



Published in final edited form as:

J Trauma Acute Care Surg. 2019 May ; 86(5): 829–837. doi:10.1097/TA.0000000000002195.

Comorbidities, Anticoagulants, and Geriatric-Specific Physiology For the Field Triage of Injured Older Adults

Craig D. Newgard, MD, MPH¹, Amber Lin, MS¹, Elizabeth Eckstrom, MD², Aaron Caughey, MD, PhD³, Susan Malveau, MS¹, Denise Griffiths, BS¹, Dana Zive, MPH¹, and Eileen Bulger, MD⁴

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

²Department of Internal Medicine, Division of Geriatrics, Oregon Health & Science University, Portland, Oregon

³Department of Obstetrics and Gynecology, Oregon Health & Science University, Portland, Oregon

⁴Department of Surgery, University of Washington, Seattle, Washington

Abstract

Background: Comorbid conditions and anticoagulants have been considered as field triage criteria to raise the sensitivity for identifying seriously injured older adults, but research is sparse. We evaluated the utility of comorbidities, anticoagulant use, and geriatric-specific physiologic measures to improve the sensitivity of the field triage guidelines for high-risk older adults in the out-of-hospital setting.

Methods: This was a cohort study of injured adults ≥ 65 years transported by 44 EMS agencies to 51 trauma and non-trauma hospitals in 7 Oregon and Washington counties from 1/1/2011 to 12/31/2011. Out-of-hospital predictors included: current field triage criteria, 13 comorbidities, pre-injury anticoagulant use, and previously developed geriatric specific physiologic measures. The primary outcome (high-risk patients) was: Injury Severity Score (ISS) ≥ 16 or need for major non-

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

AUTHOR CONTRIBUTIONS

Study conception and design: Newgard.

Acquisition of data: Newgard; Zive; Bulger.

Analysis: Lin and Newgard.

Database management and linkage: Malveau.

Interpretation of data: Newgard; Lin; Eckstrom; Caughey; Malveau; Griffiths; Zive; Bulger.

Obtained funding: Newgard.

Drafting of manuscript: Newgard.

Critical revision: Newgard; Lin; Eckstrom; Caughey; Malveau; Griffiths; Zive; Bulger.

Dana Zive assisted with acquisition of data for the project (electronic EMS data from 3 counties, trauma registry data, and POLST records), interpretation of data and the study results, and critical revision of the submitted manuscript. She died on September 30, 2018.

Meetings: Findings from this study have not been presented at any national or regional meetings.

Conflicts of Interest: No author had conflicts of interest related to this study.

orthopedic surgical intervention. We used binary recursive partitioning to develop a clinical decision rule with a target sensitivity of 95%.

Results: There were 5,021 older adults, of which 320 (6.4%) had ISS ≥ 16 or required major non-orthopedic surgery. Of the 2,639 patients with pre-injury medication history available, 400 (15.2%) were taking an anticoagulant. Current field triage practices were 36.6% sensitive (95% CI 31.2 – 42.0%) and 90.1% specific (95% CI 89.2 – 91.0%) for high-risk patients. Recursive partitioning identified (in order): any current field triage criteria; GCS ≥ 14 ; geriatric-specific vital signs; and comorbidity count ≥ 2 . Anticoagulant use was not identified as a predictor variable. The new criteria were 90.3% sensitive (95% CI 86.8 – 93.7%) and 17.0% specific (95% CI 15.8 – 18.1%).

Conclusions: The current field triage guidelines have poor sensitivity for high-risk older adults. Adding comorbidity information and geriatric-specific physiologic measures improved sensitivity, with a decrement in specificity.

Level of Evidence—Level II evidence. Retrospective cohort study with consecutive patients, compared to a criterion gold standard – diagnostic test/criteria.

Keywords

trauma; triage; emergency medical services; geriatric

BACKGROUND

Field triage processes have been used by emergency medical services (EMS) in US trauma systems for over 30 years¹ and are an integral mechanism for concentrating seriously injured patients in major trauma centers.² Field triage is guided by a national algorithm called the Field Triage Decision Scheme.³ The function and efficiency of field triage is measured through accuracy metrics, with national targets for sensitivity of 95% and specificity of 65 – 75% to minimize missing seriously injured patients and resource overuse in trauma systems.² Previous studies and traditional thinking held that triage sensitivity was high and specificity low.⁴ However, more recent research has shown the opposite to be true, particularly for older adults.^{5, 6} A prospective validation study of field triage processes showed that half of seriously injured older adults are missed by the guidelines and transported to non-trauma centers.⁵ Because older adults are a particularly vulnerable population with high morbidity and mortality following injury,⁷⁻¹¹ developing better methods for the early identification of high-risk patients is a major priority for field triage.

