# Deaths and high-risk trauma patients missed by standard trauma data sources

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**BACKGROUND:** Trauma registries are used to evaluate and improve trauma care, yet potentially miss certain trauma deaths and high-risk patients. We estimated the number of missed deaths and high-risk trauma patients using commonly available sources of trauma data and resulting bias in quality metrics for field trauma triage.

**METHODS:** This was a preplanned secondary analysis of a population-based prospective cohort of injured patients transported by 44 emergency medical services agencies to 28 hospitals in seven Northwest counties from January 1, 2011 to December 31, 2011 and followed through hospitalization. We used a stratified probability sampling design for 17,633 patients, weighted to represent all 53,487 injured patients transported by emergency medical services. We compared patients meeting National Trauma Data Bank (NTDB) criteria (weighted n = 5,883), all injured patients presenting to major trauma centers (weighted n = 16,859), and all admitted patients (weighted n = 18,433), to the full sample. Outcomes included in-hospital mortality, Injury Severity Score (ISS) of 16 or higher, and critical resource use within 24 hours.

**RESULTS:** Among 53,487 injured patients, there were 520 emergency department and in-hospital deaths, 1,745 with ISS of 16 or higher, and 923 requiring early critical resources. Compared to the full cohort, the NTDB cohort missed 62.1% of deaths, 39.2% of patients with ISS of 16 or higher, and 23.8% requiring early critical resources, especially older adults injured by falls and admitted to nontrauma hospitals. The admission cohort missed the fewest patients—23.3% of deaths, 10.5% with an ISS of 16 or higher, and 13.1% requiring early resources. Compared to triage sensitivity in the full cohort (66.2%), sensitivity estimates ranged from 63.6% (all admissions) to 93.4% (NTDB). Compared to triage specificity in the full cohort (87.8%), estimates ranged from 36.4% (NTDB) to 77.3% (all admissions).

**CONCLUSION:** Common sources of trauma data miss substantial numbers of trauma deaths and high-risk trauma patients and can generate biased estimates for trauma system quality metrics. (*J Trauma Acute Care Surg.* 2017;83: 427–437. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

**LEVEL OF EVIDENCE:** Epidemiologic, level III.

**KEY WORDS:** Trauma; data; bias; emergency medical services.

Trauma registry data are collected by trauma centers to provide a consistent source of detailed injury information, prehospital and in-hospital processes of trauma care, and outcomes. However, most trauma registries only capture a subset of injured patients due to the need to balance the use and accuracy of these data against the resources and costs required to sustain such registries. Upon recognition of the variability in inclusion/exclusion criteria and content of trauma registries across trauma systems,[1] the National Trauma Data Bank (NTDB) was created to standardize the inclusion criteria and definitions for key variables across registries.[2] While trauma registries and the NTDB have been extremely important sources of information for quality improvement and research, the number of trauma deaths and high-risk patients missed by these data sources remains unknown. Similarly, whether missed patients create bias in generating trauma system quality metrics is unclear. Understanding these issues could improve interpretation of quality metrics and research using these data sources, as well as guide development of more comprehensive data systems for trauma.

In a recent report from the National Academy of Sciences, the concept of a National Trauma Care System was detailed, including recommendations for development of data systems that capture information across the full trauma patient experience.[3] The report describes the inconsistent capture and linkage of prehospital data to emergency department (ED) and inpatient data for trauma patients as one area of focus in building a "learning trauma care system."[3] Because most of the seriously injured patients in civilian trauma systems present through the 9-1-1 system, linking prehospital data to subsequent phases of care is critical in measuring the ability to efficiently concentrate all high-risk patients in major trauma centers and in achieving zero preventable deaths. Metrics such as undertriage (seriously injured patients transported to nontrauma hospitals) and overtriage (patients without serious injuries transported to major trauma centers) are used to assess this ability, with national targets for accuracy.[4] Whether current trauma data systems generate valid estimates for these measures is unclear. Missed patients and systematically biased estimates for trauma system performance may misinform key decision makers and detract from a comprehensive learning trauma care system.

In this study, we conducted a preplanned secondary analysis of a prospective injury cohort transported by 9-1-1 emergency services in seven Northwest counties[5] to estimate the number of missed trauma deaths and high-risk patients using three commonly available sources of trauma data, compared to

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Findings from this study have not been presented at any national or regional meetings.
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a population-based sample. We also assessed the magnitude of bias in calculating standard field triage accuracy metrics using each of these data sources.

# METHODS

## Study Design

This was a preplanned secondary analysis of a population-based, prospective, consecutive patient cohort in seven counties in the Northwestern United States used to validate the national field triage guidelines.[5] The study was reviewed and approved by institutional review boards in all study sites with a waiver of the requirement for informed consent.

