patients, including higher risks associated with operative intervention, increased comorbidity burden, greater potential for medical complications, different physiologic responses to injury, unclear benefit of trauma centers,[1] and end-of-life considerations, all of which make this population unique. Whether separate elder-specific triage criteria should be used and the benefit of trauma care among seriously injured elders[1] remain ongoing questions. As children were also under-triaged at a higher rate than adults in our study, these findings suggest that field trauma triage processes are most effective at identifying adult major trauma patients (18 to 54 years), but lose sensitivity at the ends of the age spectrum.

The rate of over-triage (defined as the proportion of patients with minor injuries meeting triage criteria or those with minor injuries transported to major trauma centers) was lower in this study compared to previous triage research. However, with the large number of injured patients cared for by EMS, even small rates of over-triage can produce large volumes of patients transported to major trauma centers, so consideration of the absolute numbers is also important. Our findings suggest that the field triage criteria are fairly selective in identifying major trauma patients and fall under the $< 50\%$ over-triage target set by ACSCOT.[19] Comparing over-triage estimates between triage criteria (lower) and transport destination (higher) suggests that while the triage criteria appear to be used selectively, injured patients not meeting triage criteria are still frequently transported to major trauma centers. Notable exceptions are sites B and F, both of which had lower sensitivity and higher specificity for accuracy assessment by transport destination. Such findings suggest that some sites successfully identify most major trauma patients using field triage criteria, but are more selective in transporting these patients to major trauma centers (or integrate lower level trauma centers for the initial evaluation). We recently explored patient transport patterns and found that among patients not meeting field triage criteria, patient/family preference and to a lesser extent hospital proximity have major influence on transport destination, resulting in a substantive number of triage-negative patients being transported to major trauma centers.[36] It is also notable that that mechanism of injury and special considerations criteria increased over-triage, but only modestly, while playing an important role in identifying many major trauma patients missed by the physiologic and anatomic criteria.

One likely reason for the differences between our results and those of previous triage research is the sampling frame. We used a comprehensive multi-site sampling strategy to capture all injured patients evaluated by EMS and therefore approximate the true denominator to who field triage guidelines are applied, rather than relying on more restrictive populations. The current sampling design yielded patients with both minor and serious injuries, transported to trauma and non-trauma hospitals and was therefore reflective of the full injured population evaluated and transported by EMS. Our study included both admitted patients and those discharged from the emergency department; the latter group has been excluded from most previous triage studies, but is still subject to field triage processes. We believe these methodological differences provided less biased estimates for triage accuracy and therefore closer approximation of the true performance of field triage, with greater generalizability of the study results. The improvement in specificity may be explained in part by including the broader denominator of patients to whom the triage guidelines are applied (e.g., patients transported to a hospital and subsequently discharged from the emergency department).

Previous triage research has used a multitude of definitions for “serious injury” including ISS ≥ 16,[22,37–41] ISS ≥ 20,[42] ISS ≥ 10 plus LOS,[43] ISS plus resource use,[22,44,45] and strictly resource-based definitions.[46–50] This variability in outcomes has reduced comparability between studies. One mechanism to resolve such discrepancies is to link the target group in trauma triage research to the patient population most likely to benefit from trauma center care (i.e., patients with ISS ≥ 16,[2,4,7,8,10] AIS ≥ 4[1]). In concert with this perspective, we used ISS ≥ 16 to evaluate the diagnostic value of field triage in this study. Using an ISS $\geq$

16 to define the target population for transport to major trauma centers is also consistent with maximizing the cost-effectiveness of trauma center care.[51]

