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Prospective Validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons

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Abstract

BACKGROUND—The national field trauma triage guidelines have been widely implemented in US trauma systems, but never prospectively validated. We sought to prospectively validate the guidelines, as applied by out-of-hospital providers, for identifying high-risk trauma patients.

STUDY DESIGN—This was an out-of-hospital prospective cohort study from January 1, 2011 through December 31, 2011 with 44 Emergency Medical Services agencies in 7 counties in 2 states. We enrolled injured patients transported to 28 acute care hospitals, including 7 major trauma centers (Level I and II trauma hospitals) and 21 nontrauma hospitals. The primary exposure term was Emergency Medical Services' use of one or more field triage criteria in the

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national field triage guidelines. Outcomes included Injured Severity Score ≥16 (primary) and critical resource use within 24 hours of emergency department arrival (secondary).

RESULTS—We enrolled 53,487 injured children and adults transported by Emergency Medical Services to an acute care hospital, 17,633 of which were sampled for the primary analysis; 13.9% met field triage guidelines, 3.1% had Injury Severity Score ≥16, and 1.7% required early critical resources. The sensitivity and specificity of the field triage guidelines were 66.2% (95% CI, 60.2–71.7%) and 87.8% (95% CI, 87.7–88.0%) for Injury Severity Score ≥16 and 80.1% (95% CI, 65.8–89.4%) and 87.3% (95% CI 87.1–87.4%) for early critical resource use. Triage guideline sensitivity decreased with age, from 87.4% in children to 51.8% in older adults.

CONCLUSIONS—The national field triage guidelines are relatively insensitive for identifying seriously injured patients and patients requiring early critical interventions, particularly among older adults.

Field triage plays an integral role in trauma systems by guiding Emergency Medical Services (EMS) personnel in identifying and transporting high-risk patients to major trauma centers, which have been shown to improve survival among seriously injured adults[1–3] and children.[4–6] The process of field triage is guided by national field triage guidelines, originally developed by the American College of Surgeons Committee on Trauma (ACS COT) in 1976, with periodic revision based on new evidence.[7] The national triage guidelines have been widely implemented in US trauma systems, EMS provider training curricula, and trauma system quality-improvement processes.[8] These guidelines represent one of the few standardized national protocols for EMS.

The goal of standardized field triage is to efficiently concentrate high-risk injured patients in major trauma centers without directing all injured patients to such centers, which would quickly overwhelm the limited trauma resources. National benchmarks for field trauma triage are set by the ACS COT[8] based on system-level rates of undertriage (proportion of seriously injured patients transported to nontrauma centers; 1-sensitivity) and overtriage (proportion of patients without serious injuries transported to major trauma centers; 1-specificity). Although early research suggested that the triage guidelines had little undertriage (≤5%),[9,10] more recent studies have yielded much higher rates of undertriage, particularly among older adults.[11–14] However, estimates for triage performance have been based primarily on retrospective studies and limited samples. Despite their widespread use and implementation, the national field triage guidelines have never been prospectively validated in a representative population. Unbiased estimates for guideline performance are important in optimizing trauma systems, improving outcomes among seriously injured patients, assuring access to high-quality trauma care, and evaluating the cost implications of field triage.

In this study, we sought to prospectively validate the national field triage guidelines for identifying high-risk trauma patients (Injury Severity Score [ISS] ≥16 or critical resource use within 24 hours of emergency department [ED] arrival) using injured patients served by 44 EMS agencies in 7 counties within the Northwest United States.

METHODS

Study design

This was a multi-site, prospective cohort study reviewed and approved by IRBs at all study sites, and requirement for informed consent was waived.

Study setting

We conducted the study with 44 EMS agencies in 7 counties in Oregon and Washington, including 2 major metropolitan areas (Portland, OR and Seattle, WA) from January 1, 2011 through December 31, 2011. Descriptions of the counties, EMS agencies, and hospitals are included in Table 1. The counties were selected for geographic diversity (urban, suburban, and rural settings), established "footprints" of EMS agency service areas, and previously validated data routines for capturing EMS electronic health records.[15,16] We considered 2 counties to be rural based on >60-minute ground transport to the nearest Level I or II trauma center; relatively low population density; and rural designation in the Centers for Medicare and Medicaid Services Ambulance Fee Schedule by ZIP code.[17] Emergency Medical Services system structures in the study regions included public and private EMS agencies using dual advanced life support (ALS), tiered basic life support and ALS, and single-agency ALS responses.

We included 28 hospitals in the study, representing a broad variety of hospital types with varying resource capabilities. These included 25 of 37 non-federal EMS-receiving hospitals in the 7 counties, plus 3 additional hospitals located just outside county lines that routinely receive injured patients from the participating EMS agencies. We identified the 28 hospitals using previously collected EMS data in these regions showing >75% capture of injured patients transported by participating EMS agencies. Participating hospitals included 5 Level I trauma centers (including 2 children's hospitals), 2 Level II trauma centers, 5 Level III trauma hospitals, 5 Level IV hospitals, and 11 nontrauma hospitals. All trauma centers in the 7 counties participated in the study. Trauma centers in these regions are designated by state authorities or verified by ACS COT. For purposes of this study, we defined "major trauma centers" as all Level I and II trauma hospitals, consistent with ACS COT guidelines for tertiary trauma care[8] and local practices within these regions.

All participating EMS agencies work under close medical direction, including regular provider training (quarterly to annually), and use standardized field trauma triage protocols based on the national triage guidelines. Because the general format for the field triage guidelines has been in place since 1987,[7] all EMS providers are initially trained on the triage algorithm during their primary training (eg, paramedic school), with retraining based on updates to the triage algorithm as they come out. The EMS training processes and assessment of competence (eg, lectures, formal testing, continuing education activities, and case-based learning) vary by county, but are generally done by EMS training officers and EMS medical directors. These systems also integrate quality-assurance review of missed trauma cases for oversight of the guidelines in practice.

Emergency Medical Services personnel in these regions are trained to use the field triage guideline for every injured patient regardless of proximity to a major trauma center. The presence of one or more field triage criteria typically triggers transport to a Level I or II trauma center, but can result in transport to a lower-level trauma center (eg, Level III or IV hospitals) depending on proximity and the EMS protocols in each system. At the time of the study, field triage protocols in all counties were based on the 2006 national field triage guidelines (Appendix 1; available at: http://www.journalacs.org),[18] with local adaptation based on the needs of each region,[19] as allowed for in the guidelines. Because we sought realistic accuracy estimates for actual EMS use of the triage guidelines based on current EMS training and quality assurance processes (an effectiveness study), we did not retrain participating EMS agencies specifically for this study.