The national Field Triage Decision Scheme³ provides the backbone for field triage processes in the US, and is a logical starting point for improving the early identification of high-risk older adults. Several studies have explored triage criteria specific to older adults,¹²⁻¹⁵ but the decision scheme remains largely geared towards seriously injured younger patients. Comorbid conditions, use of anticoagulants, and geriatric-specific physiologic measures are three potential criteria to target high-risk older adults. Comorbidities were included in the triage guidelines from 1987 to 2006,^{1, 16} but were removed in 2011 due to lack of supporting evidence.³ Anticoagulant use is mentioned in the current decision scheme as “Anticoagulants and bleeding disorders – Patients with head injury are at high risk for rapid

deterioration,”³ although there has been a paucity of out-of-hospital literature directly supporting this criterion. A recent study by Nishijima et al suggested that using anticoagulant and antiplatelet medications as triage criteria could potentially identify older adults with serious brain injury otherwise missed by triage processes.¹⁷ A previous study also suggested that geriatric-specific physiologic parameters would raise the sensitivity of field triage.¹² To date, no studies have tested all three of these criteria (comorbidities, anticoagulant use, and revised physiologic measures) against the current field triage guidelines to determine their potential role in better identifying high-risk older adults in the out-of-hospital setting.

In this study, we evaluated the utility of adding comorbidities, anticoagulant use, and geriatric-specific physiologic measures^{12, 13} to the field triage guidelines to improve the sensitivity for identifying high-risk injured older adults (Injury Severity Score¹⁸ [ISS] ≥ 16 or need for major non-orthopedic surgery) in the out-of-hospital setting. We also assessed how new criteria could mesh with the current triage algorithm to facilitate implementation and use.

METHODS

Study Design:

This was a retrospective cohort study that was reviewed and approved by Institutional Review Boards in all study sites, which waived the requirement for informed consent.

Study Setting:

We conducted the study in 7 counties in Oregon and Washington. The counties included urban, suburban, rural, and frontier settings served by 44 public and private EMS agencies transporting to 51 hospitals. The counties use multiple types of EMS systems, including dual advanced life support (ALS) response, tiered response, and single agency ALS response. The agencies work under close medical direction and use standardized field trauma triage protocols based on the national guidelines. Both states have established, inclusive trauma systems, with participating hospitals categorized as Level I – V trauma centers. Level I and II trauma hospitals are considered major trauma centers, consistent with the American College of Surgeons Committee on Trauma (ACSCOT) national guidelines for tertiary trauma care.² For patients who were transferred from the initial receiving hospital, we tracked information at all hospitals, which resulted in the inclusion of 6 additional hospitals. The 57 hospitals have varying capabilities and services, and include: 3 Level I trauma centers, 7 Level II trauma centers, 10 Level III trauma hospitals, 9 Level IV hospitals, 1 Level V hospital and 27 non-trauma hospitals.

Selection of Participants:

We included consecutive injured adults ≥ 65 years transported by 44 EMS agencies in 7 counties from January 1, 2011 through December 31, 2011 with a matched Medicare record. Every patient was tracked for 12 months following the 911 call (follow-up through December 31, 2012). We restricted the sample to patients with continuous Medicare fee-for-service coverage during the 30 days prior to 911 contact and through the index ED/hospital

visit to capture pre-injury comorbidity and medication use. We included patients regardless of receiving hospital, injury severity or admission status. The presence of injury was based on EMS provider primary or secondary impression. We excluded patients with a hospice claim or a Physician Orders for Life-Sustaining Treatment (POLST) form specifying “Limited Treatment” or “Comfort Measures Only” prior to the date of 911 contact, as these patients often have different goals of care and may be managed differently with regard to field triage.

Data Processing:

We collected EMS data as part of a prospective cohort study validating the national field triage guidelines.⁵ We used probabilistic linkage^{19, 20} (LinkSolv, v.9.0.0190, Strategic Matching, Inc., Morrisonville, NY) to match EMS records to state trauma registries, state discharge databases, state death registries, and the Oregon electronic POLST registry. We used validated electronic data methods²¹ and probabilistic linkage routines.²² An external data contractor for the Centers for Medicare and Medicaid Services deterministically matched Medicare claims data to the EMS cohort for one year before and one year after 911 contact. Using a random subset of 3,140 patients from the full cohort, we independently validated the accuracy of probabilistic linkage ($n = 1,350$) and key study variables ($n = 3,140$).²³ Our overall match rate of electronic records into the EMS cohort was 87.3%, with 59.4% matching to the index visit.

Variables:

We captured field triage status (positive versus negative), as determined by EMS providers, independent of hospital destination, injury severity, and admission. To minimize misclassification bias for determining triage status, we triangulated ambulance records, fire department records, trauma registry data, and base hospital phone records.²⁴ We coded out-of-hospital variables based on standardized definitions from the National EMS Information System.²⁵ Out-of-hospital variables included: age; sex; rural versus urban county of 911 response; initial physiologic measures (Glasgow Coma Scale [GCS] score, systolic blood pressure [SBP], respiratory rate, and heart rate); mechanism of injury; intravenous line placement; need for assisted ventilation (bag-mask ventilation or intubation); mode of transport; and receiving hospital. We also coded previously-developed geriatric-specific physiologic triage criteria: GCS ≥ 14 ; SBP ≥ 110 or ≥ 200 mmHg; respiratory rate ≥ 10 or ≥ 24 breaths/minute; and heart rate ≥ 60 or ≥ 110 beats/minute.^{12, 13} The geriatric physiologic measures were analyzed with and without heart rate to account for previous research questioning use of heart rate as a criterion in this population.¹³

We coded comorbidities using the framework of the Charlson Comorbidity Index (CCI).²⁶ Comorbid conditions were based on pre-injury Medicare records from the previous 12 months, the Medicare Chronic Conditions Warehouse, and comorbidities noted in state trauma registries. Rather than using the CCI term, which weights comorbidities differently, we used the 13 individual comorbidities included in the CCI: myocardial infarction, ulcer, cancer, congestive heart failure, stroke, dementia, diabetes, hepatic failure, paralysis, pulmonary dysfunction, renal insufficiency, rheumatic arthritis, and vascular disease. We

also created a non-weighted count-based measure to represent the total number of comorbid conditions.