Taken together, our findings suggest that there is opportunity for improvement in the field-identification of major trauma patients and matching patient need with hospital capability. However, improving the concentration of seriously injured patients in major trauma centers is likely more complicated than simply revising the triage criteria. There are logistical, financial and philosophical questions built into the optimization of matching need to capacity. A primary logistical question is defining which patients require immediate transport to a major trauma center and the timeliness of trauma center care.[52–54] If a window of time exists during which "early" trauma center care still provides an outcome benefit (e.g., < 24 hours), the effective concentration of seriously injured patients in trauma centers may be most efficiently achieved through the combined efforts of primary (field) and secondary (hospital) triage. Our results suggest that the combined primary and secondary triage processes currently fail to fully concentrate major trauma patients in Level I/II trauma centers. These findings point towards a continued opportunity for developing more inclusive trauma systems, improved primary triage processes, formal transfer agreements between hospitals, timely interhospital transport processes, and more objective secondary triage instruments to further optimize the concentration of seriously injured patients in major trauma centers. The cost implications, cost effectiveness and future funding of trauma systems must also be considered. With the cost of care being notably higher in trauma centers[51,55] and the cost effectiveness of trauma centers driven by younger patients with more severe injuries (i.e., AIS ≥ 4),[51] expanding the field triage criteria to capture ≥ 95% of seriously injured patients runs the risk of substantially increasing the costs of trauma systems (i.e., through over-triage) without improving cost effectiveness. Considering the financial efficiency and costs of a trauma care are necessary aspects of preserving the viability of trauma systems, which continue to face constrained budgets,[27] challenges of maintaining on-call panels,[56,57] and a declining workforce of trauma surgeons.[58]

There are limitations in this study that must be considered when interpreting the results. A primary limitation is the retrospective study design. While we applied rigorous strategies for patient sampling, careful attention to identifying patients meeting field triage criteria and matching outcomes to patients regardless of hospital destination, the retrospective nature of the study still limits these findings. In addition, we did not directly measure the frequency of training for EMS personnel on field triage, EMS quality assurance processes and other local EMS factors that likely affect the application and use of field triage criteria. However, the broad inclusion criteria, sampling strategy, and variety of different EMS agencies, hospitals and regions included in this study are a substantial improvement in assessing the diagnostic value of field triage. Prospective efforts to validate the Field Triage Decision Scheme are currently underway.

We attempted to track outcomes for all injured patients transported by EMS, including those subsequently transferred to another hospital, though tracking interhospital transfers was challenging. This process involved delineating which hospital a patient was initially transport to, the location of final hospitalization (if a different hospital) and making certain assumptions about what occurred in between these events (i.e., interhospital transfer). While we were able to provide some assessment of the role of secondary triage in concentrating major trauma patients in Level I and II centers, there may have been additional interhospital transfers that we were unable to identify. Also, the data sources did not allow us to assess the timing of transfer. Furthermore, we did not assess the role of Level III and IV trauma centers and the potential for a tiered or staged process for field triage.

Certain analytic methods (probabilistic linkage and multiple imputation) were central to this study. Both of these methodologies have been well-studied and validated, though there remains the possibility that our findings may be different if outcomes were available for every injured patient evaluated by EMS (i.e., not restricted to patients with a matched hospital record). Because we took a more conservative strategy of restricting the primary analysis to EMS records that matched to a hospital record (including sites that did and did not have ED data available), it is possible that this strategy introduced some selection bias. However, inter-site comparisons did not suggest substantive differences by these factors.

CONCLUSIONS

In this multisite cohort investigation, the sensitivity of the Field Triage Decision Scheme for identifying major trauma patients was notably lower than previously described (particularly among injured elders), while the specificity was higher. Assessing the diagnostic value of field triage by initial or final transport to Level I and II trauma centers did not qualitatively change these findings. Efforts to further optimize trauma systems may incorporate refinement of trauma triage criteria *and* strengthening other aspects of trauma systems (e.g., secondary triage). The challenge going forward will be to develop, evaluate and integrate effective triage strategies for allocating trauma care in an increasingly resource- and cost-constrained healthcare environment without compromising the quality of trauma care or patient outcomes.