Selection of participants

We included all injured children and adults with EMS evaluation at the scene within the 7 counties during the study period. Patients were included based on EMS provider primary impression of "injury" or "trauma" (ie, the population to whom the triage guidelines are routinely applied). We used a probability sampling design to create a feasible primary sample for chart abstraction at the 28 participating hospitals based on the following strata: urban vs rural county type, triage status (positive or negative), age group (0 to 14 years, 15 to 54 years, and 55 years and older), and type of receiving hospital (major trauma center vs nontrauma hospital) (Fig. 1). Specifying the sample in this manner allowed for an out-of-hospital injury cohort defined through the lens of the EMS provider, including patients with mild, moderate, and serious injuries. We excluded inter-hospital transfers that did not have an initial EMS response within the 7 counties.

Methods and measurements

The primary exposure variable (ie, test for which diagnostic accuracy was evaluated) was whether the patient met any of the triage criteria listed in the national field triage guidelines (the entire triage algorithm)[18] as determined by EMS providers. To reduce misclassification bias and account for missing triage status in EMS charts, we defined triage status (positive vs negative) based on any of the following: 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; a matched trauma registry record specifying a "scene" (EMS-identified) trauma patient; or a matched base hospital phone record specifying a patient entered into the trauma system (for counties where EMS providers are required to contact the base hospital prior to arrival). We have used similar triangulation of data sources to establish field triage status in previous research.[14] All other patients were considered triage negative. Triage status was considered independent of transport destination and injury severity. We also tracked the type of initial receiving hospital and final hospital destination after accounting for inter-hospital transfers. Additional out-of-hospital variables included age and sex, physiologic measures (systolic blood pressure, Glasgow Coma Scale score, respiratory rate, and heart rate), procedures, mechanism of injury, transport mode, and reason for selecting the initial hospital.

For ED and hospital information, trained research personnel abstracted hospital charts at the 28 hospitals using standardized data-collection forms. Hospital variables included presence and timing of airway management, mechanical ventilation, surgical procedures, bloodproduct transfusion, ICU stay, complications, inter-hospital transfer, Abbreviated Injury Scale scores,[20] and in-hospital mortality. For patients transferred between hospitals, we abstracted records at all facilities. To supplement the abstracted hospital data and assure complete capture of eligible patients, we matched records from 9 trauma registries to the full cohort of transported patients and mapped trauma registry data fields to the standardized data collection forms. We compared a portion of records (n = 404) that were double-abstracted (study abstractor vs trauma registrar and study abstractor vs study abstractor) to assure reliable and consistent chart abstraction.

Outcomes

Based on evaluation of the national field triage guidelines as a diagnostic test, we considered the reference standard (primary end point) to be "serious injury," defined as an ISS[21] ≥16. Injury Severity Score is calculated from the highest Abbreviated Injury Scale scores in 3 different body regions.[20] This measure is recommended by ACS COT for tracking triage accuracy within trauma systems[8] and defines the subset of injured patients with high mortality[21] and patients most likely to benefit from care in major trauma centers.[1,2]

The secondary end point was a composite measure of early critical resource use, defined as any of the following within 24 hours of ED arrival: emergent airway intervention in the ED, major nonorthopaedic surgical intervention (brain, spine, neck, thoracic, abdominal, or pelvic procedures), interventional radiology procedures, blood transfusion ≥6 units (or any blood transfusion in a child), or death. We included patients who died within 24 hours of ED arrival to retain high-risk patients who might not have survived long enough to undergo critical interventions. The definition for early critical resource use was based on previous trauma triage research,[22–25] a recent national consensus study,[26] and a 5-member study Advisory Committee of trauma and EMS experts. In this study, we collectively refer to patients with either ISS ≥16 or early critical resource use as "high-risk" trauma patients.

Analysis

To determine sample size for the primary sample, we used previously collected EMS and hospital data for injured patients in these counties.[14,16] The sample size was based on the desired precision (95% CI) around estimates for triage sensitivity for identifying patients with ISS ≥16. We estimated that a primary sample of 13,331 patients would provide a 95% CI of ±4.0% for overall triage sensitivity, ±9.0% for children (0 to 14 years), ±5.5% for adults (15 to 54 years), and ±7.0% for patients 55 years or older. We oversampled by 3% to account for missing hospital charts and we used matched records from the 9 trauma registries to maximize capture of eligible patients and supplement hospital data collection (pragmatic study design for increased efficiency with data collection). The sampling scheme is depicted in Figure 1. We assessed inter-rater reliability for hospital data abstraction using κ and intraclass correlation.

We generated all estimates of triage sensitivity and specificity by weighting data from the primary sample to represent the full cohort of injured patients transported by EMS, accounting for the probability of sampling patients not meeting field triage criteria (verification bias).[27,28] We also assumed that the proportion of triage-negative patients with serious injury in each age group was the same at participating and nonparticipating hospitals (Fig. 1). The primary analysis was designed to evaluate the national field triage guidelines as a diagnostic test to identify high-risk trauma patients, regardless of the type of hospital to which they were transported. However, we also quantified triage accuracy based on the type of hospital to which the patient was initially transported and final hospital destination, after accounting for inter-hospital transfers.

To minimize bias, preserve sampling structure, and preserve study power, we used multiple imputation to handle missing values.[29] We have demonstrated the validity of multiple imputation for imputing missing out-of-hospital values and trauma data[30,31] and have rigorously evaluated the use of multiple imputation in a similar trauma cohort.[16] We used flexible chains regression models[32] that included all features of the sampling scheme[31] with generation of 10 multiply imputed data-sets. Sensitivity and specificity were estimated from each dataset independently and combined using Rubin's rules to appropriately account for variance within and between datasets.[29] The proportion of missing values for key variables included age (0.2%), triage status (4.6%), destination hospital (0.4%), ISS (21.1%), critical resource use (21.1%), and out-of-hospital physiologic measures (7.9% to 23.7%). There were no patients missing both triage status and ISS.

Multiple imputation was conducted using IVEware (Survey Methodology Program, Survey Research Center, Institute for Social Research, University of Michigan) and all other analyses were conducted using SAS software, version 9.3 (SAS Institute).

RESULTS

There were 67,047 injured patients evaluated by participating EMS agencies during the 12-month study period, 53,487 (79.8%) of which were transported to acute care hospitals (Fig. 1). Of the 53,487 patients, 44,508 (83.2%) were transported to the 28 participating hospitals and 17,633 were selected for the primary sample using probability sampling methods. Among the 17,633 primary sample patients, 13,918 had hospital data collected (9,392 abstracted records and 4,526 matched trauma registry records), which was a 78.9% follow-up rate. Inter-rater reliability measures for key hospital variables ranged from 0.84 to 1.00.

Of the 17,633 patients, 7,299 (weighted proportion, 13.9%) met at least one field triage criterion, as applied by EMS; 1,198 (weighted proportion, 3.1%) had ISS ≥16; 738 (weighted proportion, 1.7%) required critical resources within 24 hours; and 1,562 (weighted proportion, 4.1%) had either ISS ≥16 or early critical resource use. Characteristics of the study sample, separated by triage status, are shown in Table 2. The components and timing of critical early resource interventions are detailed in Table 3. The frequency of individual triage criteria used by EMS is illustrated in Figure 2.

