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A COMPARISON OF SCORING SYSTEMS FOR PREDICTING SHORT- AND LONG-TERM SURVIVAL AFTER TRAUMA IN OLDER ADULTS

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Author Contribution

EB – secured funding, study design, manuscript revision

CN – secured funding, developed initial study question, performed multiple imputation, study oversight and guidance, manuscript revision

SM – Study design, manuscript revision

AL – statistical analysis, interpretation of data, manuscript revision

AM – literature review, study design, interpretation of data, drafting and revision of manuscript

ABSTRACT

Objectives: Early identification of geriatric patients at high risk for mortality is important to guide clinical care, medical decision-making, palliative discussions, quality assurance, and research. We sought to identify injured older adults at highest risk for 30-day mortality using an empirically derived scoring system from available data, and to compare it with current prognostic scoring systems.

Methods: This was a retrospective cohort study of injured adults ≥ 65 years transported by 44 emergency medical services (EMS) agencies to 49 emergency departments in Oregon and Washington from 1/1/2011 through 12/31/2011, with follow-up through 12/31/2012. We matched data from EMS, to Medicare, inpatient, trauma registries, and vital statistics. Using a primary outcome of 30-day mortality, we empirically derived a new risk score using binary recursive partitioning and compared it to the Charlson comorbidity index (CCI); modified frailty index (MFI); geriatric trauma outcome score (GTOS); GTOS II; and injury severity score (ISS).

Results: There were 4,849 patients, of whom 234 (4.8%) died within 30 days and 1,040 (21.5%) died within 1 year. The derived score, the Geriatric Trauma Risk Indicator (GTRI) (emergent airway or CCI ≥2), had 87.2% sensitivity (95% CI 83.0-91.5%) and 30.6%% specificity (95% CI 29.3-31.9%) for 30-day mortality (AUROC 0.589, 95% CI: 0.566-0.611). AUROC values for other scoring systems ranged from 0.592 to 0.678. When the sensitivity for each existing score was held at 90%, specificity values ranged from 7.5% (ISS) to 30.6% (GTRI).

Conclusions: Older, injured, adults transported by EMS to a large variety of trauma and non-trauma hospitals were more likely to die within 30 days if they required emergent airway management or have a higher comorbidity burden. When compared to other risk measures and holding sensitivity constant near 90%, the GTRI had higher specificity, despite a lower AUROC. Using GTOS II or the GTRI may better identify high-risk older adults than traditional scores, such as ISS, but identification of an ideal prognostic tool remains elusive.

INTRODUCTION

The number of older adults with traumatic injuries is increasing in the United States. The population age 65 and older had 48,000 fatal injuries and 578, 000 nonfatal injuries in 2010, resulting in over 47 billion dollars of estimated costs. (1) This population has been identified as having worse outcomes, including death and prolonged disability when compared with younger patients.(2) Identification of the specific older adult at highest risk for poor outcome, particularly death, has been elusive, despite multiple studies seeking to develop prognostic tools for this population.(3-7) Early prediction of those at highest risk of a poor outcome, including death or permanent disability, can aid medical decision-making, such as transfer to a higher level of care or intensive care unit admission. The ability to predict outcome at the individual level may also facilitate communication with families regarding expected outcome and prognostication in determining the goals of care. An appropriate definition for high-risk geriatric trauma patients is also important in tracking the quality of care, field triage processes, inter-hospital transfer patterns, and selection of appropriate hospitals in trauma systems. While several studies have shown that geriatric trauma patients are consistently under-triaged and are less likely to transfer to trauma centers, these studies have used more traditional definitions of high-risk trauma patients.(8-10) A geriatric-specific definition of high-risk patients may yield different estimates for under-triage and other trauma quality assurance measures.

A number of scoring systems have been developed for injured patients in general, and have been applied to injured older adults specifically, as an attempt to better identify those at high-risk for poor outcome. The Injury Severity Score (ISS) was developed more than forty years ago with the aim of standardizing trauma patients' global injury assessment, as well as give prognosis based on the severity of injury.(11) The American College of Surgeons Committee on Trauma (ACSCOT) defines a severely injured trauma patient as those with an ISS ≥ 16, and recommends these high-risk trauma patients be cared for in major trauma centers. Despite its widespread use and adoption by ACSCOT, the ISS has not been shown to correlate well with outcome in many trauma populations, particularly in older adults. (5, 11-14) Similarly, the Charlson Comorbidity Index (CCI) has been used to account for comorbidity burden that may increase the likelihood of poor outcome, but has not been shown to correlate with prognosis following injury.(6) Recognizing that prognosis is multifactorial, the geriatric trauma outcome score (GTOS) was developed specifically for the geriatric injured population, and includes age, ISS, and administration of blood within the first 24 hours.(3, 15, 16) This scoring system has been validated in a population of patients treated at a Level 1 trauma center, but has not been applied to the broader population of injured older adults managed in non-trauma hospitals. The modified frailty index (MFI) is another score that was developed for identification of surgical patients at highest risk of poor outcome, and has recently been applied to trauma patients. (17, 18) Most of these scoring systems have been applied to injured patients in academic trauma centers, but have not been evaluated in a broader cohort of injured older adults. Existing scoring systems require knowledge of the patient's specific injuries, and often can only be calculated after discharge. However, early identification of high-risk patients in the emergency department (ED) may improve outcomes in older adults.