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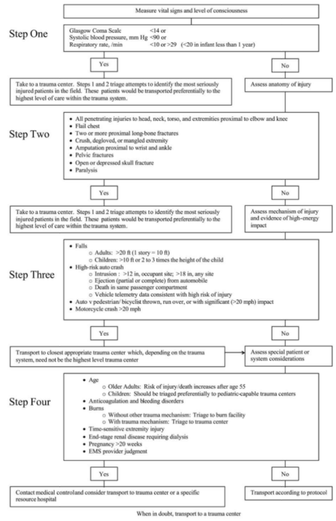
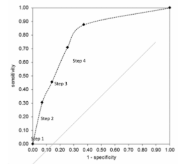


Figure 1.
The 2006 ACSCOT Field Triage Decision Scheme. (Reprinted with permission from: Resources for the Optimal Care of the Injured Patient. Chicago, IL, American College of Surgeons, 2006.)



Step*	n†	% of triage + pts	n ISS ≥ 16†	Cumulative Steps: Sens %	Spec %	Under triage %	Over triage %	PPV %	NPV %	+LR	-LR	Independent Steps: Sens %	Spec %	Under triage %	Over triage %	PPV %	NPV %	+LR	-LR
1	7,506	20.7	1,734	30.3	93.1	69.7	6.9	23.1	95.1	4.40	0.75	30.3	93.1	69.7	6.9	23.1	95.1	4.40	0.75
2	9,309	25.7	1,374	45.5	86.0	54.5	14.0	18.1	95.8	3.24	0.63	24.0	90.5	76.0	9.5	14.8	94.6	2.53	0.84
3	15,670	43.3	2,536	70.8	74.7	29.2	25.3	16.1	97.4	2.80	0.39	44.3	84.3	55.7	15.7	16.2	95.7	2.83	0.66
4	19,610	54.2	2,595	87.5	62.7	12.5	37.3	13.8	98.7	2.35	0.20	45.4	79.7	54.6	20.3	13.2	95.5	2.23	0.69

Figure 2.

Diagnostic metrics and receiver operating characteristic curve for identifying major trauma patients (ISS ≥ 16) using each "step" of the Field Triage Decision Scheme among 6 sites (n = 89,441). *Data were restricted to 6 sites, as the 7th site did not collect adequate information necessary to categorize the triage steps. Diagnostic metrics for the "Cumulative Steps" section includes patients from each of the previous incremental steps in the triage algorithm, while metrics for the "Independent Steps" section assesses each of the triage steps independently. There were 36,230 (40.5%) patients in the 6-site sample that met field triage criteria and 5,720 (6.4%) with ISS ≥ 16. The overall ROC value for the Field Triage Decision Scheme using the 6-site sample is 0.75. *Triage steps include: 1 (physiologic), 2 (anatomic), 3 (mechanism of injury) and 4 (special considerations). †The number of patients in each triage step is based on the total number of patients meeting triage criteria for each independent step. As patients can meet criteria from multiple different triage steps, the column totals for number of triage-positive patients and number of patients with ISS ≥ 16 will be greater than the actual number of patients (ie, the triage steps are not mutually exclusive). EMS, emergency medical services; ISS, Injury Severity Score; sens, sensitivity; spec, specificity; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio; AUC, area under the curve.

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Table 1

Description of Sites, EMS Systems and Hospitals in the 7 Study Regions

							Hospitals				
Site	**EMS service area population***	**Geographic area, sq miles**	**Population density, persons per sq mile**	**Service area description**	**EMS agencies†**	**Type EMS response**	**Hospitals**	**Level I**	**Level II**	**Level III**	**Level IV**
A	2,082,318	3,655	570	Primarily urban/suburban, some rural	10	Single tier, dual ALS	16	2	1	0	0
B	1,916,441	2,126	901	Primarily urban/suburban, some rural	32	Tiered response, BLS/ALS	18	1	0	3	5‡
C	610,345	153	3,989	Urban/suburban	1	Tiered response, BLS/ALS	11	4	2	0	0
D	744,041	46	16,175	Urban	1	Tiered response, BLS/ALS	12	1	0	0	0
E	549,644	1,254	438	Primarily urban/suburban, some rural	2	Tiered response, BLS/ALS	28	1	1	0	0
F	2,503,631	1,740	1,439	Urban/suburban	2	Single tier, dual ALS	20	3	1	0	0
G	2,112,957	3,616	584	Primarily urban/suburban, some rural	46	Tiered response, BLS/ALS	17	3	3	0	0
Total	10,519,377	12,590	836	-	94	-	122	15	8	3	5

*2009 population estimates, except site D (2006 estimate).