## Study Setting

We conducted the study with 44 emergency medical services (EMS) agencies in seven counties in Oregon and Washington from January 1, 2011 through December 31, 2011. The counties represented urban, suburban, rural, and frontier regions. Of 37 nonfederal acute care hospitals in the seven counties, we included 28 hospitals for data collection, representing 83.2% of injured patients transported by EMS in these regions. The hospitals included trauma and nontrauma centers, with varying resource capabilities: five Level I trauma centers (including two children's hospitals); two Level II trauma centers; five Level III trauma hospitals; five Level IV hospitals; and 11 nondesignated hospitals. Trauma centers in these regions are designated by state authorities or verified by the American College of Surgeons Committee on Trauma (ACSCOT). We defined a "major trauma center" as a Level I or II trauma hospital, consistent with ACSCOT guidelines for tertiary trauma care[4] and local practices within these regions. We matched prehospital to hospital data and tracked patients throughout their hospital stay, including transfers between hospitals. The participating EMS agencies work under close medical direction, use standardized field trauma triage protocols based on national guidelines, and regularly train providers based on updates and revisions to the triage algorithm. The methodology of the parent study has been described in detail elsewhere.[5]

## Patient Population and Defining the Cohorts

The primary cohort (Cohort 1) included all injured children and adults in the seven counties transported by EMS. To create a representative sample feasible for chart abstraction at the 28 hospitals, we used a stratified probability sampling design using the following strata: geographic region, triage status, age, and type of receiving hospital.[5] The sample size for the primary cohort was based on the desired precision of estimates for field triage sensitivity, as detailed previously.[5] The sampling design provided a population-based out-of-hospital injury cohort, representing the full denominator of injured patients served by EMS for whom the field triage guidelines are routinely applied, regardless of ED or hospital disposition. Interhospital transfers with an initial EMS transport within the seven counties were included in the sample. Deaths in the field and nontransported patients were excluded. Every aspect of the parent study was designed to minimize bias in the estimation of field triage accuracy metrics and identify all high-risk patients in these regions.[5]

Each of the three additional cohorts represents a subcohort of Cohort 1 and is intended to exemplify commonly available sources of trauma data used for quality assurance and trauma research. The cohorts are listed in order of decreasing sample size and increasing restrictiveness of inclusion/exclusion criteria. Cohort 2 included all patients transported by EMS and admitted to a hospital (including patients transferred between hospitals), reflecting patients captured in administrative hospital discharge databases such as the National Inpatient Sample[6] and state inpatient discharge databases.[7] Cohort 3 included all injured patients transported by EMS to major trauma centers (Level I or II hospitals). This cohort reflects the injured patient population accessible in major trauma centers, including patients discharged from the ED[8] and excluded from NTDB inclusion criteria.[2] Finally, Cohort 4 included all patients transported by EMS to major trauma centers and meeting standard NTDB inclusion/exclusion criteria: *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis code in 800–959.9, except for 905–909.9 (late effects of injury), 910–924.9 (superficial injuries and contusions), and 930–939.9 (foreign bodies), plus admission to a trauma center, in-hospital death (in a trauma center), or transfer to/from a trauma center.[2] Cohort 4 represents a typical trauma registry population using standardized national criteria.

## Variables

We defined triage status (positive vs. negative) using three closely related definitions of field triage: (1) field identification, based on EMS provider use of the national field triage decision scheme; (2) initial hospital destination (major trauma center vs. other hospital); and (3) final hospital destination (major trauma center vs. other hospital), after accounting for interhospital transfers. We triangulated multiple data sources (EMS charts, matched trauma registry records, and matched base hospital phone records) to generate triage status[5] and minimize misclassification bias. We have used this strategy successfully in previous research.[9,10]

We collected multiple out-of-hospital variables from EMS electronic patient care reports, mapped to standardized National EMS Information System definitions.[11] These variables included the following: patients' demographics; initial out-of-hospital physiology (systolic blood pressure [SBP] and Glasgow Coma Scale score); assisted ventilation (bag-valve mask ventilation, supraglottic device, or endotracheal intubation); intravenous line placement; mechanism of injury; air versus ground transport; and initial receiving hospital. We have previously validated the electronic EMS data collection processes used in this study against manually abstracted EMS charts for injured patients.[12]

Trained data abstractors collected all ED and hospital variables using a standardized data collection form. These variables included the presence and timing of airway management, surgical procedures, blood product transfusion, intensive care unit stay, duration of hospital stay, interhospital transfer, Abbreviated Injury Scale (AIS) scores,[13] and in-hospital mortality. For patients transferred between hospitals, we abstracted records at both facilities. To supplement the abstracted hospital data, we matched records from nine trauma registries to the sample. A portion of hospital records was double-abstracted to assure reliable and consistent chart abstraction.[5]

**TABLE 1.** Characteristics of Injured Patients Transported by EMS in Seven Counties Using Inclusion/Exclusion Criteria for Common Sources of Trauma Data*