We aimed to derive a prognostic tool that could be used to identify high-risk injured older adults transported by emergency medical services (EMS) and cared for in a variety of trauma and non-trauma hospitals. We compared this new prognostic tool with existing prognostic scoring systems (general and geriatric-specific) that are frequently used for prognostication and quality assurance in trauma systems. We hypothesized that the traditional scoring systems (i.e., ISS $\geq$ 16) would not predict short- and long-term mortality among injured older adults as well as scoring systems specifically derived for the geriatric population.

METHODS

Study Design, Study Setting, and Patient Population

This was a retrospective cohort study of injured adults ≥ 65 years transported by 44 emergency medical services (EMS) agencies to 49 emergency departments (ED) in 7 counties across Oregon and Washington from January 1 through December 31, 2011, with 12-month follow-up through December 31, 2012. The 49 receiving hospitals included: 3 Level I trauma centers, 4 Level II centers, 9 Level III hospitals, 7 Level IV hospitals, 1 Level V hospitals, and 25 non-trauma hospitals. For patients subsequently transferred between hospitals, we tracked patient information and outcomes at all acute care hospitals (this added an additional 6 hospitals to the project). The study was reviewed and approved by Institutional Review Boards at all sites, which waived the requirement for informed consent.

We collected all EMS records for injured older adults served by these 44 EMS agencies, and matched these records to two state discharge databases, two state trauma registries, two state death registries, Medicare claims data, and the Oregon Physician Orders for Life-Sustaining Treatment (POLST) registry. Oregon and Washington maintain statewide databases of administrative and billing data for all patients admitted to acute care hospitals in the state. These databases follow standardized processes for data collection and coding. The Oregon POLST registry is an electronic resource providing real-time access to legal orders for specific end of life preferences for resuscitation, medical interventions and artificial nutrition. The presence of "injury" was based on EMS provider primary or secondary impression. For the primary sample, we required that patients had continuous Medicare fee-for-service coverage in the month prior to the date of 911 contact (the "index event"), through 1 year after the date (or until death). Matched Medicare claims were necessary to adequately capture pre-injury comorbidities, pre-injury medication use (i.e., anticoagulants), and post discharge medical events. Patients with recent hospice admission prior to the index event or those with care limitations via end of life orders (a matched POLST form specifying limited interventions or comfort measures only) were excluded from the primary sample. The methods for linkage and validation of these data are described in detail elsewhere, including validation of probabilistic linkage, key variables, and multiply imputed values.(19)

Variables and Outcomes

We first sought to empirically identify a combination of variables to predict patients at high risk of death within 30 days by using binary recursive partitioning. Variables included patient and injury characteristics available during the hospital stay: age; ISS; Abbreviated Injury Scale (AIS) in different body regions; emergent airway management (need for intubation and ventilation) in the prehospital, or in-hospital settings (ED and inpatient combined); hospital procedures; blood transfusion; CCI; MFI; pre-injury use of oral anticoagulants (OAC); inpatient admission within 30 days prior to the index event; and current residence in a skilled nursing facility (defined as a skilled nursing facility claim within 7 days prior to 911 contact). We calculated CCI using ICD-9-CM diagnoses codes occurring prior to the index event. (20) We generated MFI via pre-injury medications and ICD-9-CM diagnoses codes occurring prior to the index event.(20, 21) Injury characteristics included injury mechanism, ISS and AIS for head, chest, abdomen/pelvis, and extremities. Hospital procedures included cardiac, orthopedic surgery, and major non-orthopedic surgical procedures (spine, brain, abdomen-pelvis, and thorax). We also calculated GTOS I and GTOS II.(7, 15, 16) Death within 30 days was the primary outcome. We used death at future time points (60-day, 90-day, 180-day, and 365-day) as secondary outcomes.

Statistical Analysis

We used binary recursive partitioning to empirically derive a scoring tool to identify older adults at highest risk of death within 30 days of 911 contact. This statistical method develops a decision tree to predict likelihood of an outcome variable with input of multiple predictor variables. (22) We included patient age, pre-injury location (skilled nursing facility or home), comorbidities (CCI, individual comorbidities, and disability status), oral anticoagulant use, injury characteristics (mechanism of injury, AIS body region, and ISS), and hospital procedures (including orthopedic, major surgeries, and blood transfusions), and set misclassification costs to yield a decision rule with approximately 90% sensitivity and maximal specificity. We compared the resulting decision rule with existing scoring systems for high-risk trauma patients, including: ISS, CCI, MFI, GTOS and GTOS II. To compare these metrics, we calculated area under the receiving operating characteristic curve (AUROC), and test characteristics including sensitivity, specificity, positive predictive value and negative predictive value for identifying patients dying within 30 days of 911 contact. We selected a cut point to generate approximately 90% sensitivity, which allowed comparison of specificity values between metrics. In this context, prognostic scores with higher specificity were favored as better able to identify true negative (i.e., patients who were negative on a score and survived to 30 days following 911 contact). To handle missing values, preserve the primary sample, and minimize bias, we used multiple imputation.(23) Results from the AUROC analysis from each imputed dataset were combined using Rubin's rule, and we generated 95% confidence intervals for all estimates. (23) We plotted ROC curves to visually compare the overall accuracy of each measure, and to assess the calibration of each model (the agreement between observed and predicted risk of mortality), we generated decile calibration plots and calculated the Hosmer-Lemeshow goodness-of-fit test.(24) To determine the performance of the various scoring systems over time, we also calculated sensitivity and specificity for mortality at 60 days, 90 days, 180 days, and 365 days. All descriptive statistics and regression analyses were performed in SAS 9.4 (Cary, NC). Binary recursive partitioning was implemented via the package "party" in RStudio 1.0.153 (Boston, MA).(22) We deemed $p<0.05$ to be statistically significant, and all tests were two-sided.