The overall sensitivity and specificity of the national field triage guidelines for identifying patients with ISS ≥16 were 66.2% (95% CI, 60.2–71.7%) and 87.8% (95% CI, 87.7–88.0%), respectively. For identifying patients requiring early critical resources, the triage guidelines were 80.1% sensitive (95% CI, 65.8–89.4%) and 87.3% specific (95% CI, 87.1–87.4%). For patients with ISS ≥16 or early critical resource use, the national triage guidelines were

66.2% sensitive (95% CI, 59.7–72.2%) and 88.4% specific (95% CI, 88.2–88.5%). Sensitivity decreased when evaluated by initial receiving hospital and increased by final hospital destination (Fig. 3).

The sensitivity of the national field triage guidelines steadily decreased with increasing patient age (Fig. 4A), and specificity gradually increased with age (Fig. 4B). Field triage sensitivity for identifying seriously injured patients by age group was: 87.4% (95% CI, 71.9–95.0%) for children 0 to 14 years; 78.7% (95% CI, 70.1–85.4%) for adults 15 to 54 years old; and 51.8% (95% CI, 44.1–59.4%) for adults 55 years and older.

We also evaluated triage processes stratified by urban vs rural counties. For patients with ISS ≥16, triage processes in rural counties appeared more sensitive (81.0%; 95% CI, 61.9–91.8%) than in urban counties (65.8%; 95% CI, 59.8–71.4%). However, only 12.5% (95% CI, 4.7–29.2%) of seriously injured patients in rural counties were initially transported to major trauma centers, and 39.3% (95% CI, 24.9–55.9%) were ultimately cared for in major trauma centers.

We conducted several sensitivity analyses to test the robustness of our findings. First, we used nonimputation strategies to handle missing values (complete case analysis; "best-case analysis" assuming that all patients missing ISS had ISS <16; and "worst-case analysis" assuming that all patients missing ISS had ISS ≥16). Although triage specificity did not change, the recalculated sensitivity estimates ranged from 18.3% (worst-case analysis) to 74.2% (complete case analysis and best-case analysis). We also tested whether strict EMS adherence to the physiologic triage criteria (step 1 of the algorithm) would have substantively improved the sensitivity of the guidelines by using initial out-of-hospital values for systolic blood pressure, respiratory rate, and Glasgow Coma Scale to determine whether a given patient met step 1 criteria. This process reclassified 1,564 triage-negative patients to triage-positive and yielded a sensitivity of 72.4% (95% CI, 66.3–77.7%) and specificity of 75.9% (95% CI, 75.1–76.7%).

DISCUSSION

We demonstrate that the national field triage guidelines are relatively insensitive for identifying high-risk trauma patients and that the concentration of such patients in major trauma centers through emergency services is not yet optimized. Our results also call into question the realistic ability to reach the national sensitivity benchmark of 95% (≤5% undertriage)[8] through field triage processes. This study differs from previous triage research by using a prospective, dedicated sampling scheme intended to minimize bias in estimating accuracy measures for field triage, defining our sample through the lens of the EMS provider (the true denominator to which the field triage guidelines are applied) and estimating the diagnostic role of field triage guidelines through actual use. We also separated the triage process into 3 steps (field identification, initial hospital selection, and final hospital destination). Separation of the identification step (application of the guidelines to identify high-risk trauma patients) allowed us to evaluate field triage across a variety of practice settings, regardless of destination options. Examination of initial hospital selection and final hospital destination was important in illustrating how key downstream steps in triage affect the ability of an entire system to concentrate seriously injured patients in major trauma centers. These findings have important implications for emergency services and trauma systems.

Compared with the national benchmark[8] and previous retrospective research,[14] we demonstrate much lower estimates for sensitivity, regardless of how high-risk patients or triage processes were defined. The differences in results between the current prospective study and a similar retrospective study[14] likely reflect the inherent potential for bias in retrospective research (eg, selection bias, misclassification bias). We designed the prospective study to directly address key sources of bias through dedicated sampling, use of rigorous methods for handling missing values, manual chart abstraction, and triangulation of data sources. Our findings support results from another retrospective study[12] and confirm that many patients requiring care in major trauma centers are not receiving such care. Access to major trauma care is likely much worse than estimates based solely on geographic proximity.[33,34] Among older adults, the guidelines were particularly insensitive, although reasons for this finding are unclear. Possible explanations include serious injuries resulting from low-velocity mechanisms (eg, ground level fall)[35] not captured by current field triage guidelines; different physiologic responses to injury[36]; high prevalence of medication use, frailty, and comorbidities; and subtle presentations of serious injury. Whether elder-specific triage criteria should be used to reduce undertriage is an ongoing question.

The national triage guidelines are regularly updated based on new evidence, although resolving the undertriage issue is likely more complex than simply revising the guidelines. Application of the triage guidelines has been shown to occur based on rapid and heuristic cognitive processing by EMS providers,[37] as the slow, methodical processing required for full application of the algorithm is not always feasible in the time-pressured out-of-hospital setting. As a result, small changes to the decision scheme are unlikely to result in major changes to field triage and individual triage criteria do not function independent of one another. This phenomenon is indirectly illustrated through the common use of “EMS provider judgment” as a field triage criterion, reflecting the clinical decision making required of field providers and the reality that current triage criteria do not fully capture the multitude of injury mechanisms and scenarios that can result in serious injury. Emergency Medical Services provider judgment has been shown to be predictive of serious injury, even after accounting for other triage criteria.[38] Selective application of the guidelines, patient choice, EMS provider knowledge and training, provider beliefs, availability of EMS units, traffic, weather, and hospital proximity can also contribute to triage decision making.

System-level changes are required to better concentrate high-risk patients in major trauma centers without increasing costs and system inefficiencies. Improved EMS adherence to the guidelines (possibly aided by decision-support software or simple checklists) and more effective inter-hospital transfer processes can improve the matching of patient needs with hospital capability. Improved out-of-hospital diagnostic capabilities (eg, point-of-care devices for biomarkers and noninvasive physiologic measures for shock and brain injury) also offer the opportunity to better identify high-risk patients without marked decreases in triage specificity. Because trauma systems remain the most established model of regionalized medical care, these findings offer important insights into the optimization of other regionalized care systems (eg, stroke, ST-elevation myocardial infarction, and out-of-hospital cardiac arrest).

Overtriage of patients without serious injuries to major trauma centers was lower in this study compared with previous triage research,[12,14] and better than the national benchmark.[8] However, one-quarter of low-risk (triage-negative) patients were still transported to major trauma centers. Such practices might reflect the close proximity of trauma centers to the site of injury, patient preferences, and silent concerns of EMS about injured patients not formally meeting field triage criteria. Because the practice of transporting low-risk injured patients to major trauma centers has been shown to account for up to 40% of acute care costs,[39] consistently transporting triage-negative patients to non-trauma hospitals offers another opportunity to refine the efficiency of trauma systems. This practice did not enhance the sensitivity of field triage (ie, when triage sensitivity was calculated based on initial receiving hospital). Rather, the sensitivity of field triage decreased when calculated by receiving hospital.