| | Cohort 1: All Injured Patients Transported by EMS** (Population-Based Full Sample) | Cohort 2: Injured Patients Transported by EMS and Admitted (Hospital Discharge Sample) | Cohort 3: Injured Patients Transported by EMS to Level I/II Trauma Centers (Trauma Center Sample) | Cohort 4: Injured Patients Transported by EMS to Level I/II Trauma Centers and Meeting Standard Trauma Registry Inclusion Criteria (Standardized Trauma Registry Sample) |
|---|---|---|---|---|
| No. of patients | 17,633 | 7,613 | 8,440 | 4,466 |
| Weighted no. of patients | 53,487 | 18,433 | 16,859 | 5,883 |
| Patients' characteristics: | | | | |
| Age, mean | 51.6 years | 58.2 years | 43.4 years | 46.6 years |
| 0–14 years | 6.6% | 4.2% | 8.2% | 8.3% |
| 15–54 years | 48.2% | 38.8% | 61.5% | 54.1% |
| ≥55 years | 45.3% | 56.9% | 30.3% | 37.6% |
| Women | 52.0% | 53.2% | 41.4% | 39.2% |
| Met ≥ 1 field triage criteria, per EMS | 13.9% | 26.1% | 32.0% | 69.0% |
| Mechanism of injury | | | | |
| Gunshot wound | 0.5% | 0.8% | 1.2% | 2.3% |
| Stabbing | 2.5% | 2.2% | 4.4% | 4.1% |
| Assault | 5.0% | 2.5% | 6.5% | 2.6% |
| Fall | 51.7% | 61.5% | 41.3% | 44.3% |
| Motor vehicle crash | 21.6% | 17.4% | 25.4% | 28.2% |
| Motor vehicle vs. pedestrian | 1.1% | 0.8% | 1.2% | 1.5% |
| Other | 17.5% | 14.8% | 20.0% | 17.0% |
| Out-of-hospital physiology and interventions | | | | |
| SBP < 90 mm Hg | 1.5% | 2.2% | 2.0% | 3.4% |
| GCS ≤ 8 | 0.9% | 1.6% | 2.4% | 5.4% |
| GCS 9–12 | 4.1% | 4.6% | 4.6% | 6.7% |
| GCS 13–15 | 95.0% | 93.8% | 93.0% | 87.9% |
| Assisted ventilation | 1.1% | 2.3% | 2.8% | 7.1% |
| Helicopter transport from scene | 0.2% | 0.4% | 0.4% | 0.9% |
| Initial hospital destination | | | | |
| Level I/II | 30.8% | 34.8% | 97.6% | 94.5% |
| Non–Level I/II hospital† | 69.2% | 65.2% | 2.4% | 5.5% |
| Injury severity, resource use, and outcome measures | | | | |
| ISS, mean | 3.1 | 5.7 | 4.2 | 8.8 |
| ISS, 0–8 | 88.5% | 72.5% | 82.9% | 56.7% |
| ISS, 9–15 | 8.2% | 19.0% | 10.5% | 25.3% |
| ISS, 16–24 | 2.1% | 5.6% | 3.9% | 10.3% |
| ISS ≥ 25 | 1.1% | 2.9% | 2.8% | 7.7% |
| Early critical resource need‡ | 1.7% | 4.4% | 4.6% | 11.9% |
| In-hospital mortality | 0.8% | 2.2% | 1.3% | 3.3% |

**Cohort 1* included all injured patients transported by EMS to 28 trauma and nontrauma hospitals, intentionally sampled to eliminate selection bias. *Cohort 2* included all patients in Cohort 1 who were admitted to the 28 hospitals. *Cohort 3* included all patients in Cohort 1 cared for in a Level I or II trauma center (including patients discharged from the ED). *Cohort 4* included all patients in Cohort 1 who met the National Trauma Data Bank standardized trauma registry inclusion criteria: *ICD9* 800–959.9 (excluding 905–909.9 [late effects of injury], 910–924.9 [superficial injuries and contusions], and 930–939.9 [foreign bodies]), with presentation to a Level I or II trauma center and death, admission, or transfer (in or out).[2] Each of the four cohorts included transfer patients, provided they were initially transported by EMS within the seven study counties.

GCS, Glasgow Coma Scale; ISS, Injury Severity Score; SBP, systolic blood pressure. Out-of-hospital assisted ventilation included bag-valve mask ventilation, intubation, supraglottic airway placement, and cricothyrotomy.

**Estimates from Reference #3: Newgard CD, Fu R, Zive D, et al. Prospective validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons. *J Am Coll Surg*. 2016;222(2):146–158.

†Non–Level I/II hospitals included Level III and IV trauma hospitals, as well as nontrauma centers.

‡Early critical resource need was defined as any of the following within 24 hours of arrival at the ED: emergent intubation in the ED; major nonorthopedic surgery (brain, spine, neck, thorax, abdominal-pelvic, or vascular surgery); interventional radiology procedures; packed red blood cell transfusion ≥ 6 units (or any transfusion in a child); or death.

