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Improving Early Identification of the High-Risk Elderly Trauma Patient By Emergency Medical Services

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Abstract

Study Objective—We sought to (1) define the high-risk elderly trauma patient based on prognostic differences associated with different injury patterns and (2) derive alternative field trauma triage guidelines that mesh with national field triage guidelines to improve identification of high-risk elderly patients.

Methods—This was a retrospective cohort study of injured adults ≥ 65 years transported by 94 EMS agencies to 122 hospitals in 7 regions from 1/1/2006 through 12/31/2008. We tracked

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current field triage practices by EMS, patient demographics, out-of-hospital physiology, procedures and mechanism of injury. Outcomes included Injury Severity Score ≥ 16 and specific anatomic patterns of serious injury using Abbreviated Injury Scale score ≥ 3 and surgical interventions. In-hospital mortality was used as a measure of prognosis for different injury patterns.

Results—33,298 injured elderly patients were transported by EMS, including 4.5% with ISS ≥ 16, 4.8% with serious brain injury, 3.4% with serious chest injury, 1.6% with serious abdominal-pelvic injury and 29.2% with serious extremity injury. In-hospital mortality ranged from 18.7% (95% CI 16.7–20.7) for ISS ≥ 16 to 2.9% (95% CI 2.6–3.3) for serious extremity injury. The alternative triage guidelines (any positive criterion from the current guidelines, GCS ≤ 14 or abnormal vital signs) outperformed current field triage practices for identifying patients with ISS ≥ 16: sensitivity (92.1% [95% CI 89.6–94.1%] vs. 75.9% [95% CI 72.3–79.2%]), specificity (41.5% [95% CI 40.6–42.4%] vs. 77.8% [95% CI 77.1–78.5%]). Sensitivity decreased for individual injury patterns, but was higher than current triage practices.

Conclusions—High-risk elderly trauma patients can be defined by ISS ≥ 16 or specific non-extremity injury patterns. The field triage guidelines could be improved to better identify high-risk elderly trauma patients by EMS, with a reduction in triage specificity.

INTRODUCTION

Injuries in older adults are common and often involve use of emergency medical services (EMS).[1,2] Current field trauma triage processes fail to identify a large proportion of seriously injured older patients, many of whom are transported to non-trauma hospitals (termed “under-triage”). [3–8] This mismatch between patient need and hospital capability is a disparity in care that can result in worse clinical outcomes.[9,10] As the population of older adults in the U.S. continues to increase, under-triage and resulting disparities in trauma care are likely to become further exaggerated unless system-level changes are implemented. While the national field triage guidelines have been modified in an effort to close this gap,[11] little evidence exists that these changes have been successful and out-of-hospital research on injured older adults remains sparse.

Elderly trauma patients are unique compared to younger patients. They can incur life-threatening injuries from low velocity mechanisms (e.g., ground-level fall[12,13]) and have a much higher prevalence of comorbid conditions and frailty compared to younger patients. Older adults take more medications (including medications potentially worsening injury[14,15]) and have different physiologic responses to injury.[16,17] They often have more complex medical and surgical decision-making than younger patients,[18] including end-of-life considerations. Thus, the one-size-fits-all approach to field triage guidelines may be inadequate for injured elderly patients. Previous studies have explored elderly-specific triage criteria,[19–21] although there is a need to pull these modifications together in a manner that allows integration with the current national triage guidelines and to compare with current triage processes. Defining “serious injury” in older adults also remains unclear, as definitions used for younger populations may not be appropriate.

Using a large multi-site cohort of injured adults ≥ 65 years transported by EMS, we sought to: (1) define the high-risk injured older adult using prognostic differences associated with different injury patterns; and (2) derive alternative field trauma triage guidelines that mesh with current national guidelines to improve identification of high-risk elderly trauma patients. This study builds upon recent work developing triage guidelines specific to injured older adults.[19–21] Sixteen Institutional Review Boards at 7 sites approved this protocol and waived the requirement for informed consent.

MATERIALS and METHODS

Study Design

This was a multi-site retrospective cohort study.