There are limitations to consider in this study. The regions represented in this study have mature and inclusive trauma systems, as well as ALS-equipped EMS agencies with close medical oversight. Our results might not be generalizable to less-developed trauma systems or other regions. In addition, we evaluated the decision scheme in its entirety, as applied by EMS. However, the lower steps (steps 3 and 4) of the triage algorithm allow flexibility in hospital selection.[18,40] Because individual triage criteria were not consistently documented, it was not possible to evaluate the triage algorithm by step. Although some trauma systems use this flexibility to transport triage-positive patients with lower likelihood of serious injury to lower-level trauma centers (or non-trauma hospitals), accounting for this flexibility would not improve the sensitivity estimates. Also, it was not possible from these data to fully ascertain whether improved EMS adherence to the triage guidelines would improve triage sensitivity, as such criteria are generally only documented when field providers have a patient who they believe meets the triage guidelines. However, when we re-estimated triage sensitivity under a scenario of strict EMS adherence to the physiologic criteria (step 1), there was modest improvement. Improved EMS adherence is unlikely to completely fix the issue of triage sensitivity.

We evaluated the 2006 national field triage guidelines, although the 2011 revised guidelines were published in January 2012, shortly after completion of enrollment.[40] Although it is possible that the 2011 guidelines might have different diagnostic accuracy, the updated guidelines integrated relatively minor changes (Appendix 2; available at: http://www.journalacs.org),[40] and previous research suggests that field application of the guidelines is based on a consolidation of the entire scheme, rather than a methodical and algorithmic assessment of each individual triage criterion.[37] Also, translation of new triage guidelines into practice has been shown to take several years.[19] Therefore, we believe our findings represent current triage practices that are unlikely to differ substantially from the most recent guidelines.

We targeted 28 receiving hospitals for hospital-based data abstraction, which accounted for 83% of injured patients transported by EMS in the 7 counties. We assumed that the distribution of patient characteristics and outcomes at nonparticipating hospitals was the same as those of participating hospitals. If this assumption was not correct, our estimates might be subject to bias.

In addition, the realized sample size was larger than expected due to a greater number of injured patients evaluated by EMS and because the realized strata sizes were larger than anticipated. Although enrollment was higher than expected, actual rates of ISS ≥16 were lower, the combination of which resulted in slightly wider 95% CI than we originally estimated. Finally, it is possible that our findings would have differed if hospital information was available for the entire cohort (no missing values). We used multiple imputation to handle missing values, preserve the sampling scheme, minimize bias, and maximize study power. The benefits of using multiple imputation compared with complete case analysis in EMS and trauma research has been detailed previously.[16,30,31]

CONCLUSIONS

The national field triage guidelines were relatively insensitive for identifying seriously injured patients and those requiring early critical interventions, particularly among older adults. Although trauma systems remain the model for regionalized health care, our results suggest that the ability to identify and direct high-risk trauma patients to major trauma centers is not yet optimized. Our results also raise questions about access to appropriate trauma care among older adults and the practical ability to fully concentrate seriously injured patients in high-resource hospitals through 9-1-1 emergency services.

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Abbreviations and Acronyms

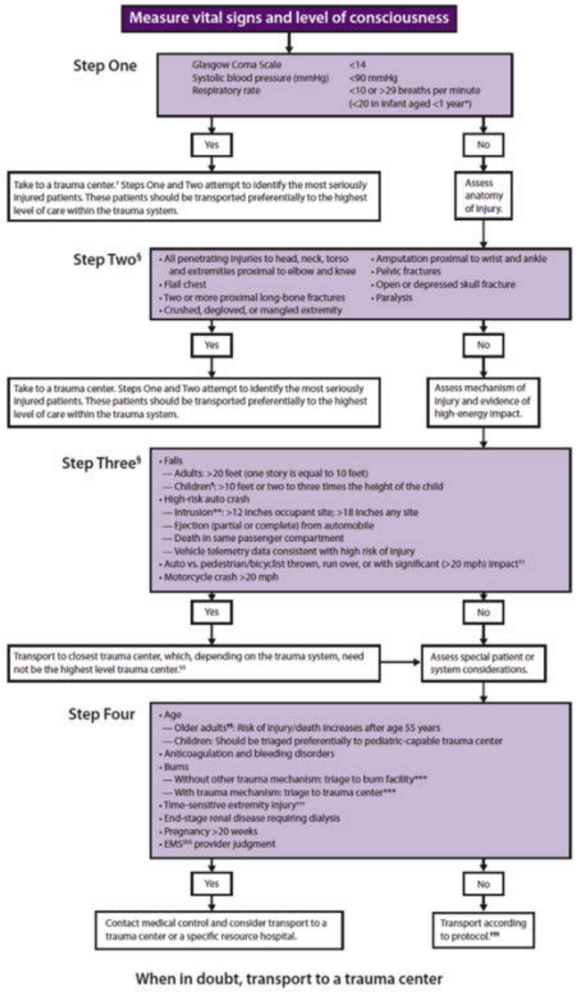
ACS	American College of Surgeons
COT	Committee on Trauma
ALS	advanced life support
ED	emergency department
EMS	Emergency Medical Services
ISS	Injury Severity Score