RESULTS

There were n=4,849 patients included in the primary sample (Figure 1). Across all patients in this cohort, 4.8% (n=234) died within 30 days of 911 contact and 21.5% (n=1,040) died within 1 year. The 1-year mortality rates for patient aged 65-74 years, 75-84 year, and ≥85 years were 13.1%, 17.4%

and 29.1%, respectively (Supplemental Table 2). Patients alive at 30 days significantly differed from patients who died (Table 1). Those who died were more likely to be male, older, have higher comorbidity burden, recent inpatient admission, and OAC use prior to 911 contact, as compared to patients that were alive at 30 days. Patients who died were also more likely to have a fall as a mechanism of injury, more severe anatomic injuries, require early blood transfusion (within 24 hours of the event), and emergent airway intervention. The percentage of missing data for different variables is included in Supplemental Table 1.

We consistently identified two variables as predictors of 30-day mortality using binary recursive partitioning: need for emergent airway management (prehospital, or in-hospital) and CCI ≥ 2 (Figure 2). We combined these variables into a measure, the geriatric trauma risk indicator (GTRI), which was defined as a patient having a need for an emergency airway or CCI ≥ 2. The GTRI had 87.2% sensitivity (95% CI: 83.0-91.5%), 30.6% specificity (95% CI: 29.3-31.9%), 6.0% positive predictive value (95% CI: 3.0-9.0%), and 97.9% negative predictive value (95% CI: 97.5-98.3%) for identifying those at highest risk for death within 30 days. Overall discrimination was measured with an AUROC of 0.589 (95% CI: 0.566-0.611). Representative ROC curves for predicting 30-day mortality for all scoring systems are plotted in Figure 3 in comparison with the GTRI. Of the existing measures, MFI had the lowest overall accuracy with an AUROC of 0.592 (0.556-0.628) (Table 2), while the GTOS II had the highest overall AUROC (0.678, 95% CI: 0.642-0.715). For each scoring system we extrapolated the value that would provide a sensitivity of approximately 90% for predicting 30-day mortality. These values were ISS ≥ 1, MFI ≥ 1, CCI ≥ 1, GTOS ≥ 85, and GTOS II ≥ 78. The GTRI was based on categorical variables and was generated with a target of 90% sensitivity. Notably, with sensitivity set at 90%, specificity was low across all existing measures, ranging from 7.5% for ISS to 22.3% for GTOS II (Table 3). We further calculated sensitivity and specificity over time for predicting 60-, 90-, 180-day, and 1-year mortality, using the same values for our secondary outcome measures (Figure 4). Sensitivity and specificity remained relatively constant for all definitions of high-risk patients over time. In a subgroup analysis of those aged 75 and over, airway consistently remained the most important predictor, and there was no significant difference in performance of the measures (Supplemental Table 2). An evaluation of the calibration of each model found that generally agreement between observed and predicted risk of mortality was poor across all measures of risk (Supplemental Table 3)

For sensitivity analyses related to derivation of the GTRI, we separately evaluated comorbidities present before the injury event, as well as those diagnosed (or documented) during the index visit. In these analyses, emergent airway management was retained as most important predictor and CCI ≥ 2 as the second predictor of all-cause mortality within 30 days. The results were similar to the primary analysis, with slightly higher sensitivity (93%).

DISCUSSION

In this retrospective cohort study of injured older adults transported by EMS, we compared a variety of existing scoring systems for patients at high-risk of death, and empirically derived an additional measure, the GTRI. The GTRI employs the two variables that consistently predicted mortality: emergency airway intervention or higher comorbidity burden. Even with the availability of both pre-injury and hospital data, we were unable to generate a risk indicator that provided both high sensitivity and specificity in predicting mortality. Many variables typically considered in "high-risk" patients (e.g., anticoagulant use, SNF residence prior to trauma, and specific anatomic injuries) were not predictive of mortality in this analysis.(6, 25, 26)

We utilized a sensitivity threshold of 90% to compare the GTRI with other risk scores as a reasonable target for sensitivity and to standardize comparison of specificity across scores. The sensitivity threshold allowed us to identify 90% of patients who will die within 30 days of injury, and compare the specificity across scores keeping sensitivity constant. This strategy also allowed illustration of the score cut-points required to generate these measures of accuracy. Using this criteria, we find that commonly used scoring systems do not perform well, had poor calibration, and require significantly lower score values than are typically used to predict mortality. For example, identification of 90% of injured older adults at highest risk of 30-day mortality requires an ISS ≥ 1, which is much lower than the ACSCOT definition of a severely injured patient (ISS ≥ 16).(12) Additionally, using an ISS ≥ 1 resulted in a very low specificity for identifying those likely to survive at 30 days. This indicates that ISS should not be used in isolation when predicting outcome in injured older adults. Existing scoring systems had slightly higher overall accuracy, as measured by AUROC. All scoring systems maintained a fairly constant level of sensitivity and specificity for mortality over time, which was an unexpected finding. Our study is unique in that we included long-term mortality, a mixture of rural and urban regions, a large variety of hospitals, capture of injured older adults beyond those included in trauma registries, and empiric derivation of a new indicator to identify injured, older adults with high mortality risk.