Study Setting

The study included injured older adults who were evaluated by 94 EMS agencies transporting 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 regions across the Western U.S. from January 1, 2006 through December 31, 2008. The 7 regions included: Portland, OR/ Vancouver, WA (4 counties); King County, WA; Sacramento, CA (2 counties); San Francisco, CA; Santa Clara, CA (2 counties); Denver County, CO; and Salt Lake City, UT (4 counties). Regions were based on EMS agency service areas, typically including a central metropolitan region and some surrounding rural areas.

Selection of Participants

The study sample included all injured adults ≥ 65 years transported by EMS to an acute care hospital (trauma and non-trauma centers) with a matched hospital record available. This cohort of patients approximates the group of older adults to whom field triage guidelines are routinely applied and includes patients with mild, moderate and serious injuries of all types. We restricted the sample to patients ≥ 65 years due to the high rate of under-triage in this age group,[4,5,8] large trauma-related mortality,[22,23] high prevalence of comorbidities and medication use, and previous research suggesting that the importance of individual triage criteria changes when older adults are defined as ≥ 65 years versus ≥ 55 years.[19] We excluded inter-hospital transfers without an initial EMS presentation, non-transported patients and deaths in the field.

Measurements

We included the following out-of-hospital variables in the analysis: age; sex; initial out-of-hospital physiology (Glasgow Coma Scale [GCS] score, systolic blood pressure [SBP], respiratory rate and heart rate); need for assisted ventilation (bag-valve mask ventilation, intubation, supraglottic airway or cricothyrotomy); 23 field trauma triage criteria currently in use at these sites; mechanism of injury (15 categories); hospital destination; and EMS reason for selecting a particular hospital. We also captured a composite, dichotomous measure of field triage to reflect actual triage practices by EMS personnel. To minimize misclassification bias, field triage status was compiled from multiple data sources, including EMS charts, matched trauma registry records and matched EMS phone records from base hospitals. For purposes of the analysis, we collapsed EMS reason for hospital selection to a dichotomous term of patient choice versus other reasons, based on previous research suggesting that patients requesting particular hospitals may have better prognosis.[24] We categorized acute care hospitals as major trauma centers (Level I and II trauma hospitals) based on American College of Surgeons accreditation status and state designation versus non-trauma hospitals.

Outcomes

We used Abbreviated Injury Scale (AIS) scores[25] to create 5 definitions of "serious injury" (AIS ≥ 3) and considered in-hospital mortality as a marker of prognosis to compare definitions. The definitions included: Injury Severity Score (ISS) ≥ 16;[26] serious traumatic brain injury (TBI, maximum head AIS ≥ 3 or any intra-cranial procedure); serious chest injury (maximum thoracic AIS ≥ 3 or thoracic surgery); serious abdomen-pelvic injury (maximum abdominal-pelvic AIS ≥ 3, therapeutic laparotomy or pelvic surgery); and serious extremity injury (maximum upper or lower extremity AIS ≥ 3 or orthopedic surgery on the extremities). Surgical procedures in each of the body regions were included to account for major interventional procedures reflecting serious injuries, in addition to standard AIS scoring. The region-specific surgical procedures were coded based on ICD9-CM procedure codes in the brain, thoracic, abdominal-pelvic and extremity regions that indicated invasive operative management. In addition, operative procedures captured through standardized trauma registry data fields and mapped to these anatomic regions were also used to supplement ICD9-CM procedure codes for surgical interventions. For each of the anatomic regions, we also evaluated isolated serious injury (defined as an AIS ≥ 3 and/or major surgical intervention for a single anatomic region, but with an ISS < 16).