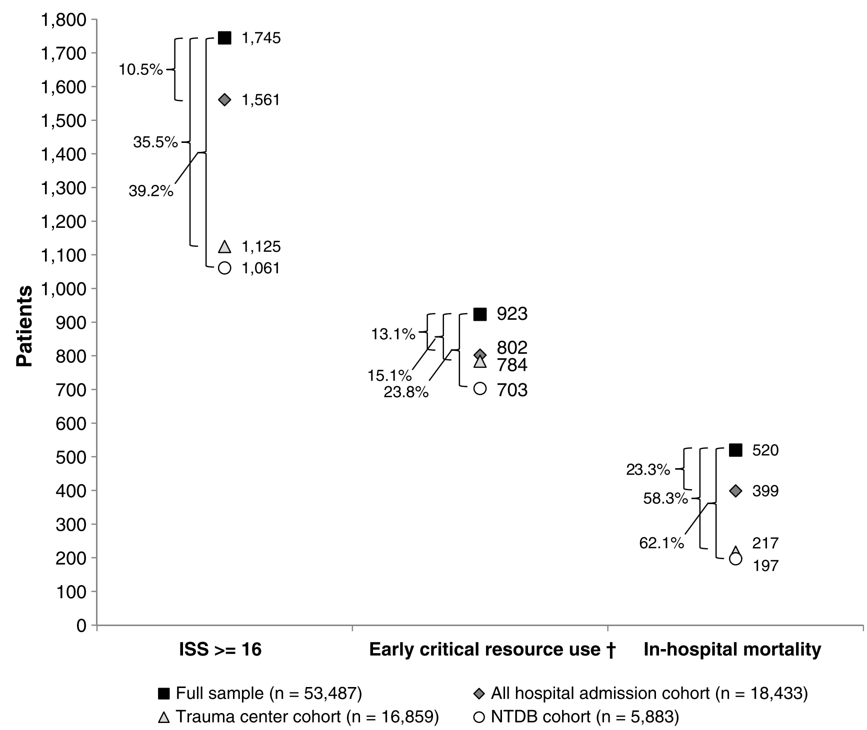


**Figure 1.** Number of trauma deaths and high-risk patients transported by *EMS* and captured using common trauma data sources. **Cohort 1* included all injured patients transported by *EMS* to 28 trauma and nontrauma hospitals, intentionally sampled to eliminate selection bias. *Cohort 2* included all patients in *Cohort 1* who were admitted to the 28 hospitals. *Cohort 3* included all patients in *Cohort 1* cared for in a Level I or II trauma center (including patients discharged from the *ED*). *Cohort 4* included all patients in *Cohort 1* who met the National Trauma Data Bank standardized trauma registry inclusion criteria: *ICD9* 800–959.9 (excluding 905–909.9 [late effects of injury], 910–924.9 [superficial injuries and contusions], and 930–939.9 [foreign bodies]), with presentation to a Level I or II trauma center and death, admission, or transfer (in or out).[2] Each of the four cohorts included transfer patients, provided they were initially transported by *EMS* within the seven study counties. †Early critical resource need was defined as any of the following within 24 hours of arrival at the *ED*: emergent intubation in the *ED*; major nonorthopedic surgery (brain, spine, neck, thorax, abdominal-pelvic or vascular surgery); interventional radiology procedures; packed red blood cell transfusion ≥ 6 units (or any transfusion in a child); or death.

## Outcomes

We used all in-hospital (ED and inpatient) deaths and defined "high-risk" trauma patients as Injury Severity Score (ISS) of 16 or higher or early critical resource use. Injury Severity Score of 16 or higher is generated from AIS values,[13] is recommended by ACSCOT for tracking triage accuracy within trauma systems,[4] and identifies the subset of injured patients at high risk of mortality[14] and most likely to benefit from care in major trauma centers.[15,16] We defined early critical resource use as any of the following within 24 hours of ED arrival: emergent intubation in the ED, major nonorthopedic surgical intervention, interventional radiology procedures, blood transfusion 6 units or more (or any blood transfusion in a child) or death. This definition is based on previous trauma triage research,[17–22] a national consensus study defining trauma center "need"[23] and a five-member advisory committee of trauma and EMS experts used for the parent study.[5]

## Statistical Analysis

We used descriptive statistics to characterize each of the cohorts. Sample strata and probability weights were incorporated in all analyses. Because the probability sample was designed to represent the full cohort of injured patients transported by EMS in the seven counties (n = 53,487), all absolute numbers are presented as weighted numbers to assure consistent, comparable estimates between cohorts. We considered the primary cohort to provide the most comprehensive and least biased estimates for trauma deaths, high-risk trauma patients, and accuracy measures for field triage based on comprehensive patient sampling[5] and previous retrospective research.[9,12]

To minimize bias and preserve study power, we used multiple imputation for missing values.[24,25] We have demonstrated the validity and rigor of using multiple imputation to handle missing trauma and EMS data.[9,26,27] We used flexible chains regression models for multiple imputation[28] with generation of 10 multiply imputed data sets using IVEware (Institute for Social Research, University of Michigan, MI). All estimates and confidence intervals were generated using Rubin's rules to appropriately account for variance within and between data sets.[25]

We used SAS v.9.3 (SAS Institute Inc., Cary, NC) for database management and all statistical analyses.

# RESULTS

During the 12-month period, 67,047 injured patients were evaluated by EMS, of which 53,487 (79.8%) were transported to acute care hospitals, 158 (0.2%) died in the field, and 13,402 (20.0%) were not transported to acute care hospitals. Cohort 1 (primary cohort) included a probability sample of 17,633 injured patients transported to 28 hospitals (78.9% in-hospital follow-up), weighted to represent the 53,487 transported patients. Compared to the primary cohort, each of the three subcohorts differed in sample size, characteristics, injury severity, resource use, and mortality (Table 1). Patients in Cohort 2 (admission cohort) were older, with more falls, higher injury severity, and higher mortality. Patients in Cohort 3 (trauma center cohort) and Cohort 4 (trauma registry cohort) were younger, with more penetrating injury, fewer falls, more severe injuries, greater need for early critical resources, and higher mortality. Compared to Cohort 1 (in-hospital mortality, 0.8%; early critical resource use, 1.7%), Cohorts 2 to 4 had higher estimates for in-hospital mortality (1.3–3.3%) and early critical resource use (4.4–11.9%).

In the full sample of 53,487 injured patients transported by EMS, there were 520 ED and in-hospital deaths, 1,745 with ISS of 16 or higher, and 923 requiring early critical resources. Figure 1 depicts differences in the absolute number of high-risk trauma patients captured in each of the cohorts. Compared to Cohort 1, all subcohorts failed to identify a portion of high-risk trauma patients. Cohort 4 (NTDB criteria) missed the greatest percentage of high-risk patients (62.1% of ED and in-hospital deaths, 39.2% with ISS of 16 or higher, and 23.8% requiring early critical resources), while Cohort 2 (admission cohort) missed the fewest (23.3% of ED and in-hospital deaths, 10.5% of patients with ISS of 16 or higher, and 13.1% with early critical resource use). Figure 1 focuses on patients transported by EMS to a hospital. When deaths in the field (n = 158, 23.3% of 678 total deaths following injury) are included in this assessment, the number of deaths missed in each of the cohorts is further increased.