The GTRI has an advantage over existing scoring systems in that it can be used in real-time throughout the clinical continuum to help identify high-risk older adults. This may occur in the ED, or later in the hospital course should the patient require intubation after hospital admission. This information could be used to guide disposition decisions, transfer discussions, early prognostication, discussions with families, and to help set realistic goals of care. Our results show that patients arriving to an ED after injury with an elevated comorbidity burden, or in respiratory failure requiring an advanced airway, are at high risk of death regardless of their injury burden. This finding is in line with recent research identifying the mortality associated with emergent airway access in older patients, in which 33% of older adults intubated in the ED die during the index hospitalization. (27)

Studies on prognostic scoring systems have generally been performed on patients treated at level 1 trauma centers and captured in trauma registries. However, previous studies demonstrate that a large portion of geriatric trauma patients are cared for in non-trauma centers.(8) Therefore, current scoring systems likely underperform when applied globally to injured older adults.(2, 7, 11, 15, 16) For example, the GTOS and GTOS II nomograms were developed from a cohort of injured patients at urban level 1 trauma centers. The predicted probability of dying increases based on injury and physiologic factors. Our analysis identified scores of 85 and 78 as correlating with an increased risk of death; however these scores are predicted to correlate with a 2% probability of death in the validating studies. (7, 16) Similarly, the ISS does not correlate with outcome in multiple studies, with a mortality rate ranging from 3-86% for those with an ISS ≥ 16. (5) Our study included injured older adults served by EMS through the 911 system and transported to many types of hospitals. Similar patients were likely missed in the development of other scoring systems. Based on our results, use of GTOS II or the GTRI would be the best current definitions for a "high-risk" injured older adult population. The GTRI had slightly lower sensitivity, but the highest specificity, positive predictive value and negative predictive value. One important difference is that GTOS II requires ISS, which is typically only available after discharge, while the GTRI could be used in real-time to identify high-risk patients. If our findings are replicated in other studies, the GTRI could serve as a tool to guide early clinical care, transfer decisions, to inform families early in a patient's clinical course, and for quality assurance related to older adults served by trauma systems. As additional information regarding the patient's clinical condition becomes available and the patients progresses through the continuum of care, the GTOS II may be used to further provide prognosis that is tailored to the patient's injury status measured through ISS.

LIMITATIONS

As with many studies utilizing administrative and claims data sources, our study is limited by the fidelity and granularity of the data. We were able to mitigate this by pulling from multiple data sources, using multiple imputation to handle missing values, and validating key variables. Our airway variable is limited to EMS or in hospital airway, as such we were unable to identify if the patient required intubation early in their clinical course, or after a prolonged stay. Also, this study was limited to patients with continuous Medicare fee-for-service coverage; thus, patients with Medicare Advantage were excluded from all analysis due to the limited availability of medical claims. This restriction could have introduced selection bias to the analysis and therefore may not be generalizable to the larger older adult population. However the large sample size may partially mitigate this potential bias.(28, 29) We used AUROC to descriptively compare these scoring systems, yet the AUROC has limitations. The AUROC is based on ranks, does not account for the goodness-of-fit of model predictions, and does not adequately represent the ability of the model to discriminate those with and without the outcome for categorical variables (e.g., GTRI) and ordinal variables (e.g., the CCI and MFI). Further, this cohort represents 7 counties in the Pacific Northwest served by two mature, statewide trauma systems, and may not be representative of other regions of the United States.

This study demonstrates the continued difficulty in identification of injured older adults at highest risk of death. Despite placing many variables that have been identified as potential predictors into an empirical model, we were unable to derive a score with both high sensitivity and high specificity. The GTRI has sufficient sensitivity identify most high-risk older adults, with modest specificity and the benefit of real-time availability of the score. Future work is needed to validate our findings in other regions, whether use of the GTRI aids in clinical decision making, and whether patients testing positive on the score have improved outcomes at major trauma centers.

CONCLUSIONS

Older, injured, adults transported by EMS to a large variety of trauma and non-trauma hospitals were more likely to die within 30 days if they required emergent airway management or have a higher comorbidity burden. When compared to other risk measures and holding sensitivity constant near 90%, the GTRI had higher specificity, despite a lower AUROC. The GTOS II requires identification of injury burden, and calculation of ISS, while the GTRI comprises two variables that are easy to remember and can be used early in the clinical course. Using GTOS II or the GTRI may better identify high-risk older adults than traditional scores, such as ISS, but identification of an ideal prognostic tool remains elusive.

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Figure 1: Inclusion and exclusion criteria for this study.