†The number of EMS agencies listed represent those included in the study. In several sites, there are additional first responder, non-transport agencies that participate in the EMS system.

‡Includes one Level V hospital.

ALS, advanced life support; BLS, basic life support; EMS, emergency medical services.

Table 2

Characteristics of Injured Patients Transported by EMS in the 7 Study Regions

	Total sample		Triage positive		Triage negative	
	n = 122,345		**n = 42,207 34.5**		**n = 80,138 65.5**	
Demographics:	**n**	**%**	**n**	**%**	**n**	**%**
Age, mean, y	46.6		42.5		48.8	
< 18	14,876	12.2	5,357	12.7	9,518	11.9
18 – 54	62,435	51.0	24,474	58.0	37,961	47.4
≥ 55	45,035	36.8	12,376	29.3	32,659	40.8
Women	58,178	47.6	16,034	38.0	42,143	52.6
Out-of-hospital physiology and procedures:						
SBP in mmHg, mean	135.2		132.2		136.7	
SBP < 90 mmHg	3,825	3.1	2,194	5.2	1,632	2.0
GCS, mean	14.4		13.9		14.6	
GCS ≤ 8	3,363	2.7	2,329	5.5	1,034	1.3
Respiratory rate in breaths/min, mean	18.7		19.0		18.5	
Intubation attempt	1,531	1.3	1,387	3.3	144	0.2
Intravenous line placement	50,065	40.9	26,172	62.0	23,893	29.8
Mechanism of injury						
Gunshot wound	1,300	1.1	1,084	2.6	215	0.3
Stabbing	2,441	2.0	1,654	3.9	787	1.0
Assault	7,467	6.1	2,196	5.2	5,271	6.6
Fall	44,834	36.6	11,264	26.7	33,570	41.9
Motor vehicle crash	41,043	33.5	16,231	38.5	24,812	31.0
Other	25,260	20.6	9,778	23.2	15,483	19.3
Hospital measures						
Interhospital transfer	7,759	6.3	3,622	8.6	4,137	5.2
Initial transport to Level I/II	46,839	38.3	25,288	59.9	21,551	26.9
Final destination Level I/II	59,795	48.9	33,201	78.7	26,593	33.2
Outcomes measures						

	Total sample		Triage positive		Triage negative	
	n = 122,345		**n = 42,207 34.5**		**n = 80,138 65.5**	
Demographics:	**n**	**%**	**n**	**%**	**n**	**%**
ISS, mean	4.3		7.3		2.7	
ISS >= 16	7,100	5.8	6,091	14.4	1,009	1.3
Maximum AIS, mean	1.2		1.7		1.0	
AIS >=3	20,782	17.0	12,854	30.5	7,927	9.9
Non-orthopaedic surgery	5,632	4.6	3,667	8.7	1,965	2.5
Orthopaedic surgery	19,194	15.7	7,987	18.9	11,207	14.0
In-hospital mortality	2,068	1.7	1,292	3.1	776	1.0

EMS, emergency medical services; SBP, systolic blood pressure; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale score; major non-orthopaedic surgery, brain, spine, neck, thorax, abdomen, interventional radiology or vascular operative procedures during hospitalization.

Table 3

Diagnostic Metrics for the Field Triage Decision Scheme (as Applied by EMS Personnel) for Identifying Major Trauma Patients (Injury Severity Score ≥ 16)