In Table 2, we characterize trauma deaths and high-risk patients missed by NTDB inclusion/exclusion criteria. Most of the missed patients were older, injured by falls, and cared for outside of major trauma centers. While 29.5% of missed patients with ISS of 16 or higher were transferred, only 5.6% of missed deaths and no missed patients requiring critical early resources were transferred. Ninety-four percent of in-hospital deaths missed by NTDB criteria occurred in nontrauma hospitals, with mean time-to-death of 2.9 days (range, 0–19 days). There was a wide range of primary *ICD9* diagnosis codes, with no single type of injury or illness represented in the majority of missed patients.

In Figure 2*A*, we illustrate differences in field triage *sensitivity* for patients with ISS of 16 or higher between the cohorts. Compared to the previously published estimate for field triage sensitivity for cohort 1 (66.2%; 95% confidence interval [CI], 60.2–71.7%),[5] subcohort estimates ranged from 63.6% (95% CI, 58.0–68.9%) for admissions to 93.4% (95% CI, 88.6–96.3%) for NTDB patients. For early critical resource use (Fig. 2*B*) and a full cohort triage sensitivity of 80.1% (95% CI, 65.8–89.4%),[5] subcohort values ranged from 80.6% (95% CI, 64.8–90.4%) for admissions to 95.8% (95% CI, 79.9–99.3%) for NTDB patients. Comparisons of triage sensitivity based on initial hospital and final hospital were similar or more biased compared to the full cohort.

In Figure 3*A*, we demonstrate differences in the *specificity* of field triage between the cohorts. In all subcohorts, specificity was biased toward lower values. Compared to the full cohort triage specificity for ISS of 16 or higher (87.8%; 95% CI, 87.7–88.0%),[5] specificity in the three subcohorts ranged from 77.3% (95% CI, 75.0–79.5%) for admissions to 36.4% (95% CI, 32.5–40.4%) for NTDB patients. For early critical resource use (Fig. 3*B*), the full cohort specificity estimate was 87.3% (95% CI, 87.1–87.4%),[5] compared to values ranging from 76.3% (95% CI, 74.0–78.5%) for admissions to 34.5% (95% CI, 30.9–38.3%) for NTDB patients. Differences in triage specificity were more marked when evaluated by initial and final hospital.

## DISCUSSION

In this study, we estimate the number of missed deaths and high-risk trauma patients using common sources of trauma data, as well as the magnitude and direction of bias in calculating field triage accuracy measures with these data. Standardized trauma registry criteria (i.e., NTDB criteria) failed to identify a substantial number of deaths and high-risk patients. Using the NTDB cohort, field triage sensitivity appeared high and specificity low, a pattern opposite to estimates generated from the population-based sample.[5] Our findings call into question the validity of certain system-level performance measures generated using standard trauma registry inclusion criteria. Other potential sources of trauma data (e.g., all hospital admissions or all injured patients presenting to major trauma centers) also missed important trauma patients and yielded biased estimates for field triage, although not to the same extent as the NTDB criteria.

Effective trauma quality assurance processes are contingent on the use of comprehensive, valid, and unbiased data. That is, making hospital- or system-level changes to improve trauma care requires faith that the data used for such purposes are accurate. For trauma systems, trauma registries typically serve as the source of such data. While registry data are generally collected by trained data abstractors and are closely monitored for quality and consistency, there has been less attention to the potential for missed patients and the effect on quality measures. Our results illustrate that standard trauma registry inclusion criteria miss a substantial proportion of important patients and outcomes, particularly for patients transported to nontrauma hospitals. Use of a less restricted cohort from trauma centers did little to improve these estimates. Our findings may help explain some of the variability in published estimates for field triage accuracy, especially from early research suggesting that field triage practices were highly sensitive but nonspecific.[29–31] An important consequence of such biased estimates is the potential to misinform policy decisions at the local, state, and national levels.

Obtaining broad patient capture and unbiased estimates of trauma system performance is time consuming, resource intensive, expensive, and therefore not feasible for most trauma systems. There is an inevitable trade-off between the comprehensiveness of patient sampling (capture) and the resources required to obtain such data. Our results suggest that regional hospital discharge data (e.g., state inpatient data[7]) miss the fewest deaths and high-risk patients while also providing the least biased estimates for field triage sensitivity and (to a lesser extent)