Figure 2: Results of Geriatric Trauma Risk Indicator derivation by binary recursive partitioning.

Figure 3: Receiver operating curves and area under the receiver operating curve results for all scoring systems.

Figure 4: Sensitivity and specificity over time of all scoring systems.

Table 1. Descriptive statistics by 30-day mortality.

	Overall (n=4849, 100%)	**30-day Alive (n=4615, 95.2%)**	**30-day Mortality (n=234, 4.8%)**	**p-value***
Pre-injury characteristics and comorbidities				
Female n, (%)	3266 (67.4%)	3135 (67.9%)	131 (56.0%)	***<0.01***
Age, mean	81.7	81.5	85.3	***<0.01***
Pre-injury location via Medicare claims				
Skilled Nursing/Inpatient Rehabilitation n, (%)	97 (2.0%)	90 (2.0%)	7 (3.0%)	0.23
Inpatient, 30 days prior to injury n, (%)	247 (5.1%)	226 (4.9%)	21 (9.0%)	***<0.01***
Oral anticoagulant, 90 days prior to injury n, (%)	719 (14.8%)	667 (14.5%)	52 (22.2%)	***0.03***
Modified Frailty Index, mean	2.5	2.5	3.1	***<0.01***
Geriatric trauma outcome score, mean	99	98.4	110.8	***<0.01***
Geriatric trauma outcome score II, mean	86.7	86.4	92.7	***<0.01***
Poor disability status n, (%)	1255 (25.9%)	1169 (25.3%)	85 (36.3%)	***<0.01***
Charlson Comorbidity Index, mean	3.4	3.3	4.5	***<0.01***
Comorbid conditions prior to the index injury				
Myocardial infarction n, (%)	1764 (36.4%)	1658 (35.9%)	106 (45.3%)	***<0.01***
Congestive heart failure n, (%)	1545 (31.9%)	1441 (31.2%)	104 (44.4%)	***<0.01***
Peripheral vascular disease n, (%)	980 (20.2%)	923 (20.0%)	57 (24.4%)	0.11
Cerebrovascular disease n, (%)	1216 (25.1%)	1151 (24.9%)	65 (27.8%)	0.33

Chronic obstructive pulmonary disease n, (%)	1364 (28.1%)	1283 (27.8%)	81 (34.6%)	***0.02***
Dementia n, (%)	1483 (30.6%)	1385 (30.0%)	98 (41.9%)	***<0.01***
Paralysis n, (%)	106 (2.2%)	101 (2.2%)	5 (2.1%)	0.96
Diabetes n, (%)	1405 (29.0%)	1334 (28.9%)	71 (30.3%)	0.64
Chronic renal failure n, (%)	1400 (28.9%)	1298 (28.1%)	102 (43.6%)	***<0.01***
Ulcers n, (%)	112 (2.3%)	103 (2.2%)	9 (3.8%)	0.11
Liver diseases n, (%)	54 (1.1%)	50 (1.1%)	4 (1.7%)	0.33
Rheumatoid arthritis n, (%)	269 (5.5%)	260 (5.6%)	9 (3.8%)	0.24
Any malignancy n, (%)	1002 (20.7%)	935 (20.3%)	67 (28.6%)	***<0.01***
Count of pre-existing conditions n, (%)	2.6	2.6	3.3	***<0.01***
Index injury clinical characteristics				
Injury Severity Score				***<0.01***
Mild (≤8) n, (%)	2999 (61.8%)	2899 (62.8%)	99 (42.3%)	
Moderate (9-15) n, (%)	1606 (33.1%)	1514 (32.8%)	93 (39.7%)	
Severe (16-24) n, (%)	209 (4.3%)	179 (3.9%)	30 (12.8%)	
Extremely Severe (≥25) n, (%)	35 (0.7%)	23 (0.5%)	12 (5.1%)	
Abbreviated Injury Score				
Chest (>2) n, (%)	79 (1.6%)	74 (1.6%)	5 (2.1%)	0.43
Abdomen and pelvic contents (>2) n, (%)	15 (0.3%)	12 (0.3%)	3 (1.3%)	***<0.01***
Extremities or pelvic girdle serious (>2) n, (%)	790 (16.3%)	727 (15.8%)	63 (26.9%)	***<0.01***

AIS head/neck serious or higher	201 (4.1%)	162 (3.5%)	39 (16.7%)	***<0.01***
<u>Presenting hospital trauma level</u>				0.71
Level 1 or 2 trauma center n, (%)	766 (15.8%)	727 (15.8%)	39 (16.7%)	
Level 3-5 trauma center n, (%)	1841 (38.0%)	1748 (37.9%)	93 (39.7%)	
Non-trauma n, (%)	2242 (46.2%)	2140 (46.4%)	102 (43.6%)	
Patient transfer n, (%)	416 (8.6%)	392 (8.5%)	24 (10.3%)	0.41
<u>Injury mechanism</u>				***<0.01***
Fall n, (%)	4155 (85.7%)	3940 (85.4%)	215 (91.9%)	
Motor vehicle n, (%)	257 (5.3%)	254 (5.5%)	3 (1.3%)	
Other n, (%)	437 (9.0%)	421 (9.1%)	16 (6.8%)	
<u>Blood transfusion</u>				***0.02***
None during index injury n, (%)	4507 (92.9%)	4293 (93.0%)	214 (91.5%)	
Within 0-1 days of injury n, (%)	133 (2.7%)	120 (2.6%)	13 (5.6%)	
≥2 days of injury (or unknown timing) n, (%)	209 (4.3%)	202 (4.4%)	7 (3.0%)	
<u>Procedures</u>				
Orthopedic n, (%)	773 (15.9%)	740 (16.0%)	33 (14.1%)	0.44
Major surgical procedures** n, (%)	89 (1.8%)	73 (1.6%)	16 (6.8%)	***<0.01***
Any airway or ventilatory assistance n, (%)	80 (1.6%)	52 (1.1%)	28 (12.0%)	***<0.01***