Hospital records from trauma registries, emergency department (ED) databases and discharge databases were used to generate injury severity measures, surgical procedures and in-hospital mortality. These records were matched to EMS records using probabilistic linkage (LinkSolv v8.2, Strategic Matching, Inc.). We have validated the use of record linkage methodology for matching ambulance records to trauma registry data[27] and have rigorously evaluated and described use of these methods in the current database.[28] Because ISS is not included in administrative data sources, we used a mapping function (ICDPIC .ado Stata module) to generate ISS from ICD-9-CM diagnosis codes,[29] which we have validated against manually abstracted ISS values.[30]

Data Analysis

We used descriptive statistics to characterize the cohort and describe injury patterns for the sample. We then used classification and regression tree (CART) analysis[31] to derive an alternative set of field triage guidelines to identify high-risk older adults (v. 8.2, Salford Systems, San Diego, CA). CART uses binary recursive partitioning to create decision trees that optimize the identification of a subgroup of patients through a series of splits in the data based on potential predictor variables, pre-specified misclassification costs and tree complexity parameters. We randomly-selected 60% of the sample to derive and cross-validate[32] the decision tree, and then used the remaining 40% to internally validate the tree. We employed ISS ≥ 16 as the primary outcome to develop the decision rule, but also derived decision trees using the anatomic-specific definitions of serious injury for comparison. Thirty-three variables were considered as potential predictors: patient demographics; individual triage criteria; dichotomous field triage status using current guidelines; physiologic measures; need for assisted ventilation (bag-mask ventilation or attempted intubation); mechanism of injury; and patient choice for hospital destination. We tested trees with and without patient choice included as a predictor to determine the role of this factor in field triage. Misclassification costs were selected to generate a tree targeted to national benchmarks for triage sensitivity (≥ 95%) and specificity (≥ 65%).[33] We combined the most consistent portions of decision trees developed using ISS ≥ 16 and the anatomic-specific outcomes into a composite set of triage guidelines appropriate for field use, then tested the accuracy of the composite rule using the validation sample.

We used multiple imputation[34] to handle missing data for key variables, including: GCS (21%); SBP (7%); respiratory rate (10%); heart rate (7%); assisted ventilation (2%); mechanism of injury (30%); reason for destination selection (36%); gender (1%); and hospital type (< 1%). The use of multiple imputation in handling missing trauma data has been validated[35] and rigorously evaluated in this database.[28] We used flexible chains regression models for multiple imputation (IVEware, Survey Methodology Program, Survey Research Center, Institute for Social Research, University of Michigan, MI)[36] 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.[34]

We used SAS (v. 9.2, SAS Institute, Cary, NC) for database management and descriptive statistics.

RESULTS

There were 33,298 injured adults ≥ 65 years transported by EMS during the study period with a matched hospital record available. The sample included 1,507 (4.5%) patients with ISS ≥ 16, 1,599 (4.8%) with serious TBI, 1,135 (3.4%) with serious chest injury, 521 (1.6%) with serious abdominal-pelvic injury and 9,732 (29.2%) with serious extremity injury. One thousand thirteen (3.0%) patients died following EMS transport. The majority of the sample (80%) was injured by falls. Descriptive characteristics of the sample are presented in Table 1.

We identified differences in the proportion of patients meeting each of the five definitions of serious injury and their associated mortality (Figure 1). Injury Severity Score ≥ 16 had the highest in-hospital mortality (18.7%, 95% CI 16.7–20.7), though patients with serious brain, chest and abdominal-pelvic injury patterns had only slightly lower mortality (12.3%–16.6%). Patients with serious extremity injuries were common and often presented as an isolated injury; this injury pattern had the lowest mortality (2.9%, 95% CI 2.6–3.3). Patients with isolated serious injury were less common overall and had lower associated in-hospital mortality than polytrauma patients; for patients with serious extremity injury, these differences were minimal.