References

1. 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; 354:366–378. [PubMed: 16436768]
2. Mullins RJ, Veum-Stone J, Helfand M, et al. Outcome of hospitalized injured patients after institution of a trauma system in an urban area. JAMA. 1994; 271:1919–1924. [PubMed: 8201736]
3. Nathens AB, Jurkovich GJ, Rivara FP, Maier RV. Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. J Trauma. 2000; 48:25–30. discussion 30–31. [PubMed: 10647561]
4. Pracht EE, Tepas JJ 3rd, Langland-Orban B, et al. Do pediatric patients with trauma in Florida have reduced mortality rates when treated in designated trauma centers? J Pediatr Surg. 2008; 43:212–221. [PubMed: 18206485]
5. Cooper A, Barlow B, DiScala C, et al. Efficacy of pediatric trauma care: results of a population-based study. J Pediatr Surg. 1993; 28:299–303. discussion 304–305. [PubMed: 8468636]
6. Wang NE, Saynina O, Vogel LD, et al. The effect of trauma center care on pediatric injury mortality in California, 1999 to 2011. J Trauma Acute Care Surg. 2013; 75:704–716. [PubMed: 24064887]
7. Mackersie RC. History of trauma field triage development and the American College of Surgeons criteria. Prehosp Emerg Care. 2006; 10:287–294. [PubMed: 16801263]
8. American College of Surgeons. [Accessed November 15, 2015] Resources for Optimal Care of the Injured Patient. 6Available at: https://www.facs.org/~/media/files/quality%20programs/trauma/vrc%20resources/resources%20for%20optimal%20care%202014%20v11.ashx
9. Lerner EB. Studies evaluating current field triage: 1966–2005. Prehosp Emerg Care. 2006; 10:303–306. [PubMed: 16801265]
10. Norcross ED, Ford DW, Cooper ME, et al. Application of American College of Surgeons' field triage guidelines by pre-hospital personnel. J Am Coll Surg. 1995; 181:539–544. [PubMed: 7582229]
11. Nakamura Y, Daya M, Bulger EM, et al. Evaluating age in the field triage of injured persons. Ann Emerg Med. 2012; 60:335–345. [PubMed: 22633339]
12. Xiang H, Wheeler KK, Groner JI, et al. Undertriage of major trauma patients in the US emergency departments. Am J Emerg Med. 2014; 32:997–1004. [PubMed: 24993680]
13. Chang DC, Bass RR, Cornwell EE, Mackenzie EJ. Undertriage of elderly trauma patients to state-designated trauma centers. Arch Surg. 2008; 143:776–781. discussion 782. [PubMed: 18711038]
14. Newgard CD, Zive D, Holmes JF, et al. A multisite assessment of the American College of Surgeons Committee on Trauma field triage decision scheme for identifying seriously injured children and adults. J Am Coll Surg. 2011; 213:709–721. [PubMed: 22107917]
15. Newgard CD, Zive D, Jui J, et al. Electronic versus manual data processing: evaluating the use of electronic health records in out-of-hospital clinical research. Acad Emerg Med. 2012; 19:217–227. [PubMed: 22320373]
16. Newgard C, Malveau S, Staudenmayer K, et al. Evaluating the use of existing data sources, probabilistic linkage, and multiple imputation to build population-based injury databases across phases of trauma care. Acad Emerg Med. 2012; 19:469–480. [PubMed: 22506952]
17. Centers for Medicare & Medicaid Services, US Department of Health and Human Services. [Accessed April 6, 2015] Ambulance fee schedule and national breakout of geographic area definitions by ZIP code. 2015. Available at: http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AmbulanceFeeSchedule/
18. 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.
19. Barnett AS, Wang NE, Sahni R, et al. Variation in prehospital use and uptake of the national Field Triage Decision Scheme. Prehosp Emerg Care. 2013; 17:135–148. [PubMed: 23452003]
20. Abbreviated Injury Scale (AIS) 2005 Manual. Barrington, IL: Association for the Advancement of Automotive Medicine; 2005.

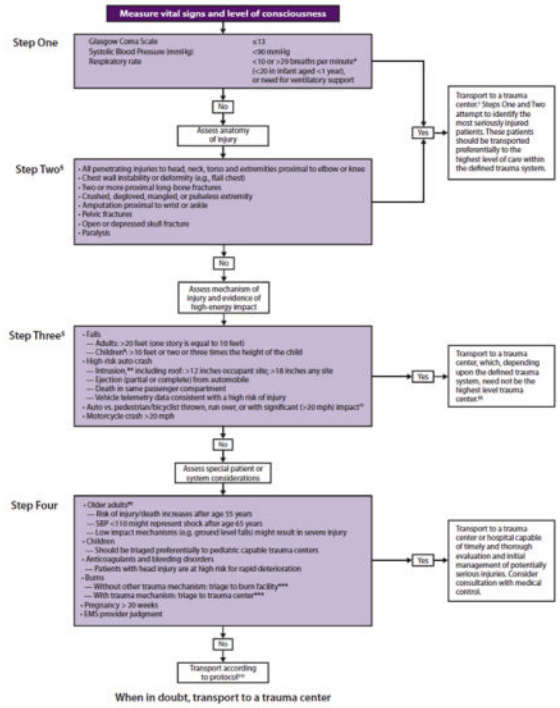
21. Baker SP, O'Neill B, Haddon W Jr, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974; 14:187–196. [PubMed: 4814394]
22. Baxt WG, Jones G, Fortlage D. The trauma triage rule: a new, resource-based approach to the prehospital identification of major trauma victims. Ann Emerg Med. 1990; 19:1401–1406. [PubMed: 2240753]
23. Henry MC, Hollander JE, Alicandro JM, et al. Incremental benefit of individual American College of Surgeons trauma triage criteria. Acad Emerg Med. 1996; 3:992–1000. [PubMed: 8922003]
24. Engum SA, Mitchell MK, Scherer LR, et al. Prehospital triage in the injured pediatric patient. J Pediatr Surg. 2000; 35:82–87. [PubMed: 10646780]
25. Newgard CD, Lewis RJ, Jolly BT. Use of out-of-hospital variables to predict severity of injury in pediatric patients involved in motor vehicle crashes. Ann Emerg Med. 2002; 39:481–491. [PubMed: 11973555]
26. Lerner EB, Willenbring BD, Pirrallo RG, et al. A consensus-based criterion standard for trauma center need. J Trauma Acute Care Surg. 2014; 76:1157–1163. [PubMed: 24662885]
27. Begg CB, Greenes RA. Assessment of diagnostic tests when disease verification is subject to selection bias. Biometrics. 1983; 39:207–215. [PubMed: 6871349]
28. Zhou XH. Correcting for verification bias in studies of a diagnostic test's accuracy. Stat Methods Med Res. 1998; 7:337–353. [PubMed: 9871951]
29. Rubin, D. Multiple Imputation for Nonresponse in Surveys. New York: John Wiley & Sons, Inc; 1987.
30. Newgard CD. The validity of using multiple imputation for missing out-of-hospital data in a state trauma registry. Acad Emerg Med. 2006; 13:314–324. [PubMed: 16495420]
31. Newgard CD, Haukoos JS. Advanced statistics: missing data in clinical research—part 2: multiple imputation. Acad Emerg Med. 2007; 14:669–678. [PubMed: 17595237]
32. Raghunathan T, Lepkowski, Van Hoewyk J, Solenberger P. A multivariate technique for multiply imputing missing values using a sequence of regression models. Survey Methodol. 2001; 27:85–95.
33. Branas CC, MacKenzie EJ, Williams JC, et al. Access to trauma centers in the United States. JAMA. 2005; 293:2626–2633. [PubMed: 15928284]
34. Nance ML, Carr BG, Branas CC. Access to pediatric trauma care in the United States. Arch Pediatrics Adolesc Med. 2009; 163:512–518.
35. Spaniolas K, Cheng JD, Gestring ML, et al. Ground level falls are associated with significant mortality in elderly patients. J Trauma. 2010; 69:821–825. [PubMed: 20938268]
36. Martin JT, Alkhoury F, O'Connor JA, et al. 'Normal' vital signs belie occult hypoperfusion in geriatric trauma patients. Am Surg. 2010; 76:65–69. [PubMed: 20135942]
37. Newgard CD, Nelson MJ, Kampp M, et al. Out-of-hospital decision making and factors influencing the regional distribution of injured patients in a trauma system. J Trauma. 2011; 70:1345–1353. [PubMed: 21817971]
38. Newgard CD, Kampp M, Nelson M, et al. Deciphering the use and predictive value of "emergency medical services provider judgment" in out-of-hospital trauma triage: a multisite, mixed methods assessment. J Trauma Acute Care Surg. 2012; 72:1239–1248. [PubMed: 22673250]
39. Newgard CD, Staudenmayer K, Hsia RY, et al. The cost of overtriage: more than one-third of low-risk injured patients were taken to major trauma centers. Health Aff (Millwood). 2013; 32:1591–1599. [PubMed: 24019364]
40. Sasser SM, Hunt RC, Faul M, et al. Guidelines for field triage of injured patients: recommendations of the National Expert Panel on Field Triage, 2011. MMWR Recomm Rep. 2012; 61(RR-1):1–20.