To capture pre-injury anticoagulant use, we used Medicare Part D claims made in the 90 days prior to 911 contact. The 90-day window represents the maximum time period for which medications are supplied by Medicare, allowing us to capture all outpatient prescriptions filled during this time period and therefore patients taking these medications at the time of 911 contact. Medication data were only available for a subset of patients because not all Medicare beneficiaries participate in Part D. We included the following medications: warfarin, enoxaparin, rivaroxaban, dabigatran, dalteparin, and fondaparinux (apixaban was not yet approved during the study period). We did not evaluate anti-platelet medications as a triage criterion because they were inconsistently recorded in Part D claims, possibly due to the over-the-counter availability of certain agents (e.g., aspirin). For purposes of the analysis, we assumed that if a patient filled a prescription within the 90-day window with adequate supply, they were taking it. As a sensitivity analysis, we also evaluated whether a patient filled a prescription within 7 days and separately within 2 days of the date of 911 contact.

Outcomes:

The primary outcome was ISS ≥ 16 or need for major non-orthopedic surgical intervention (brain, neck, chest, abdominal-pelvic, or spine surgery). This measure integrates the primary metric recommended by ACSCOT for tracking field triage and trauma system performance (ISS ≥ 16)² and a resource-based measure of specialized interventional trauma care. Because injury severity is not included in claims data, we used a mapping function (ICDPIC module for Stata v11, StataCorp, College Station, TX) to convert ICD9-CM diagnosis codes into Abbreviated Injury Scale (AIS) scores and ISS,¹⁷ which we have previously validated.²⁷ For procedures, we used the AHRQ Clinical Classification System²⁸ to categorize ICD9-CM procedure codes into the following major operative groups: brain, neck, chest, abdominal-pelvic, spine, and orthopedic. We also tracked blood transfusion and cardiac procedures (percutaneous coronary intervention, coronary artery bypass grafting, and valve repair). Secondary outcomes included: serious injuries (AIS ≥ 3) to the head, chest, or abdominal-pelvic regions; 30-day mortality; and 1-year mortality.

Analysis:

We used binary recursive partitioning²⁹ to evaluate the utility of comorbid conditions, anticoagulant use, and geriatric-specific physiologic measures as predictors of ISS ≥ 16 or major non-orthopedic surgical intervention. We sought to test these criteria against the current triage criteria and used misclassification costs to favor a high-sensitivity decision tree ($\geq 95\%$), consistent with the national sensitivity target.² To fully explore the predictive value of comorbid conditions, we included each of the 13 conditions as a dichotomous variable (yes/no), as well as a continuous variable for total comorbidity count. We included anticoagulant use and geriatric-specific physiologic measures (both with and without the heart rate criterion) as dichotomous variables. We had two analysts independently perform binary recursive partitioning with the same data and two different software programs (Classification and Regression Tree analysis v8.0, Salford Systems, San Diego, CA and “party” in RStudio 1.0.153, Boston, MA).²⁹ The use of different software programs and

different analysts working independently with the same data increased the rigor of the tree-building process and consistency in the final results. Following the independent analyses, the analysts compared results and combined them into a final decision tree.

To handle missing values, we used multiple imputation.^{30, 31} We generated 10 multiply imputed datasets using flexible chains regression models³² (IVEware, University of Michigan, MI), analyzing each multiply imputed dataset separately using binary recursive partitioning. We compared the resulting decision trees from all multiply imputed datasets, then generated a final decision tree based on the most consistent results across all 10 datasets and the two analyses. We generated sensitivity, specificity, and corresponding 95% confidence intervals (CIs) using Rubin's rules to combine estimates across the multiply imputed datasets and to appropriately account for overall variance.³⁰ We used SAS (v. 9.4, SAS Institute, Cary, NC) for database management and to generate descriptive statistics for the sample.

RESULTS

Of the 15,649 injured older adults transported by EMS during the study period, 5,021 had a matched Medicare fee-for-service record and formed the primary sample. Comparison of included versus excluded patients demonstrated similar characteristics, but with a higher proportion of patients in the primary sample meeting field triage criteria, having a fall mechanism, and transported to Level III-V trauma centers (data not shown). Of the 5,021 patients, 248 (4.9%) had ISS ≥ 16 , 101 (2.0%) required a major non-orthopedic operation, and 320 (6.4%) had ISS ≥ 16 or required major non-orthopedic surgery. The mortality rates at 30 days, 90 days, and 365 days were 4.7%, 9.1%, and 20.9%, respectively. There were 2,639 (52.6% of the primary sample) patients with Medicare Part D medication data available, of which 400 (15.2%) had filled an anticoagulant prescription within 90 days of 911 contact. Characteristics of the study sample are listed in Table 1. In Figure 1, we demonstrate the frequency of use for individual triage criteria by EMS among patients meeting current field triage guidelines. None of the 44 EMS agencies listed anticoagulant use as a criterion. Age, EMS judgment, and "medical condition" were the three most commonly used criteria (all categorized as part of the Step 4 "Special Considerations" criteria in the triage guidelines).