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We used 19,897 patients to derive the alternative triage guidelines and 13,401 patients to validate their diagnostic accuracy compared to current triage guidelines. The alternative triage guidelines included: any positive triage criterion from the current guidelines; GCS ≤ 14; and abnormal vital signs (Figure 2). Compared to current field triage practices (sensitivity 75.9%, 95% CI 72.3–79.2%; specificity 77.8%, 95% CI 77.1–78.5%), the alternative guidelines had higher sensitivity (92.1%, 95% CI 89.6–94.1%) and lower specificity (41.5%, 95% CI 40.6–42.4%), as demonstrated in Table 2. Using area under the curve, the current guidelines generally had higher discrimination in correctly classifying older adults with and without serious injuries, despite having lower sensitivity. The vital sign parameters proposed in Figure 2 are broader than current field triage physiologic criteria (GCS ≤ 14 vs. GCS ≤ 13; SBP ≤ 110 or ≥ 200 vs. SBP < 90; respiratory rate ≤ 10 or ≥ 24 vs. respiratory rate < 10 or > 29) and include heart rate (≤ 60 or ≥ 110), which is not a current triage criterion. Most patients in the sample identified solely by the abnormal vital signs step had a single vital sign abnormality. In simulating use, the alternative guidelines would have identified an additional 98 patients with ISS ≥ 16 (67% reduction in under-triage), while targeting an additional 4,645 patients without serious injuries for transport to major trauma centers (164% increase in over-triage). The alternative triage guidelines were less sensitive for identifying patients with anatomic-specific serious injuries, yet they did improve upon the deficits in identifying such patients by current triage guidelines (Table 2).

DISCUSSION

Our findings suggest that it is possible to improve the identification of high-risk older adults in the out-of-hospital setting, although over-triage would be expected to increase with changes to field triage practices. We also demonstrate that a global measure of injury severity (ISS ≥ 16) and specific injury patterns (serious brain, chest and abdomen-pelvic injuries) are all associated with substantial mortality and thus may be used to define the high-risk subset of injured older adults. Patients with serious extremity injuries generally had isolated injuries and low mortality, representing an ineffective target for field triage.

We demonstrate that elderly-specific triage guidelines can be applied to the current national triage guidelines. Because the national guidelines are designed for application to *all* age groups, integrating age-specific triage guidelines without adding undue complexity to the algorithm is a potential challenge. The current national triage guidelines include certain criteria specific to older adults (e.g., "Older adults –SBP < 110 might represent shock after age 65 years"),[11] yet these criteria represent a small portion of the algorithm and it is unclear if they have had any meaningful effect on reducing under-triage. The decision scheme developed here is designed for application following completion of the standard triage guidelines, which may allow more straightforward implementation and EMS training without adversely affecting use of the triage algorithm for younger patients. This integration could be further simplified by changing the GCS criterion for all ages to ≤ 14 from the current GCS ≤ 13, as previous research has suggested that this modification would reduce under-triage among all age-groups[37] and is of particular value among injured older adults.[19–21]

We were not able to develop a triage algorithm that had 95% sensitivity,[33] without a major decrease in specificity. The inverse relationship between triage sensitivity and specificity has been previously demonstrated.[37] Some iterations of the decision tree included high-risk mechanisms of injury (e.g., falls) to further increase sensitivity, though because 80% of patients were injured by falls, such a criterion resulted in an unacceptable drop in specificity. Furthermore, while the alternative triage guidelines were relatively sensitive in identifying patients with ISS ≥ 16, they were less sensitive in identifying patients with specific types of serious injuries. The alternative guidelines improved the identification of older adults with serious injuries, although the overall diagnostic accuracy (as measured through the area under the curve) decreased compared to current triage practices, reflecting major decrements in specificity. These findings demonstrate the challenge in attempting to reach the national target for under-triage – the ability to correctly classify both seriously and non-seriously injured patients may actually decrease in order to reach this target. This trade-off is important for trauma systems and broader healthcare communities to consider. The ability to identify a higher proportion of high-risk patients without a marked decrease in specificity may require additional variables (e.g., point-of-care biomarkers) or more targeted field assessment (e.g., physical exam findings) to raise sensitivity, while preserving specificity and guideline discrimination. Despite these limitations, the alternative triage guidelines identified more high-risk patients than current guidelines, with the opportunity to improve early clinical management to reduce morbidity and mortality among patients with specific injury patterns.