Appendix 1



Field triage decision scheme, 2006.[18]

Appendix 2



Field triage decision scheme, 2011.[40] These guidelines were developed in 2011, but published in January 2012

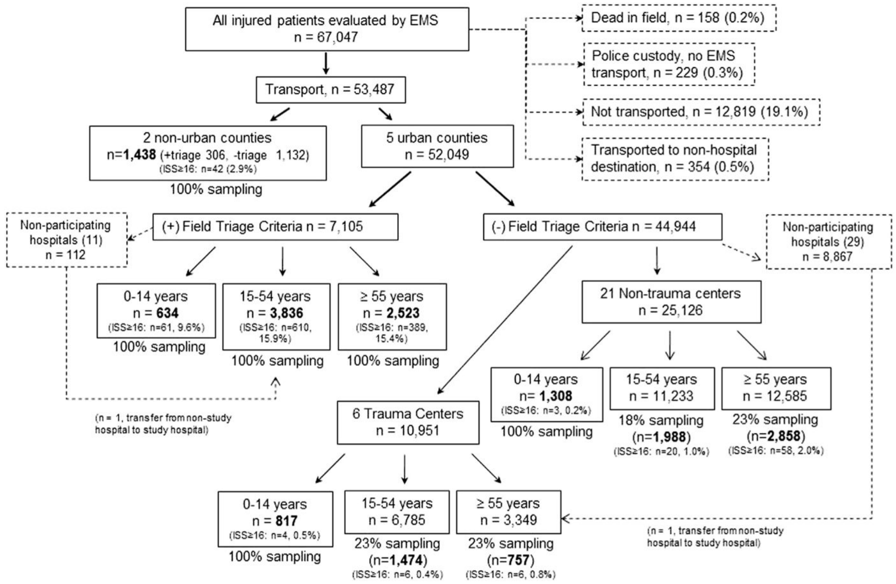


Figure 1.

Enrollment and sampling schematic. Numbers in bold represent patients sampled for the primary sample.

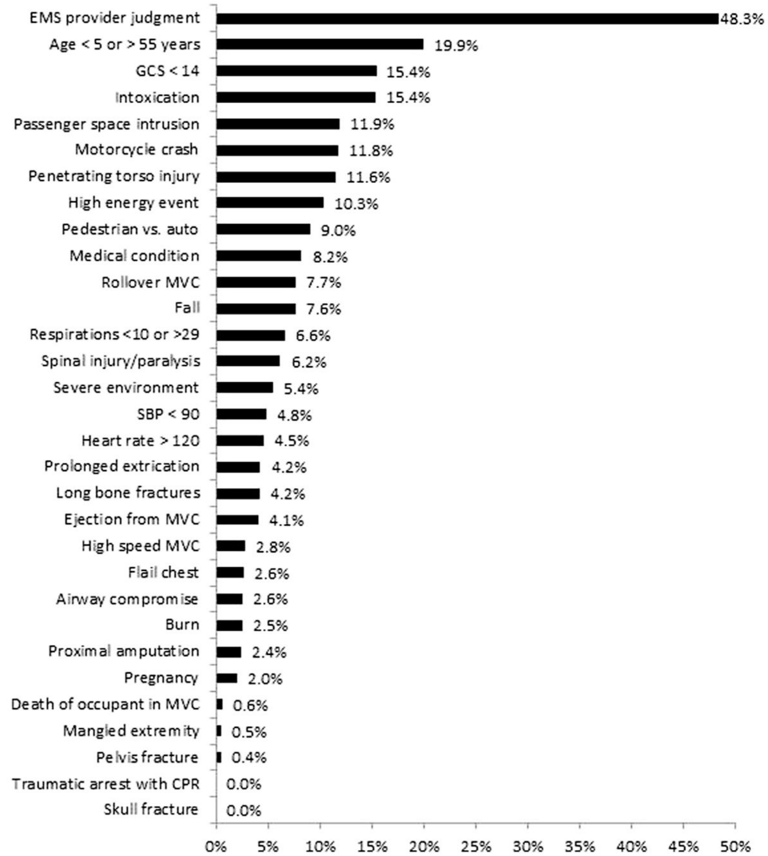


Figure 2.

Frequency of individual field triage criteria applied by Emergency Medical Services personnel among patients with known triage criteria (n = 4,372); 60% of the 7,299 triage-positive patients had individual triage criteria known and formed the denominator for this figure.

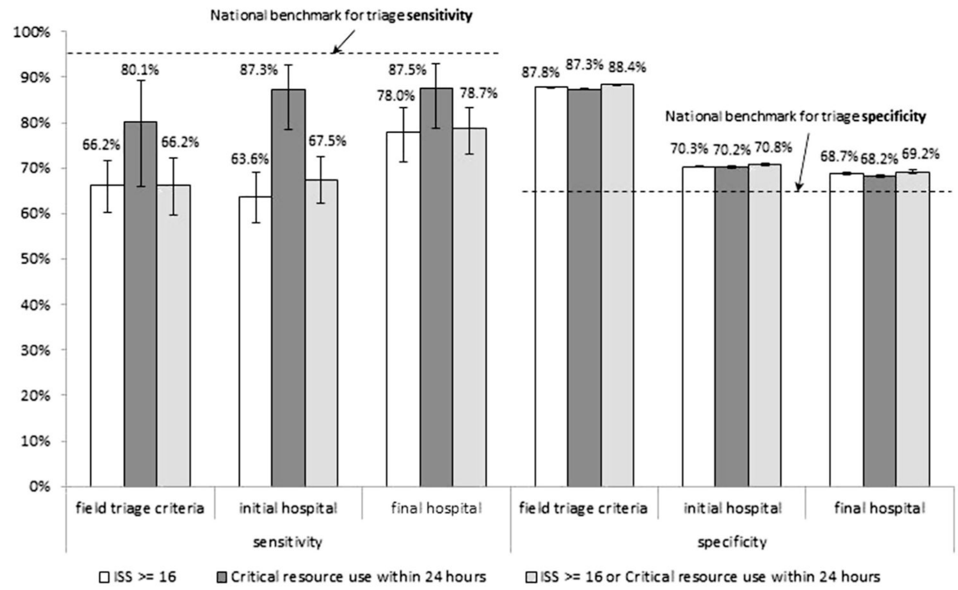


Figure 3.