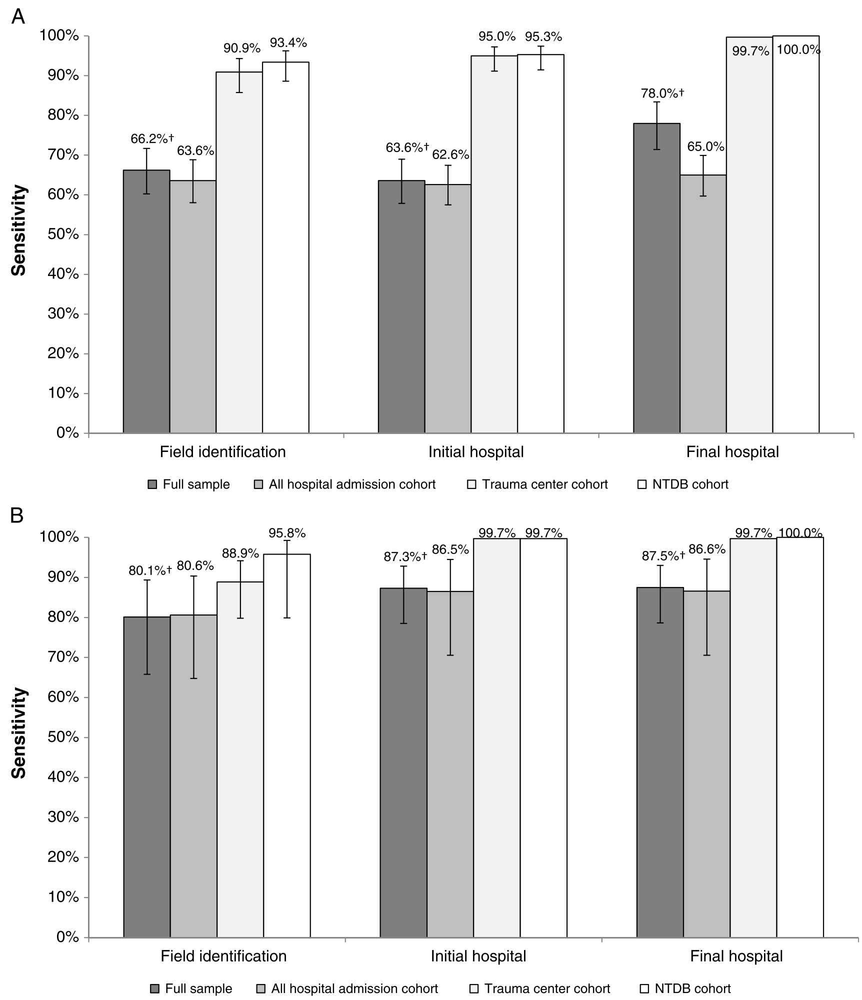


**Figure 2.** Triage sensitivity calculated using common trauma data sources and a population-based cohort, separated by the three phases of triage (field identification, initial hospital selection, and final hospital destination). (*A*) Injury Severity Score ≥ 16. (*B*) Early critical resource use. **Cohort 1* included all injured patients transported by *EMS* to 28 trauma and nontrauma hospitals, intentionally sampled to eliminate selection bias. *Cohort 2* included all patients in *Cohort 1* who were admitted to the 28 hospitals. *Cohort 3* included all patients in *Cohort 1* cared for in a Level I or II trauma center (including patients discharged from the *ED*). *Cohort 4* included all patients in *Cohort 1* who met the National Trauma Data Bank standardized trauma registry inclusion criteria: *ICD9* 800–959.9 (excluding 905–909.9 [late effects of injury], 910–924.9 [superficial injuries and contusions], and 930–939.9 [foreign bodies]), with presentation to a Level I or II trauma center and death, admission, or transfer (in or out).[2] Each of the four cohorts included transfer patients, provided they were initially transported by *EMS* within the seven study counties. †Estimates from reference #3: Newgard CD, Fu R, Zive D, et al. Prospective validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons. *J Am Coll Surg.* 2016;222(2): 146–158. ‡Early critical resource need was defined as any of the following within 24 hours of arrival at the emergency department: emergent intubation in the emergency department; major non-orthopedic surgery (brain, spine, neck, thorax, abdominal-pelvic or vascular surgery); interventional radiology procedures; packed red blood cell transfusion ≥ 6 units (or any transfusion in a child); or death.

specificity. However, administrative hospital discharge data sources have limitations, including poor timeliness, requirement for ICD mapping programs to generate injury severity,[32–34] exclusion of nonadmitted patients (e.g., deaths in the ED), and lack of detail that is provided in trauma registries (e.g., mode of arrival, physiologic information, injury severity coding, etc.).

Characterization of traumatic deaths and high-risk patients missed by standard trauma registry criteria provides important insight for future trauma data systems. Missed patients tended to be older, injured by falls and cared for in non-trauma hospitals. These findings refute the belief that trauma centers and trauma registries capture all high-risk patients in trauma systems. The findings also highlight an increasing concern about mismatches between patient's need and hospital capability, especially regarding the care of injured older adults.[5,10,35–37] While reasons for these mismatches and missed patients remain unclear, they may relate to patient preference,[38] high decision thresholds for transfer from nontrauma centers,[39] hospital-level variability in trauma transfer practices,[40,41] end-of-life preferences, financial pressures, provider bias, and initial transport decisions made by EMS. All current trauma data sources missed high-risk trauma patients, yet the all-hospital admission cohort missed the fewest and may offer the least biased perspective on injured patients using existing data sources.