*Chi-square test of association for categorical data and t-test for numeric data with correction for imputed data.

**Spine, brain abdomen, thorax or neck

Table 2. Area under the receiver operating characteristics curve for predictors of mortality

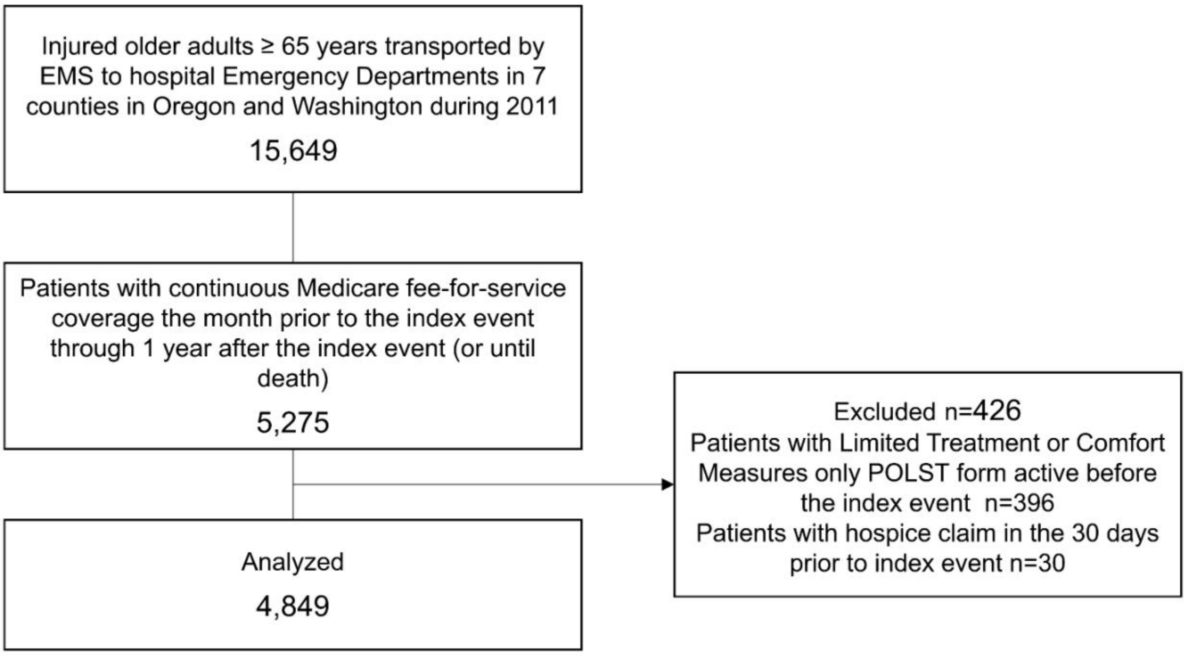
Measure	Pooled AUROC (95% CI)
ISS	0.632 (0.591-0.673)
MFI	0.592 (0.556-0.628)
CCI	0.618 (0.582-0.654)
GTOS	0.674 (0.635-0.712)
GTOS II	0.678 (0.642-0.715)
GTRI	0.589 (0.566-0.611)

*ISS – injury severity score, MFI – modified frailty index, CCI – Charlson comorbidity index, GTOS – geriatric trauma outcome score; GTRI – geriatric trauma risk indicator