Sensitivity and specificity of field triage practices in 7 counties using the national field trauma triage guidelines, initial hospital destination, and final hospital destination (n = 17,633). Critical resources within 24 hours included emergent intubation in the emergency department; major nonorthopaedic surgical intervention (ie, brain, spine, neck, thorax, abdominal-pelvic, or vascular surgery); interventional radiology procedures; packed RBC transfusion ≥6 U (or any transfusion in a child); or death. Estimates based on “field triage criteria” are calculated without respect to the type of hospital to which a patient was transported. Estimates using “initial hospital” are based on the type of hospital to which a patient was initially transported (ie, Level I or II trauma center vs other), regardless of field triage status. Results using “final hospital” are based on the final hospital destination (Level I or II vs other) after accounting for inter-hospital transfers, regardless of field triage status.

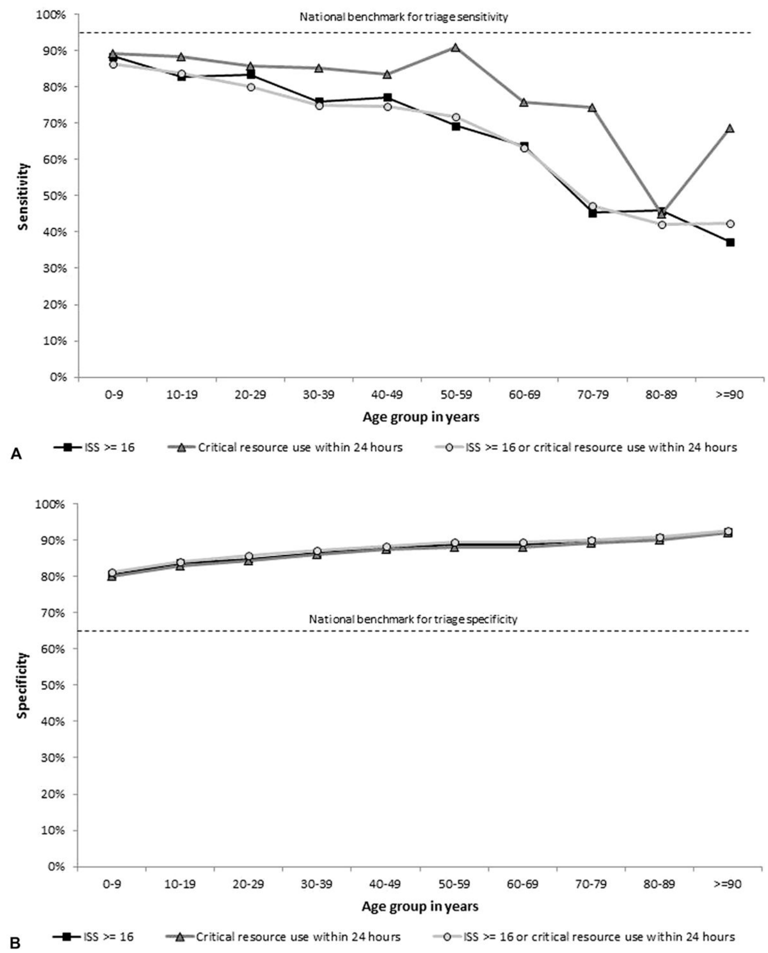


Figure 4.

(A) Sensitivity and (B) specificity of the national field triage criteria in 7 counties, by age group (n = 17,633).

Table 1

Description of County Populations, Emergency Medical Services Systems, and Hospitals in the 7 Counties

County	2010 Population	Persons per square mile	Urban or rural classification[17]	EMS agencies, n	Hospitals	Hospital trauma level, n				
						I	II	III	IV	Noncategorized hospitals
Oregon										
Multnomah	735,334	1,705	Urban	2	8	4*	0	0	0	4
Washington	529,710	731	Urban	3	4	0	0	0	0	4
Clackamas	375,992	201	Urban	3	2	0	0	0	0	2
Josephine	82,713	50	Rural	1	2	0	0	1	1	0
Washington										
King	1,931,249	913	Urban	32	7	1	0	3	3	0
Clark	425,363	676	Urban	3	2	0	1	0	0	1
Skamania	11,066	7	Rural	1	0	0	0	0	0	0
—	—	—	—	44†	28‡	5	2‡	5‡	5‡	11

*Multnomah County has 2 children's hospitals and 2 Level I trauma centers. Because the children's hospitals provide Level I services for the state, they are tabulated as Level I hospitals.

†One EMS agencies serves 2 counties.

‡Three hospitals (1 Level II, 1 Level III and, 1 Level IV) reside outside the 7 counties, but were included in the study because they routinely receive injured patients from the participating EMS agencies.

EMS, Emergency Medical Services.

Table 2

Characteristics of Injured Patients Transported by Emergency Medical Services in the 7 Counties Overall and Separated by Field Triage Status

	Total sample (n = 17,633)		Triage positive (n = 7,299)		Triage negative (n = 10,334)	
Characteristics	**Unweighted patients, n**	**Weighted % (95% CI)**	**Unweighted patients, n**	**Weighted % (95% CI)**	**Unweighted patients, n**	**Weighted % (95% CI)**
Demographics						
Age						
0–14 y	2,832	6.6 (6.5–6.7)	660	9.0 (8.4–9.8)	2,172	6.2 (6.1–6.2)
15–54 y	7,816	48.2 (48.0–48.3)	3,992	54.7 (53.5–55.9)	3,824	47.1 (47.0–47.2)
55 y or older	6,985	45.3 (45.1–45.5)	2,646	36.3 (35.1–37.4)	4,339	46.7 (46.6–46.8)
Women	8,316	52.0 (51.0–52.9)	2,908	39.8 (38.7–41.0)	5,408	53.9 (52.8–55.0)
Urban county	16,195	97.3 (97.2–97.4)	6,993	95.9 (95.5–96.2)	9,202	97.5 (97.5–97.6)
Nonurban county	1,438	2.7 (2.6–2.8)	306	4.1 (3.8–4.5)	1,132	2.5 (2.4–2.5)
Out-of-hospital physiology, procedures, and transport						
SBP <90 mmHg	397	1.5 (1.3–1.7)	216	3.0 (2.6–3.4)	181 *	1.2 (1.0–1.5)
Glasgow Coma Scale						
≤8	414	0.9 (0.8–1.0)	395	5.4 (4.9–6.0)	19 *	0.17 (0.10–0.29)
9–12	924	4.1 (3.5–4.8)	544	7.5 (6.8–8.2)	380 *	3.6 (2.9–4.4)
13–15	16,295	95.0 (94.3–95.6)	6,359	87.1 (86.2–88.0)	9,936	96.3 (95.4–96.9)
Assisted ventilation (bag-valve mask ventilation, intubation, supraglottic airway placement, cricothyrotomy)	498	1.1 (1.0–1.2)	471	6.5 (5.9–7.0)	27 *	0.26 (0.17–0.39)
IV or intraosseus line placement	5,792	22.4 (21.7–23.1)	3,874	53.1 (51.9–54.2)	1,918	17.4 (16.6–18.2)