**TABLE 2.** Characteristics of Trauma Deaths and High-Risk Patients Missed by NTDB Inclusion/Exclusion Criteria*

| | ISS ≥ 16 | Early Critical Resource Use | In-Hospital Deaths |
|---|---|---|---|
| Weighted no. of patients | 684 | 220 | 323 |
| % missed | 39.2% | 23.8% | 62.1% |
| Patients' characteristics | | | |
| Age, mean | 62.8 | 57.4 | 77.6 |
| 0–14 years | 1.5% | 2.1% | 0.4% |
| 15–54 years | 30.2% | 41.2% | 8.6% |
| ≥55 years | 68.2% | 56.6% | 91.0% |
| Women | 46.3% | 47.4% | 61.6% |
| Met ≥ 1 field triage criteria, per EMS | 17.4% | 20.0% | 7.2% |
| Mechanism of injury | | | |
| Gunshot wound | 0.5% | 1.3% | 0.1% |
| Stabbing | 0.9% | 8.8% | 1.3% |
| Assault | 2.5% | 8.0% | 0.4% |
| Fall | 67.4% | 55.6% | 77.3% |
| Motor vehicle crash | 14.5% | 11.6% | 6.6% |
| Motor vehicle vs. pedestrian | 0.7% | 0.3% | 0.5% |
| Other | 13.5% | 14.4% | 13.8% |
| Out-of-hospital physiology and interventions | | | |
| SBP < 90 mm Hg | 3.3% | 5.6% | 5.2% |
| GCS ≤ 8 | 3.6% | 6.7% | 7.4% |
| GCS, 9–12 | 6.1% | 8.7% | 16.6% |
| GCS, 13–15 | 90.3% | 84.6% | 76.0% |
| Assisted ventilation | 2.7% | 8.3% | 4.9% |
| Helicopter transport from scene | 0.4% | 0.7% | 0.1% |
| Initial hospital destination | | | |
| Level I/II | 8.3% | 36.9% | 6.0% |
| Nontrauma center† | 91.7% | 63.1% | 94.0% |
| Transfer from initial hospital | 29.5% | 0% | 5.6% |
| Final hospital | | | |
| Level I/II | 9.4% | 36.9% | 6.0% |
| Non–Level I/II hospital* | 90.6% | 63.1% | 94.0% |
| Hospital measures and outcomes | | | |
| *ICD9* diseases and injuries tabular index: | Injury and poisoning—80.5% | Injury and poisoning—43.1% | Injury and poisoning—49.3% |
| | Endocrine, nutritional/metabolic, and immunity disorders—6.9% | Endocrine, nutritional/metabolic, and immunity disorders—20.0% | Infectious and parasitic diseases—14.0% |
| | Circulatory system—4.1% | Nervous system—8.1% | Endocrine, nutritional/metabolic, and immunity disorders—8.2% |
| | Infectious and parasitic diseases—1.8% | Circulatory system—8.0% | Circulatory system—8.2% |
| | Blood and blood-forming organs—1.8% | Infectious and parasitic diseases—6.9% | Blood and blood-forming organs—7.0% |
| | Mental disorders—1.8% | | Nervous system—7.0% |
| Top ICD9 diagnoses: | Intracranial injury (ICD9, 850–854) and fracture of skull (*ICD9*, 800–804)—36.6% | Fracture of lower limb (ICD9 820–829)—16.5% | Septicemia and bacterial infection (ICD9 38–41)—14.0% |
| | Fracture of neck and trunk (*ICD9*, 805–809)—21.2% | Malnutrition (ICD9 263.9)—12.3% | Intracranial injury (ICD9 850–854) and Fracture of Skull (ICD9 800–804)—11.7% |
| | Internal injury of thorax, abdomen, and pelvis (*ICD9*, 860–869)—10.5% | Disorders of thyroid and other endocrine glands (ICD9, 240–259)—8.2% | Fracture of lower limb (ICD9 820–829)—8.4% |
| ISS, mean | 20.4 | 7.2 | 10.9 |
| ISS, 0–8 | 0% | 61.1% | 53.4% |
| ISS, 9–15 | 0% | 25.5% | 16.1% |
| ISS 16–24 | 77.7% | 9.2% | 11.4% |
| ISS ≥ 25 | 22.3% | 4.1% | 19.0% |
| Early critical resource need‡ | 4.3% | 100% | 7.0% |
| Duration of hospital stay–mean | 5.8 days | 4.5 days | 2.9 days |
| In-hospital mortality | 14.4% | 10.2% | 100% |

*Standard trauma registry inclusion criteria were defined based on the National Trauma Data Bank standardized trauma registry inclusion criteria: *ICD9* 800–959.9 (excluding 905–909.9 [late effects of injury], 910–924.9 [superficial injuries and contusions], and 930–939.9 [foreign bodies]), with presentation to a Level I or II trauma center and death, admission, or transfer (in or out).[2]

Out-of-hospital assisted ventilation included bag-valve mask ventilation, intubation, supraglottic airway placement, and cricothyrotomy.

†Non–Level I/II hospitals included Level III and IV trauma hospitals, as well as nontrauma centers.

‡Early critical resource need was defined as any of the following within 24 hours of arrival at the ED: emergent intubation in the ED; major nonorthopedic surgery (brain, spine, neck, thorax, abdominal-pelvic, or vascular surgery); interventional radiology procedures; packed red blood cell transfusion ≥ 6 units (or any transfusion in a child); or death.

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There are limitations to consider in this study. We assumed that our primary cohort provided unbiased estimates of field triage accuracy and 100% capture of high-risk trauma patients. While we were careful to design the parent study to ensure broad patient capture and to avoid common sources of bias, it is possible that these estimates were biased if the distribution of patients' characteristics and outcomes at nonparticipating hospitals were different from those at participating hospitals. In addition, this