Current field triage practices identified 117 of the 320 patients with an ISS ≥ 16 or major non-orthopedic surgery (sensitivity 36.6%, 95% CI 31.2 – 42.0%; specificity of 90.1%, 95% CI 89.2 – 91.0%). Recursive partitioning yielded the following predictors (in order of priority): any of the current field triage criteria; GCS ≤ 14 ; geriatric-specific vital signs, including heart rate; and comorbidity count ≥ 2 (Figure 2). Overall, this decision rule had 90.3% sensitivity (95% CI 86.8 – 93.7%) and 17.0% specificity (95% CI 15.8 – 18.1%) for identifying older adults with ISS ≥ 16 or requiring major non-orthopedic surgery. Accuracy estimates for field triage with the sequential addition of each new criterion, plus secondary outcomes, are demonstrated in Table 2. Current field triage guidelines were poor at identifying patients with short and long-term mortality. However, the new decision rule had similar sensitivity and specificity for short- and long-term mortality outcomes to other definitions of high risk patients.

Anticoagulant use was not identified as a primary predictor variable in recursive partitioning analyses using the 2,639 patients with medication data. When analyses were repeated using a definition of anticoagulant fill within 7 days of 911 contact (353 of 400 patients, 88.3%) or within 2 days of 911 contact (335 of 400, 83.8%), the results did not qualitatively change. However, we evaluated the decision rule with and without anticoagulant use to assess its potential contribution to field triage (Table 2). Adding anticoagulant use to the decision tree (in addition to current field triage criteria, GCS ≥ 14 , geriatric-specific vital signs, and comorbidity count ≥ 2) demonstrated 94.1% sensitivity (95% CI 90.1 – 98.1%) and 14.0% specificity (95% CI 12.6 – 15.4%). Replacing comorbidity count with anticoagulant use generated a decision tree with 78.9% sensitivity (95% CI 71.5 – 86.2%) and 40.8% specificity (95% CI 38.7 – 42.9).

We also evaluated ambulance transport patterns for older adults. Of the 5,021 injured patients transported by EMS, 803 (16.0%) were initially transported to Level I/II trauma centers. Among the 583 patients meeting current field triage criteria, 222 (38.1%) were transported to Level I/II trauma centers. Using hospital destination as a measure of triage, 114 of 320 patients with ISS ≥ 16 or major non-orthopedic surgery were initially transported to a Level I/II trauma center (sensitivity 35.6%, 95% CI 30.1 – 41.1%). Of the 4,701 patients without serious injuries or requiring specialized operative intervention, 689 were transported to major trauma centers (specificity 85.3%, 95% CI 84.3 – 86.3%). Among the 206 high-risk patients initially transported to non-major trauma centers, 51 (24.8%) were subsequently transferred to Level I/II hospitals, resulting in the following accuracy metrics calculated by final destination Level I/II trauma center: sensitivity 50.8% (95% CI 45.0 – 56.6%) and specificity 84.5% (95% CI 83.5 – 85.6%).

DISCUSSION

In this study, we confirm the poor sensitivity of current field triage practices for identifying high-risk older adults. Whether calculated by overall serious injury, specific types of serious injuries, need for operative intervention, or short- and long-term mortality, the current guidelines missed the majority of high-risk older adults. Among patients who *did* meet current field triage criteria, the majority were not transported to major trauma centers. These findings highlight major gaps in trauma systems for older adults. Using pre-injury comorbidity and medication data in combination with geriatric-specific physiologic measures, we developed a decision algorithm to better identify high-risk older adults. The addition of any abnormal GCS, abnormal vital signs, and comorbidities substantially improved the sensitivity of field triage, at the expense of specificity. These findings demonstrate that high-sensitivity out-of-hospital identification of high-risk older adults is possible, with inherent trade-offs in specificity and over-triage. Previous triage research using an all-age sample suggested that there is a marked drop in specificity when pushing sensitivity from 90% to 95%;³³ our results illustrate a similar drop in specificity that occurs at a much lower sensitivity value for older adults. Whether trauma systems, hospitals, and patients are willing to accept such large increases in over-triage and major shifts in ambulance transport patterns to achieve a major reduction in under-triage is unclear. Our findings and these concepts are highly relevant to the next revision of the Field Triage Decision Scheme.

Comorbidity-based criteria were previously included in the field triage guidelines (1987, 1990, 1999, and 2006),^{1, 16} but were removed in 2011 due to lack of evidence.³ Our results provide this evidence and quantify their contribution to triage processes for older adults. There was no single comorbidity that consistently identified high-risk older adults. Rather, the total comorbidity burden was a stronger predictor. Having two or more comorbid conditions from the CCI list was a useful predictor of high-risk patients, including those with overall serious injury, specific types of serious injuries, need for operative intervention, and short- and long-term mortality. Because the current triage guidelines have such poor sensitivity for high-risk older adults, additional criteria will be required to identify this unique population.