Site	Total n	Triage + n	ISS ≥ 16 n	Sens %	95%CI (%)	Spec %	95%CI (%)	Under-triage %	Over-triage %	PPV %	NPV %	+LR	−LR	AUC
A	15,427	7,307	1,887	90.2	(88.8–91.5)	58.6	(57.8–59.4)	9.8	41.4	23.3	97.7	2.18	0.17	0.74
B	12,071	6,116	2,101	84.9	(83.3–86.4)	56.5	(55.6–57.5)	15.1	43.5	29.1	94.7	1.95	0.27	0.71
C	8,523	3,070	926	84.8	(82.5–87.1)	69.9	(68.9–71.0)	15.2	30.1	25.6	97.4	2.82	0.22	0.77
D	3,476	1,054	100	97.0	(93.6–1.00)	71.7	(70.1–73.2)	3.0	28.3	9.2	99.9	3.42	0.04	0.84
E	2,300	897	118	76.3	(68.6–84.0)	63.0	(61.0–65.0)	23.7	37.0	10.0	98.0	2.06	0.38	0.70
F	47,644	17,763	588	93.2	(91.2–95.2)	63.4	(63.0–63.9)	6.8	36.6	3.1	99.9	2.55	0.11	0.78
G	32,904	6,000	1,380	78.7	(76.5–80.9)	84.4	(84.0–84.8)	21.3	15.6	18.1	98.9	5.05	0.25	0.82
Total	122,345	42,207	7,100	85.8	(85.0–86.6)	68.7	(68.4–68.9)	14.2	31.3	14.4	98.7	2.74	0.21	0.77

EMS, emergency medical services; ISS, Injury Severity Score; sens, sensitivity; spec, specificity; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio; AUC, area under the curve.

Table 4

Diagnostic Metrics for Identifying Major Trauma Patients (Injury Severity Score ≥ 16), Based on Initial and Final Destination Hospital, Regardless of Triage Criteria, Initial Emergency Medical Services Transport to a Level I/II Trauma Center

Site	n	n Initial Level I/II	n ISS ≥ 16	Sens %	95%CI (%)	Spec %	95%CI (%)	Under-triage %	Over-triage %	PPV %	NPV %	+LR	−LR	AUC
A	15,427	9,365	1,887	93.3	(92.2–94.5)	43.9	(43.0–44.7)	6.7	56.1	18.8	97.9	1.66	0.15	0.69
B	12,071	3,890	2,101	67.8	(65.8–69.8)	75.3	(74.4–76.1)	32.2	24.7	36.6	91.7	2.74	0.43	0.72
C	8,523	6,438	926	95.9	(94.6–97.2)	27.0	(26.0–28.0)	4.1	73.0	13.8	98.2	1.31	0.15	0.61
D	3,476	1,850	100	98.0	(95.2–100)	48.1	(46.4–49.8)	2.0	51.9	5.3	99.9	1.89	0.04	0.73
E	2,300	1,321	118	91.5	(86.5–96.6)	44.4	(42.3–46.5)	8.5	55.6	8.2	99.0	1.65	0.19	0.68
F	47,644	14,979	588	55.3	(51.2–59.3)	68.9	(68.4–69.3)	44.7	31.1	2.2	99.2	1.77	0.65	0.62
G	32,904	8,996	1,380	44.1	(41.4–46.7)	73.4	(72.9–73.9)	55.9	26.6	6.8	96.8	1.66	0.76	.59
Total	122,345	46,839	7,100	73.4	(72.4–74.4)	63.9	(63.6–64.2)	26.6	36.1	11.1	97.5	2.03	0.42	0.69

EMS, emergency medical services; ISS, Injury Severity Score; sens, sensitivity; spec, specificity; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio; AUC, area under the curve.

Table 5

Diagnostic Metrics for Identifying Major Trauma Patients (Injury Severity Score ≥ 16), Based on Initial and Final Destination Hospital, Regardless of Triage Criteria, Final Destination of Level I/II Trauma Center