Although our results and those from other recent studies[20,21] suggest that methods exist to better identify high-risk injured older adults, this is just the first step in matching patient need with hospital capability. Following field identification of high-risk patients, selection of a hospital destination can be affected by patient choice,[24] hospital proximity, provider training, provider experience, weather and geography, and other factors. Even with effective triage guidelines that identify high-risk elders, any of these factors can potentially disrupt the triage process and create mismatches between patient need and hospital capability. We explored the role of patient choice in field triage, but found inconsistent results. While patient choice has been associated with better prognosis[24] and therefore could theoretically serve as another factor to consider during field triage, including this measure in field triage guidelines raises potential difficulties related to its subjective nature and variability between individual patients.

Importantly, before adopting and implementing any new guidelines, two factors should be considered. First, because we found that application of our alternative guidelines would increase over-triage, there are potential cost and resource implications for the healthcare system that must be considered. Previous research has suggested that up to 40% of acute care costs among injured patients served by EMS are attributable to low-risk patients being transported to major trauma centers.[38] Before adopting new triage guidelines that may further increase over-triage, formal study of these implications (including costs) should be conducted. One such study is currently underway. Second, the role of major trauma centers in caring for older injured adults remains unclear, as research on the survival benefit of providing care for injured older adults in major trauma centers remains mixed.[39–41] Discrepancies between studies are likely explained in part due to differences in how “serious injury" is defined (AIS ≥ 3[39] vs. ISS ≥ 16[41] vs. ICD-9 diagnoses with severe mortality risk[40]). Resource-based measures (e.g., need for surgical intervention, major blood transfusion) are difficult to use as triage targets among older adults due to differences in medical and surgical decision-making regarding procedural interventions[18] and aggressiveness of care compared to younger patients.

In previous studies comparing appropriately-triaged and under-triaged older adults with serious injuries, there were no significant survival differences up to 60 days post-injury[41] and under-triaged patients appeared to have better prognosis than seriously injured adults transported to major trauma centers.[24] As suggested by these studies, there are likely unobserved factors associated with triage that can influence outcome. Simply reducing under-triage may not necessarily translate into improved outcomes among seriously injured older adults. The complex interplay of these factors among injured older adults and their relation to revising field trauma triage requires additional research.

We used a retrospective cohort for this project and restricted the sample to patients who matched to a hospital record, both of which may have introduced bias to the analysis. Our data did not provide information on comorbidities, pre-injury medications, baseline mentation, intoxication or end-of-life preferences, all of which can play important roles in out-of-hospital decision-making. The vital sign values we used in the decision rule were sharpened versions of cut-points we previously developed in a sample of injured adults ≥ 55 years,[19] plus heart rate. While the previous study showed only modest improvement in sensitivity among a sample that included patients ≥ 55 years,[19] the current study was restricted to patients ≥ 65 years, with greater gains in sensitivity. Whether these findings reflect true age-based differences or otherwise are unclear. We also assumed that all older adults meeting the alternative triage criteria would be transported to major trauma centers, although actual EMS adherence to the guidelines may be lower. For these reasons, the guidelines developed in this study require prospective evaluation and assessment during actual out-of-hospital use. The intent with this study was not necessarily to create the definitive decision tool for identifying high-risk elderly trauma patients, but rather to develop a potential instrument to reduce under-triage that could interface with the national guidelines and deepen the evidence base on this topic.

Under-triage of older adults remains incompletely understood and is likely related to more than just field triage guidelines, many of which we were unable to account for in this study. It is unlikely that simply revising the national triage guidelines will completely resolve discrepancies in under-triage and the resulting disparities in trauma care among older adults. However, the ability to effectively identify older adults with serious injuries shortly after injury is an important first step in providing more effective and comprehensive care for injured elders.

CONCLUSIONS

Our findings suggest that the field triage guidelines could be improved to better identify older adults with serious injuries, with resulting increases in over-triage. Seriously injured elders may be defined using a traditional global anatomic measure of injury severity (ISS ≥ 16) or specific injury patterns involving the brain, chest or abdominal-pelvic regions.