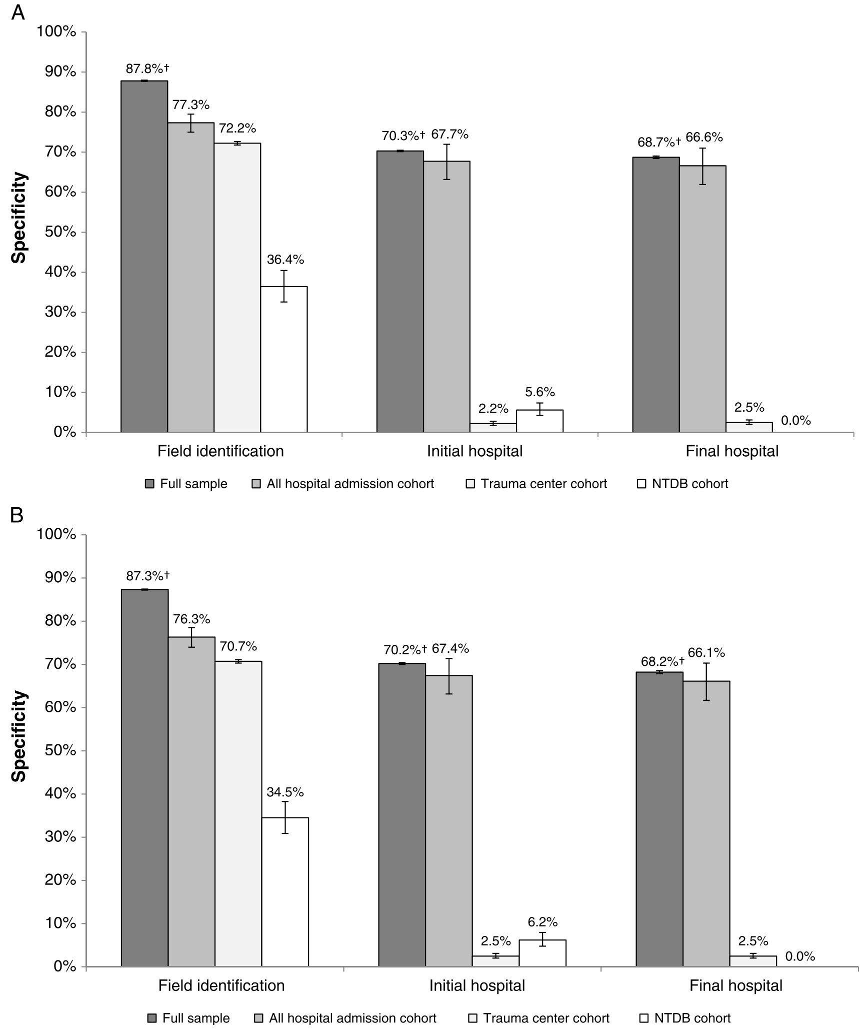


**Figure 3.** Triage specificity calculated for four trauma cohorts, separated by the three phases of triage (field identification, initial hospital selection, and final hospital destination). (*A*) Injury Severity Score ≥ 16. (*B*) Early critical resource use. **Cohort 1* included all injured patients transported by *EMS* to 28 trauma and nontrauma hospitals, intentionally sampled to eliminate selection bias. *Cohort 2* included all patients in *Cohort 1* who were admitted to the 28 hospitals. *Cohort 3* included all patients in *Cohort 1* cared for in a Level I or II trauma center (including patients discharged from the *ED*). *Cohort 4* included all patients in *Cohort 1* who met the National Trauma Data Bank standardized trauma registry inclusion criteria: *ICD9* 800–959.9 (excluding 905–909.9 [late effects of injury], 910–924.9 [superficial injuries and contusions], and 930–939.9 [foreign bodies]), with presentation to a Level I or II trauma center and death, admission, or transfer (in or out).[2] Each of the four cohorts included transfer patients, provided they were initially transported by *EMS* within the seven study counties. †Estimates from Reference 3, Newgard CD, Fu R, Zive D, et al. Prospective validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons. *J Am Coll Surg.* 2016;222(2):146–158. ‡Early critical resource need was defined as any of the following within 24 hours of arrival at the *ED*: emergent intubation in the *ED*; major nonorthopedic surgery (brain, spine, neck, thorax, abdominal-pelvic or vascular surgery); interventional radiology procedures; packed red blood cell transfusion ≥ 6 units (or any transfusion in a child); or death.

sample did not include injured patients arriving to hospitals outside of the 9-1-1 emergency care system.

These data come from two Northwest states with mature, inclusive trauma systems. Therefore, our estimates may not necessarily reflect other trauma systems. We used *ICD9* discharge diagnose codes to characterize patients missed by trauma registries, which were limited by known diagnoses and the order in which they were listed. In addition, we defined the trauma registry cohort using standardized NTDB inclusion criteria, yet individual hospital registries or state trauma systems may be broader and more comprehensive than the criteria used for the NTDB.

In summary, commonly used sources of trauma data missed a substantive portion of trauma deaths and high-risk trauma patients, and yielded biased estimates of field triage accuracy. These findings suggest that trauma system quality metrics generated from these data sources are at risk of bias and may yield potentially misleading conclusions. There is an opportunity to optimize future trauma data systems for comprehensive patient capture and accurate quality metrics.

 

## AUTHORSHIP

C.N. and R.F. conceptualized and designed the study. C.N., R.F., M.D., J.J., E.B., L.W., and T.R. collected the data. C.N. and R.F. analyzed the data. C.N., R.F., E.B.L., M.D., D.W., J.J., N.C.M., E.B., J.H., L.W., D.L., and T.R. interpreted the data. C.N. obtained funding for this work. C.N. drafted the manuscript. C.N., R.F., E.B.L., M.D., D.W., J.J., N.C.M., E.B., J.H., L.W.,D.L., and T.R. critically revised the manuscript.

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## DISCLOSURE

The authors declare no conflicts of interest.
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