Anticoagulant use was not a good identifier of high-risk patients, particularly in comparison to current triage criteria, geriatric-specific physiologic measures, and comorbidities. This was an unexpected finding. Use of anticoagulants is already mentioned in the field triage algorithm (Step 4 criterion “Anticoagulants and bleeding disorders”), although was not cited as an individual triage criterion by any of the 44 EMS agencies. It is possible that this criterion has already largely been integrated to triage practices (even if not explicitly listed by EMS providers) and represented through other triage criteria (e.g., EMS judgement or medical condition). However, our findings do contrast with recent research by Nishijima and colleagues demonstrating the potential value of anticoagulant use in identifying older adults with serious brain injury.¹⁷ The differences in our findings may reflect how we considered anticoagulants in the analysis. To assess the predictive utility of anticoagulant use, we evaluated this criterion against all current and potential triage criteria. This analytic strategy allowed anticoagulant use to be compared to other triage criteria, as would be done in practice. Another possibility is that comorbidity information already largely encompasses conditions that lead to anticoagulation use and therefore serves as a more important predictor of high-risk patients.

Additional considerations are how to align the new triage criteria for older adults with triage guidelines that are intended for use in all ages, as well as the ideal type of hospital to care for high-risk older adults. Separate triage guidelines for different age groups is likely too complicated for the field, as the current triage algorithm is already complex. The additional criteria for older adults could be included in Step 4 (“special considerations”) to highlight subtle presentations of serious injury among a vulnerable population. Alternatively, the geriatric-specific physiologic criteria could be integrated to Step 1 (physiologic step), including notation that they only apply to patients 65 years and older, with integration of the comorbidity criterion to Step 4. In addition to identifying high-risk patients, the triage guidelines direct hospital selection. The guidelines are predicated on the idea that patients with serious injuries have better outcomes when cared for in major trauma centers. While this concept has been proven in younger patients,³⁴ the benefit of major trauma centers for older adults remains unclear.³⁴⁻³⁶ Nonetheless, we believe that early identification of high-risk older adults is an important first step in the out-of-hospital decision-making process.

Because this analysis focused on evaluation of comorbidities and medications as potential field triage criteria, we restricted the sample to patients with pre-injury information available, which could have introduced selection bias. While characteristics of patients

included versus excluded from the analysis were generally similar, our sensitivity estimates for current field triage practices were lower than that of similar cohorts drawn from the same geographic regions.^{5, 12, 37} This comparison suggests that if bias was present in the sample, the direction appears toward worsening triage sensitivity, reflecting greater difficulty in creating a high-sensitivity decision rule. Therefore, we believe our results provide conservative estimates for how the proposed decision rule may work in practice.

Another factor reflected in our results is the disconnect between identifying high-risk older adults in the field and selecting an appropriate receiving hospital. That is, the majority of patients meeting current triage guidelines were not transported to major trauma centers. So, even if more than 90% of high-risk older adults were identified using revised triage criteria, most of these patients would still not be transported to major trauma centers. If major trauma centers are assumed to be the ideal destination for high-risk older adults, this disconnect will need to be addressed. Our estimates also assume that EMS personnel can obtain timely and accurate information about comorbidities and be compliant with the additional triage criteria. Some research has suggested that EMS personnel have incomplete adherence to the triage algorithm.³⁸ If comorbidity information is to be integrated into the triage guidelines, the importance of obtaining accurate comorbidity information in the field will need to be highlighted, integrated to EMS training activities, and studied. With the goal of getting “the right patient to the right place at the right time”,² our findings demonstrate that several additional aspects of triage and transport processes beyond just the criteria need attention.

Finally, we used a retrospective cohort study design, which has inherent limitations. Our findings will need to be replicated using a prospective study design, ideally performed in regions beyond those used to derive the decision rule, before considering integration to national guidelines.

In summary, the current field triage guidelines had poor sensitivity for identifying high-risk older adults. We propose additional triage criteria to better identify these patients. Adding key physiologic and comorbidity information notably improved the identification of high-risk older adults and represent an opportunity to improve triage processes for the older adult population.

Acknowledgments

Source of Funding:

This project was supported by grant number R01HS023796 from the Agency for Healthcare Research and Quality. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

REFERENCES

1. Mackersie RC. History of trauma field triage development and the American College of Surgeons criteria. *Prehosp Emerg Care*. 2006;10(3):287–94. [PubMed: 16801263]
2. Resources for Optimal Care of the Injured Patient. 6th. ed. Trauma. Co, editor: American College of Surgeons; 2014.
3. Sasser SM, Hunt RC, Faul M, Sugerman D, Pearson WS, Dulski T, Wald MM, Jurkovich GJ, Newgard CD, Lerner EB, et al. Guidelines for field triage of injured patients: recommendations of

the National Expert Panel on Field Triage, 2011. MMWR Recommendations and reports : Morbidity and mortality weekly report Recommendations and reports / Centers for Disease Control. 2012;61(RR-1):1–20.