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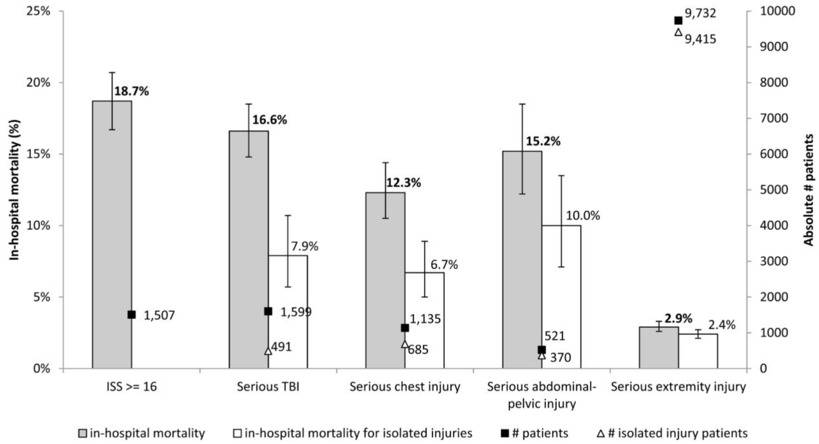

Figure 1.

Frequency and mortality for different definitions of "serious injury" in injured patients over 65 years transported by EMS (n = 33,298).

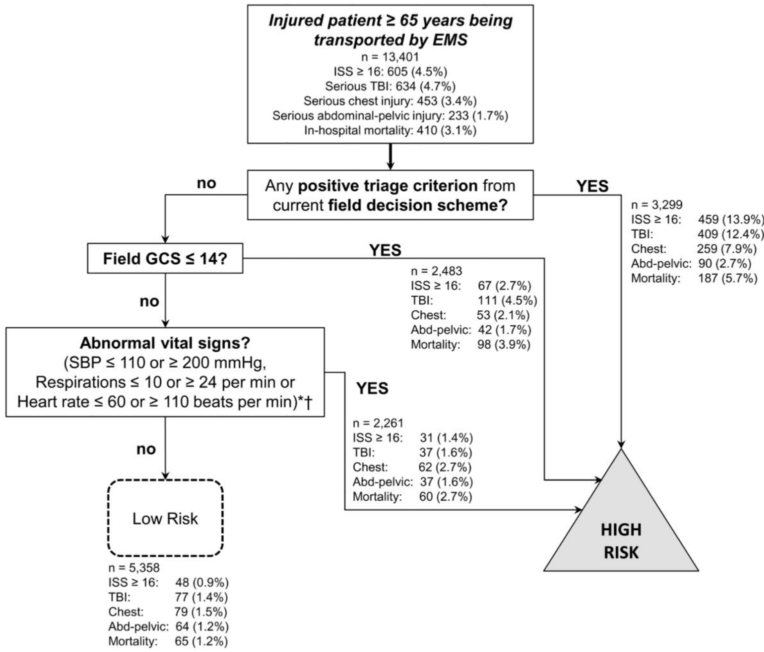

Figure 2.

Alternative out-of-hospital method for identifying older adults with Injury Severity Score ≥ 16 (validation sample n = 13,401).

*Including high-risk mechanism (fall, motor vehicle occupant, auto vs. pedestrian/bicycle, significant medical illness, or suffocation) as a separate triage criterion following the "abnormal vital signs" step increased sensitivity (99.8%) with a severe decrease in specificity (1.6%). Coupling abnormal vital signs with high-risk mechanisms at this step slightly decreased sensitivity (90.4%), but increased specificity (48.5%).

†Patient choice (patients requesting a specific hospital) was considered as an additional predictor in decision rule derivation. This factor was not predictive of patients with ISS ≥ 16 or serious chest injuries. However, the lack of patient choice (hospitals selected by EMS for reasons other than patient choice) increased the probability of having serious abdominal injury and serious TBI. This factor may represent another aspect to consider in the out-of-hospital risk assessment of older patients.

Table 1

Characteristics of injured patients 65 years and older transported by EMS in 7 regions (n = 33,298).