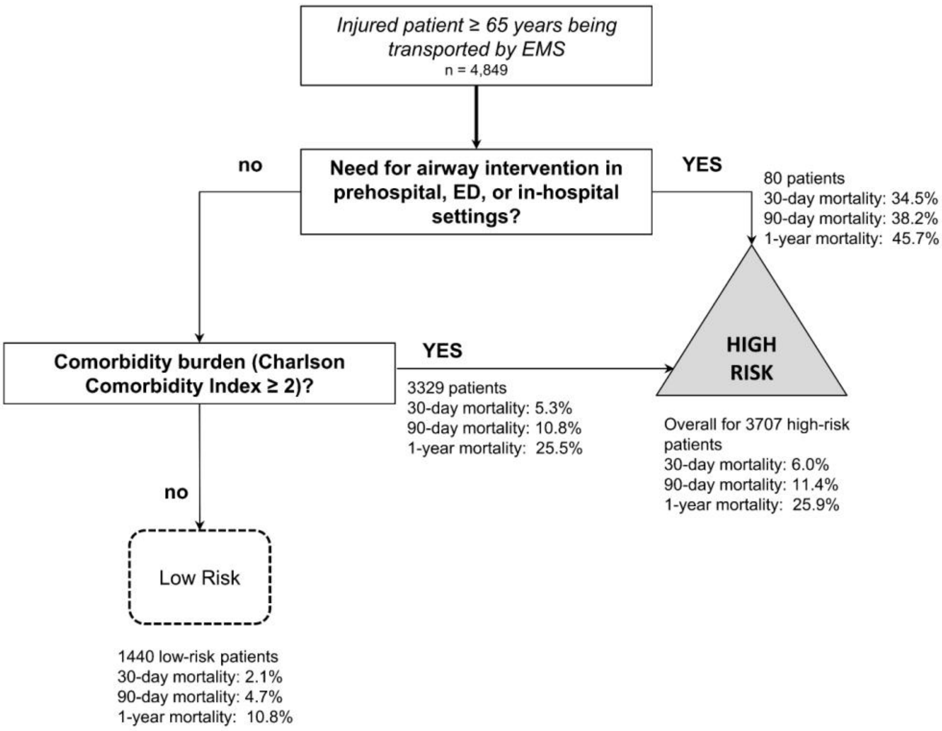
Table 3. Test characteristics for various thresholds for predicting 30-day mortality

Measure	Sensitivity (95% CI)	Specificity (95% CI)	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)
ISS ≥ 1	92.3% (88.9-95.7%)	7.5% (6.7-8.3%)	3.3% (1.0-5.6%)	95.0% (94.4-95.6%)
MFI ≥ 1	89.7% (85.6-93.6%)	17.7% (16.6-18.8%)	5.2% (2.4-8.0%)	97.1% (96.6-97.6%)
CCI ≥ 1	91.9% (88.4-95.4%)	16.2% (15.1-17.3%)	5.3% (2.4-8.2%)	97.5% (97.0-98.0%)
GTOS ≥ 85	90.4% (86.5-94.2%)	19.0% (17.9-20.2%)	5.4% (2.5-8.3%)	97.5% (97.0-98.0%)
GTOS II ≥ 78	89.3% (85.3-93.3%)	22.3% (21.1-23.5%)	5.5% (2.6-8.4%)	97.6% (97.2-98.0%)
GTRI	87.2% (83.0-91.5%)	30.6% (29.3-31.9%)	6.0% (3.0-9.0%)	97.9% (97.5-98.3%)

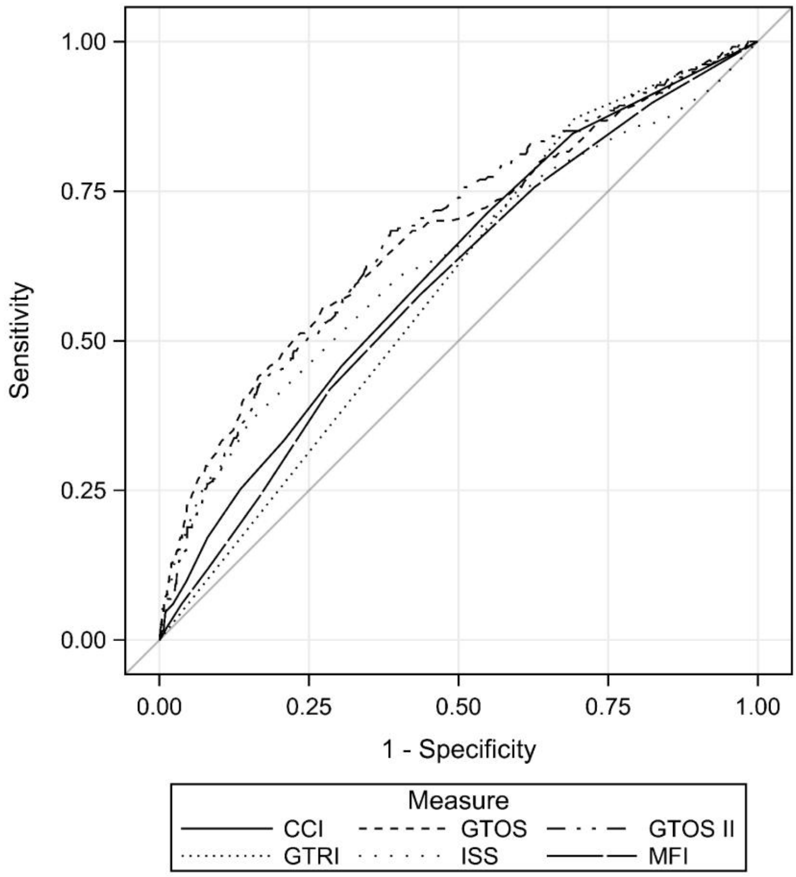
*ISS – injury severity score, MFI – modified frailty index, CCI – Charlson comorbidity index, GTOS – geriatric trauma outcome score, GTRI – geriatric trauma risk indicator