4. Lerner EB. Studies evaluating current field triage: 1966-2005. *Prehosp Emerg Care.* 2006;10(3): 303–6. [PubMed: 16801265]
5. Newgard CD, Fu R, Zive D, Rea T, Malveau S, Daya M, Jui J, Griffiths DE, Wittwer L, Sahni R, et al. Prospective Validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons. *J Am Coll Surg.* 2016;222(2):146–58. [PubMed: 26712244]
6. Xiang H, Wheeler KK, Groner JI, Shi J, Haley KJ. Undertriage of major trauma patients in the US emergency departments. *Am J Emerg Med.* 2014;32(9):997–1004. [PubMed: 24993680]
7. Livingston DH, Lavery RF, Mosenthal AC, Knudson MM, Lee S, Morabito D, Manley GT, Nathens A, Jurkovich G, Hoyt DB, et al. Recovery at one year following isolated traumatic brain injury: a Western Trauma Association prospective multicenter trial. *J Trauma.* 2005;59(6):1298–304; discussion 304. [PubMed: 16394900]
8. Mosenthal AC, Lavery RF, Addis M, Kaul S, Ross S, Marburger R, Deitch EA, Livingston DH. Isolated traumatic brain injury: age is an independent predictor of mortality and early outcome. *J Trauma.* 2002;52(5):907–11. [PubMed: 11988658]
9. Platts-Mills TF, Flannigan SA, Bortsov AV, Smith S, Domeier RM, Swor RA, Hendry PL, Peak DA, Rathlev NK, Jones JS, et al. Persistent Pain Among Older Adults Discharged Home From the Emergency Department After Motor Vehicle Crash: A Prospective Cohort Study. *Ann Emerg Med.* 2016;67(2):166–76 e1. [PubMed: 26092559]
10. Platts-Mills TF, Nebolisa BC, Flannigan SA, Richmond NL, Domeier RM, Swor RA, Hendry PL, Peak DA, Rathlev NK, Jones JS, et al. Post-Traumatic Stress Disorder among Older Adults Experiencing Motor Vehicle Collision: A Multicenter Prospective Cohort Study. *Am J Geriatr Psychiatry.* 2017.
11. Platts-Mills TF, Nicholson RJ, Richmond NL, Patel KV, Simonsick EM, Domeier RM, Swor RA, Hendry PL, Peak DA, Rathlev NK, et al. Restricted activity and persistent pain following motor vehicle collision among older adults: a multicenter prospective cohort study. *BMC Geriatr.* 2016;16:86. [PubMed: 27094038]
12. Newgard CD, Holmes JF, Haukoos JS, Bulger EM, Staudenmayer K, Wittwer L, Stecker E, Dai M, Hsia RY, Western Emergency Services Translational Research Network I. Improving early identification of the high-risk elderly trauma patient by emergency medical services. *Injury.* 2016;47(1):19–25. [PubMed: 26477345]
13. Newgard CD, Richardson D, Holmes JF, Rea TD, Hsia RY, Mann NC, Staudenmayer K, Barton ED, Bulger EM, Haukoos JS, et al. Physiologic field triage criteria for identifying seriously injured older adults. *Prehosp Emerg Care.* 2014;18(4):461–70. [PubMed: 24933614]
14. Ichwan B, Darbha S, Shah MN, Thompson L, Evans DC, Boulger CT, Caterino JM. Geriatric-specific triage criteria are more sensitive than standard adult criteria in identifying need for trauma center care in injured older adults. *Ann Emerg Med.* 2015;65(1):92–100 e3. [PubMed: 24908590]
15. Werman HA, Erskine T, Caterino J, Riebe JF, Valasek T, Members of the Trauma Committee of the State of Ohio EMSB. Development of statewide geriatric patients trauma triage criteria. *Prehosp Disaster Med.* 2011;26(3):170–9. [PubMed: 22107767]
16. Sasser SM, Hunt RC, Sullivent EE, Wald MM, Mitchko J, Jurkovich GJ, Henry MC, Salomone JP, Wang SC, Galli RL, et al. Guidelines for field triage of injured patients. Recommendations of the National Expert Panel on Field Triage. MMWR Recommendations and reports : Morbidity and mortality weekly report Recommendations and reports / Centers for Disease Control. 2009;58(RR-1):1–35.
17. Nishijima DK, Gaona SD, Waechter T, Maloney R, Bair T, Blitz A, Elms AR, Farrales RD, Howard C, Montoya J, et al. Out-of-Hospital Triage of Older Adults With Head Injury: A Retrospective Study of the Effect of Adding “Anticoagulation or Antiplatelet Medication Use” as a Criterion. *Ann Emerg Med.* 2017;70(2):127–138. [PubMed: 28238499]
18. Baker SP, O’Neill B, Haddon W Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma.* 1974;14(3):187–96. [PubMed: 4814394]