Site	n	Final Level I/II	n ISS ≥ 16	Sens %	95%CI (%)	Spec %	95%CI (%)	Under-triage %	Over-triage %	PPV %	NPV %	+LR	−LR	AUC
A	15,427	9,670	1,887	94.9	(93.9–95.9)	41.8	(41.0–42.6)	5.1	58.2	18.5	98.3	1.63	0.12	0.68
B	12,071	4,178	2,101	72.2	(70.3–74.2)	73.3	(72.4–74.2)	27.8	26.7	36.3	92.6	2.71	0.38	0.73
C	8,523	6,454	926	96.1	(94.8–97.3)	26.8	(25.8–27.8)	3.9	73.2	13.8	98.2	1.31	0.15	0.61
D	3,476	1,864	100	98.0	(95.2–100)	47.7	(46.0–49.4)	2.0	52.3	5.3	99.9	1.87	0.04	0.73
E	2,300	1,388	118	100	(97.5–100)	41.8	(39.7–43.9)	0	58.2	8.5	100.0	1.72	0	0.71
F	47,644	26,296	588	95.2	(93.5–97.0)	45.3	(44.9–45.8)	4.8	54.7	2.1	99.9	1.74	0.11	0.70
G	32,904	9,945	1,380	64.4	(61.9–67.0)	71.3	(70.8–71.8)	35.6	28.7	8.9	97.9	2.24	.50	.68
Total	122,345	59,795	7,100	82.6	(81.7–83.5)	53.2	(52.9–53.5)	17.4	46.8	9.8	98.0	1.76	0.33	0.68

Assessing final destination of Level I/II trauma center allows for combined assessment of primary (field) and secondary (hospital) triage processes, whether major trauma patients were ultimately cared for in a major trauma center. Final destination of a major trauma center includes both initial transports to a Level I/II hospital and subsequent interhospital transfers to a Level I/II hospital after initial EMS transport to a non-Level I/II hospital.

EMS, emergency medical services; ISS, Injury Severity Score; sens, sensitivity; spec, specificity; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio; AUC, area under the curve.

Table 6

Characteristics of Under-Triaged Patients

	ISS ≥ 16, triage criteria negative	
	n = 1,009	
	n	%
Demographics		
Age, mean, y	51.3	
< 18	111	11.0
18 – 54	425	42.1
≥ 55	473	46.9
Women	367	36.3
Out-of-hospital physiology and procedures		
SBP,mmHg, mean	134.7	
SBP < 90 mmHg	58	5.7
GCS, mean	13.6	
GCS ≤ 8	80	8.0
Respiratory rate, breaths/min, mean	18.9	
Intubation attempt	27	2.6
Intravenous line placement	347	34.4
Mechanism of injury		
Gunshot wound	12	1.2
Stabbing	8	0.8
Assault	73	7.2
Fall	471	46.6
Motor vehicle crash	298	29.5
Other	147	14.6
Hospital measures		
Interhospital transfer	365	36.2
Initial transport to Level I/II	464	45.9
Final destination Level I/II	621	61.5
Outcomes measures		
Injury Severity Score, mean	20.4	
ISS >= 16	1,009	100
Maximum AIS, mean	3.8	
AIS >=3	1,009	100
Major non-orthopedic surgery	242	24.0
Orthopedic surgery	201	19.9
In-hospital mortality	84	8.3

SBP, systolic blood pressure; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale; major non-orthopaedic surgery, brain, spine, neck, thorax, abdomen, interventional radiology or vascular operative procedures during hospitalization.

Table 7

Diagnostic Metrics for the Field Triage Decision Scheme (as Applied by EMS Personnel) for Identifying Major Trauma Patients (Injury Severity Score ≥16), Stratified by Age Group

Age group, y	n	n triage +	n ISS ≥ 16	Sens %	95%CI (%)	Spec %	95%CI (%)	Under-triage %	Over-triage %	PPV %	NPV %	+LR	−LR	AUC
0 – 17	14,874	5,355	697	84.1	(81.3–86.8)	66.4	(65.6–67.1)	15.9	33.6	10.9	98.8	2.50	0.24	0.75
18 – 54	62,442	24,480	4,050	89.5	(88.6–90.4)	64.3	(63.9–64.7)	10.5	35.7	14.8	98.9	2.51	0.16	0.77
>= 55	45,029	12,372	2,353	79.9	(78.3–81.5)	75.4	(75.0–75.8)	20.1	24.6	15.2	98.6	3.25	0.27	0.78

EMS, emergency medical services; ISS, Injury Severity Score; sens, sensitivity; spec, specificity; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio; AUC, area under the curve.