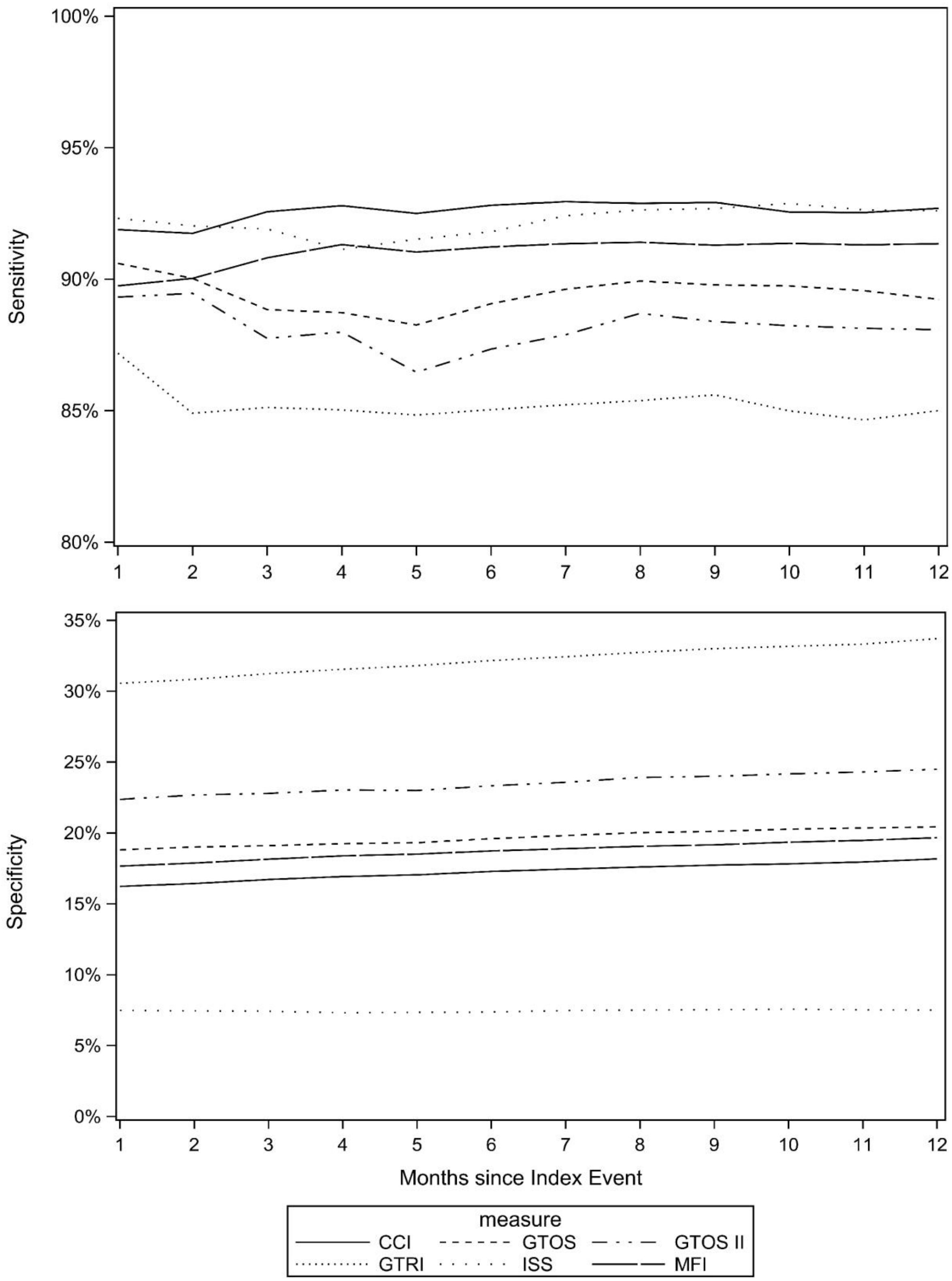


Injured older adults ≥ 65 years transported by EMS to hospital Emergency Departments in 7 counties in Oregon and Washington during 2011
15,649
Patients with continuous Medicare fee-for-service coverage the month prior to the index event through 1 year after the index event (or until death)
5,275
Excluded n=426
Patients with Limited Treatment or Comfort Measures only POLST form active before the index event n=396
Patients with hospice claim in the 30 days prior to index event n=30
Analyzed
4,849



Injured patient ≥ 65 years being transported by EMS
n = 4,849
Need for airway intervention in prehospital, ED, or in-hospital settings?
no
YES
80 patients
30-day mortality: 34.5%
90-day mortality: 38.2%
1-year mortality: 45.7%
Comorbidity burden (Charlson Comorbidity Index ≥ 2)?
YES
3329 patients
30-day mortality: 5.3%
90-day mortality: 10.8%
1-year mortality: 25.5%
HIGH RISK
Overall for 3707 high-risk patients
30-day mortality: 6.0%
90-day mortality: 11.4%
1-year mortality: 25.9%
no
Low Risk
1440 low-risk patients
30-day mortality: 2.1%
90-day mortality: 4.7%
1-year mortality: 10.8%


1.00
0.75
0.50
0.25
0.00
Sensitivity
0.00
0.25
0.50
0.75
1.00
1 - Specificity
Measure
CCI
GTOS
GTOS II
GTRI
ISS
MFI


100%
95%
90%
85%
80%
Sensitivity
35%
30%
25%
20%
15%
10%
5%
0%
Specificity
1 2 3 4 5 6 7 8 9 10 11 12
Months since Index Event
measure
CCI
GTOS
GTOS II
GTRI
ISS
MFI