19. Jaro MA. Probabilistic linkage of large public health data files. *Stat Med*. 1995;14(5-7):491–8. [PubMed: 7792443]
20. Dean JM, Vernon DD, Cook L, Nechodom P, Reading J, Suruda A. Probabilistic linkage of computerized ambulance and inpatient hospital discharge records: a potential tool for evaluation of emergency medical services. *Ann Emerg Med*. 2001;37(6):616–26. [PubMed: 11385330]
21. Newgard CD, Zive D, Jui J, Weathers C, Daya M. Electronic versus manual data processing: evaluating the use of electronic health records in out-of-hospital clinical research. *Acad Emerg Med*. 2012;19(2):217–27. [PubMed: 22320373]
22. Newgard CD. Validation of probabilistic linkage to match de-identified ambulance records to a state trauma registry. *Acad Emerg Med*. 2006;13(1):69–75. [PubMed: 16365326]
23. Newgard CD, Malveau S, Zive D, Lupton J, Lin A. Building A Longitudinal Cohort From 9-1-1 to 1-Year Using Existing Data Sources, Probabilistic Linkage, and Multiple Imputation: A Validation Study. *Acad Emerg Med*. 2018.
24. Newgard CD, Fu R, Malveau S, Rea T, Griffiths DE, Bulger E, Klotz P, Tirrell A, Zive D. Out-of-Hospital Research in the Era of Electronic Health Records. *Prehosp Emerg Care*. 2018:1–12.
25. Dawson DE. National Emergency Medical Services Information System (NEMSIS). *Prehosp Emerg Care*. 2006;10(3):314–6. [PubMed: 16801268]
26. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373–83. [PubMed: 3558716]
27. Fleischman RJ, Mann NC, Dai M, Holmes JF, Wang NE, Haukoos J, Hsia RY, Rea T, Newgard CD. Validating the Use of ICD-9 Code Mapping to Generate Injury Severity Scores. *J Trauma Nurs*. 2017;24(1):4–14. [PubMed: 28033134]
28. HCUP Clinical Classifications Software (CCS) for ICD-9-CM Rockville, MD: Agency for Healthcare Research and Quality; 2017 [Accessed January 8, 2018]. Available from: <https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp>.
29. Hothorn T HK, Zeileis A. Unbiased Recursive Partitioning: A Conditional Inference Framework. *J Comput Graph Stat*. 2006;15(3):651–74.
30. Rubin D Multiple Imputation for Nonresponse in Surveys. Hoboken, NJ: John Wiley & Sons, Inc.; 1987.
31. Little R, Rubin D. Statistical Analysis with Missing Data. 2 ed. York New: John Wiley & Sons, Inc.; 2002.
32. Raghunathan T, Lepkowski, Van Hoewyk J, Solenberger P. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Surv Methodol*. 2001;27:85–95.
33. Newgard CD, Hsia RY, Mann NC, Schmidt T, Sahni R, Bulger EM, Wang NE, Holmes JF, Fleischman R, Zive D, et al. The trade-offs in field trauma triage: a multiregion assessment of accuracy metrics and volume shifts associated with different triage strategies. *J Trauma Acute Care Surg*. 2013;74(5):1298–306; discussion 306. [PubMed: 23609282]
34. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, Salkever DS, Scharfstein DO. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med*. 2006;354(4):366–78. [PubMed: 16436768]
35. Pracht EE, Langeland-Orban B, Flint L. Survival advantage for elderly trauma patients treated in a designated trauma center. *J Trauma*. 2011;71(1):69–77. [PubMed: 21818016]
36. Staudenmayer KL, Hsia RY, Mann NC, Spain DA, Newgard CD. Triage of elderly trauma patients: a population-based perspective. *J Am Coll Surg*. 2013;217(4):569–76. [PubMed: 24054408]
37. Newgard CD, Zive D, Holmes JF, Bulger EM, Staudenmayer K, Liao M, Rea T, Hsia RY, Wang NE, Fleischman R, et al. A multisite assessment of the American College of Surgeons Committee on Trauma field triage decision scheme for identifying seriously injured children and adults. *J Am Coll Surg*. 2011;213(6):709–21. [PubMed: 22107917]
38. Newgard CD, Fu R, Lerner EB, Daya M, Jui J, Wittwer L, Schmidt TA, Zive D, Bulger EM, Sahni R, et al. Role of Guideline Adherence In Improving Field Triage. *Prehosp Emerg Care*. 2017:1–11.

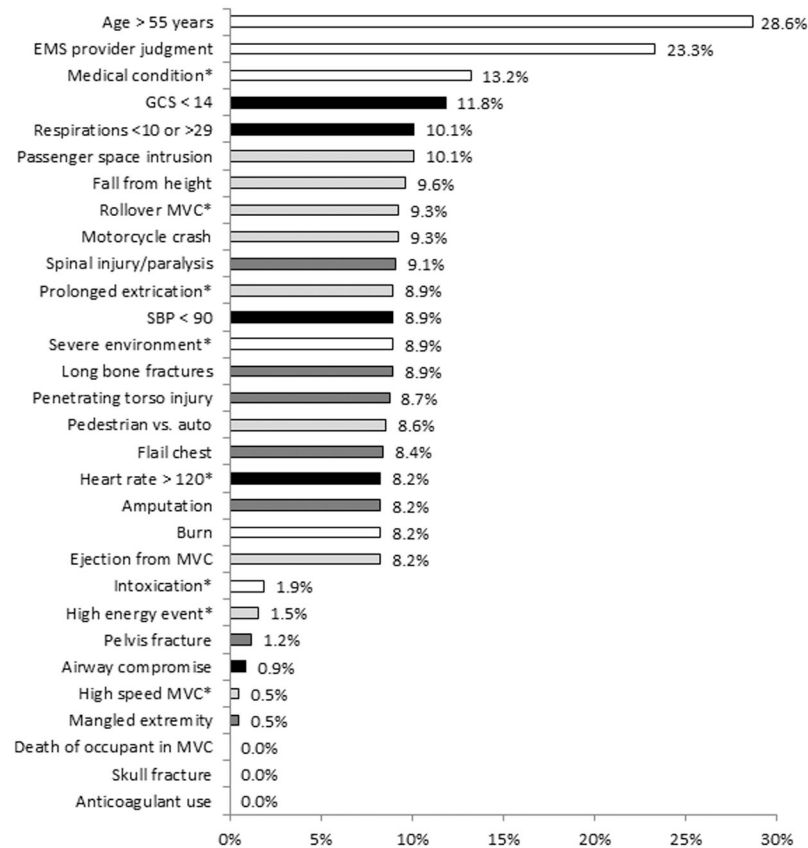


Figure 1.