Characteristics	Total sample (n = 17,633)		Triage positive (n = 7,299)		Triage negative (n = 10,334)	
	Unweighted patients, n	Weighted % (95% CI)	Unweighted patients, n	Weighted % (95% CI)	Unweighted patients, n	Weighted % (95% CI)
Helicopter transport	77	0.15 (0.12–0.18)	69	0.94 (0.74–1.19)	8	0.02 (0.01–0.03)
Initial transport to Level I/II	8,300	30.8 (30.6–30.9)	5,242	71.9 (70.8–72.9)	3,058	24.2 (24.1–24.2)
Mechanism of injury						
Gunshot wound	215	0.48 (0.38–0.60)	197	2.7 (2.3–3.1)	18	0.12 (0.04–0.32)
Stabbing	539	2.5 (2.1–3.1)	311	4.3 (3.7–4.9)	228	2.2 (1.8–2.8)
Assault	687	5.0 (4.5–5.6)	162	2.2 (1.9–2.6)	525	5.5 (4.9–6.2)
Fall	8,427	51.7 (49.8–53.6)	3,128	42.9 (41.6–44.1)	5,299	53.1 (50.9–55.3)
Motor vehicle crash	4,273	21.6 (20.4–22.9)	2,281	31.3 (30.0–32.3)	1,992	20.1 (18.7–21.5)
Motor vehicle vs pedestrian	263	1.1 (0.9–1.4)	160	2.2 (1.8–2.6)	103	1.0 (0.7–1.3)
Other	3,228	17.5 (15.8–19.3)	1,059	14.5 (13.6–15.5)	2,169	18.0 (16.1–20.1)
ED disposition						
Discharge home	8,790	60.0 (51.5–68.0)	1,842	25.1 (17.5–34.6)	6,948	65.7 (56.6–73.7)
Admission to ward	7,008	32.7 (24.2–42.5)	4,225	57.9 (48.1–67.2)	2,783	28.6 (20.1–38.9)
Admission to ICU	892	2.7 (2.3–3.1)	759	10.4 (9.6–11.3)	133	1.5 (1.1–2.0)
Admission to operating room	685	2.9 (1.3–6.3)	394	5.4 (4.2–6.8)	291	2.5 (0.8–7.0)
Transfer	258	1.3 (0.3–5.9)	78	1.0 (0.3–2.8)	180	1.3 (0.3–6.5)
Hospital measures						
Final destination Level I/II	8,554	32.7 (32.4–33.0)	5,333	73.1 (72.0–74.2)	3,221	26.2 (25.9–26.6)
Any inter-hospital transfer	431	2.7 (2.4–3.0)	203	2.8 (2.4–3.2)	228	2.7 (2.3–3.1)
ISS, weighted, mean (95% CI)	3.14 (3.04–3.24)		7.77 (7.53–8.01)		2.40 (2.29–2.50)	

Characteristics	Total sample (n = 17,633)		Triage positive (n = 7,299)		Triage negative (n = 10,334)	
	Unweighted patients, n	Weighted % (95% CI)	Unweighted patients, n	Weighted % (95% CI)	Unweighted patients, n	Weighted % (95% CI)
ISS ≥16	1,198	3.1 (2.8–3.5)	1,093	15.0 (14.1–15.9)	105	1.2 (1.0–1.6)
Critical resource use within 24 h	738	1.7 (1.4–2.0)	695	9.5 (8.8–10.3)	43	0.4 (0.2–0.8)
Orthopaedic surgical procedure (any)	1,526	7.6 (6.5–9.0)	893	12.2 (11.4–13.1)	633	6.9 (5.6–8.5)
In-hospital mortality	247	0.8 (0.6–1.1)	202	2.8 (2.4–3.2)	45	0.5 (0.3–0.8)

Critical resources within 24 hours included emergent intubation in the ED; major nonorthopaedic surgery (ie, brain, spine, neck, thorax, abdominal-pelvic, or vascular surgery); interventional radiology procedures; packed RBC transfusion ≥6 U (or any transfusion in a child); or death.

ED, emergency department; ISS, Injury Severity Score; SBP, systolic blood pressure.

*These patients represent injured persons who met step 1 criteria of the triage algorithm (step 1), but were deemed triage negative by Emergency Medical Services provider application of the algorithm.

Table 3

Components and Timing of Critical Resource Interventions among Injured Patients

	Within 24 h		At any time during ED and hospital stay	
Components	**Patients, unweighted, n**	**Weighted % (95% CI)**	**Patients, unweighted, n**	**Weighted % (95% CI)**
Emergent intubation after arrival to the ED	119	0.35 (0.28–0.43)	119	0.35 (0.28–0.43)
Major nonorthopaedic surgery				
Ventriculostomy or craniotomy	67	0.18 (0.14–0.22)	103	0.32 (0.24–0.40)
ICP monitor	46	0.12 (0.09–0.16)	57	0.18 (0.12–0.24)
Spine surgery	88	0.23 (0.18–0.28)	196	0.70 (0.56–0.84)
Neck surgery	31	0.08 (0.05–0.11)	74	0.24 (0.17–0.31)
Thoracotomy	195	0.53 (0.45–0.61)	290	0.89 (0.76–1.02)
Pericardiocentesis	14	0.04 (0.02–0.06)	14	0.04 (0.02–0.06)
Abdominal or pelvic surgery (including cesarean section)	110	0.29 (0.24–0.35)	147	0.42 (0.34–0.49)
Vascular surgery	284	0.78 (0.68–0.88)	396	1.1 (1.0–1.2)
Interventional radiology	4	0.04 (0.00–0.09)	18	0.11 (0.05–0.18)
Transfusion ≥6 U *	73	0.25 (0.17–0.32)	73	0.25 (0.17–0.32)
Death	53	0.14 (0.10–0.18)	199	0.74 (0.60–0.88)
Composite total	679	2.0 (1.8–2.1)	1,006	3.3 (3.1–3.6)

Numbers for critical resource use represent observed, nonimputed values. There were 738 patients in the fully imputed primary sample (Table 2) who required early resource use vs 679 patients with observed values to detail individual aspects of resource use for Table 3.

* For patients younger than 18 years, this criterion includes any blood transfusion.

ED, emergency department.