Demographics:	
65 – 74 years	8,448 (25.4%)
75 – 84 years	12,588 (37.8%)
≥85 years	12,262 (36.8%)
Female	22,587 (67.8%)
Out-of-hospital physiology and procedures:	
SBP < 100 mmHg	1,274 (3.8%)
GCS 13 – 15	32,035 (96.2%)
GCS 9 – 12	840 (2.5%)
GCS ≤ 8	423 (1.3%)
Assisted ventilation or intubation attempt	209 (0.6%)
Mechanism of Injury:	
Gunshot wound	40 (0.1%)
Stabbing	69 (0.2%)
Assault	188 (0.6%)
Fall	26,503 (79.6%)
Motor vehicle crash	3,309 (9.9%)
Pedestrian vs. auto	418 (1.3%)
Bicycle	107 (0.3%)
Other	2,664 (8.0%)
EMS triage and transport:	
≥1 field triage criterion	8,382 (25.2%)
Helicopter scene transport	43 (0.1%)
Inter-hospital transfer after initial EMS transport	1,017 (3.1%)
Final care in Level I or II trauma center	9,063 (27.2%)
EMS reason for hospital selection:	
Patient or family choice	24,058 (72.3%)
Hospital proximity	3,630 (10.9%)
Specialty hospital	2,676 (8.0%)
Ambulance diversion	682 (2.1%)
On-line medical control or MD request	428 (1.3%)
Other	1,826 (5.5%)
Injury severity, hospital procedures and mortality:	
ISS 0 – 8 (minor injury)	24,624 (74.0%)
ISS 9 – 15 (moderate injury)	7,167 (21.5%)
ISS ≥ 16 (serious injury)	1,507 (4.5%)
Serious TBI	1,599 (4.8%)
Serious chest injury	1,135 (3.4%)

Serious abdominal-pelvic injury	521 (1.6%)
Serious extremity injury	9,732 (29.2%)
Major non-orthopedic surgery	1,372 (4.1%)
Orthopedic surgery	9,112 (27.4%)
Blood transfusion	4,923 (14.8%)
In-hospital mortality	1,013 (3.0%)

[*] ISS = Injury Severity Score; SBP = systolic blood pressure (in mmHg); GCS = Glasgow Coma Scale score; EMS = emergency medical services; ISS = Injury Severity Score; TBI = traumatic brain injury.

Table 2

Accuracy measures of the alternative triage guidelines compared to current triage guidelines for identifying seriously injured patients 65 years and older (validation sample n = 13,401).

	Current triage guidelines	Alternative triage guidelines
ISS ≥ 16:	n = 605	
Sensitivity	75.9% (72.5–79.3%)	92.1% (89.8–94.5%)
Specificity	77.8% (77.1–78.5%)	41.5% (40.6–42.4%)
AUC	0.77 (0.75– 0.79)	0.67 (0.66–0.68)
# patients under-triaged	146	48
# patients over-triaged	2,840	7,485
Serious TBI:	n = 634	
Sensitivity	64.5% (60.8–68.2%)	87.9% (85.2–90.5%)
Specificity	77.4% (76.6–78.1%)	41.4% (40.5–42.2%)
AUC	0.71 (0.69–0.73)	0.65 (0.63–0.66)
# patients under-triaged	225	77
# patients over-triaged	2,890	7,485
Serious chest injury:	n = 453	
Sensitivity	57.2% (52.6–61.7%)	82.6% (79.0–86.3%)
Specificity	76.5% (75.8–77.3%)	40.8% (39.9–41.6%)
AUC	0.67 (0.65–0.69)	0.62 (0.60–0.64)
# patients under-triaged	194	79
# patients over-triaged	3,040	7,668
Serious abdominal-pelvic injury:	n = 233	
Sensitivity	38.6% (32.4–44.9%)	72.5% (66.2–78.8%)
Specificity	75.6% (74.9–76.4%)	40.2% (39.4–41.1%)
AUC	0.57 (0.54–0.60)	0.56 (0.53–0.60)
# patients under-triaged	143	64
# patients over-triaged	3,209	7,874

[*] Parentheses represent 95% confidence intervals. ISS = Injury Severity Score; TBI = traumatic brain injury; AUC = area under the curve.