Current use of individual triage criteria by EMS among older adults meeting the field trauma triage guidelines (n = 583).

* Triage criteria used by EMS agencies that are not included in the current (2011) national field triage guidelines.

† Color scheme for histogram bars follows steps of national Field Triage Decision Scheme: Step 1 criteria (physiologic) = black; Step 2 criteria (anatomic) = dark grey; Step 3 criteria (mechanism) = light grey; Step 4 criteria (special considerations) = white.

‡ Data for individual triage criteria were collected only when EMS marked a criterion as present. To account for varying proportions of missingness, percentages were calculated using a fixed denominator of 583 triage-positive patients. Multiple criteria could be applied to a single patient, so the percentages do not add to 100%.

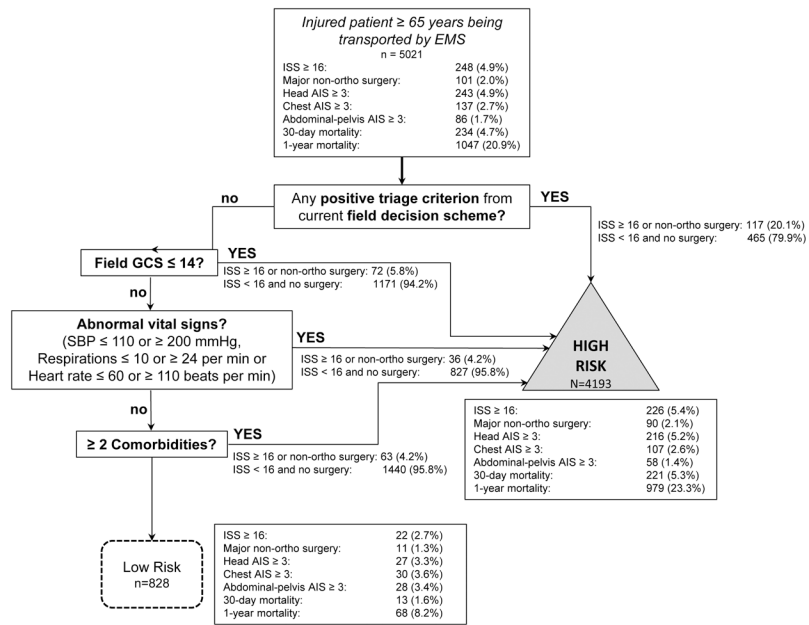


Figure 2. Derived clinical decision rule aligning the current triage guidelines with geriatric-specific physiology and comorbidity criteria to better identify high-risk injured older adults (n = 5,021).

Table 1.

Characteristics of injured older adults transported by emergency medical services (n = 5,021).

Demographics:		
Mean – age		81.5 years
65 - 74 years	1,256	(25.0%)
75 – 84 years	1,624	(32.3%)
85 – 94 years	1,871	(37.3%)
95 years	270	(5.4%)
Women	3,373	(67.2%)
Urban county	4,826	(96.1%)
Rural county	195	(3.9%)
Pre-911 comorbidities:		
Myocardial infarction	1,822	(36.3%)
Congestive heart failure	1,594	(31.8%)
Dementia	1,516	(30.2%)
Diabetes	1,464	(29.2%)
Chronic renal failure	1,445	(28.8%)
COPD	1,429	(28.5%)
Cerebrovascular disease	1,252	(24.9%)
Peripheral vascular disease	1,008	(20.1%)
Cancer	1,027	(20.5%)
Rheumatoid arthritis	283	(5.6%)
Ulcers	116	(2.3%)
Paralysis	114	(2.3%)
Liver disease	59	(1.2%)
Mean - total count of comorbidities	2.6	(range 0 – 10)
Pre-injury anti-coagulation use (among 2,639 with known medication data)*:		
Any	400	(15.2%)
Warfarin	385	(14.6%)
Non-warfarin anti-coagulants (enoxaparin, rivaroxaban, dabigatran, dalteparin, and fondaparinux)	33	(1.3%)
Out-of-hospital triage, physiology and procedures:		
Met 1 current field triage criteria, per EMS	583	(11.6%)
SBP 110 mmHg	503	(10.0%)
SBP 200 mmHg	193	(3.8%)
GCS 8	22	(0.4%)
GCS 9 – 12	93	(1.8%)
GCS 13 – 15	4,906	(97.7%)
Respiratory rate 10 or 24 breaths/minute	288	(5.7%)
Heart rate 60 or 110 beats/minute	631	(12.6%)

Assisted ventilation (bag-valve mask ventilation, intubation, supraglottic airway)	29	(0.6%)
Intravenous or intraosseous line	889	(17.7%)
<i>Mechanism of Injury</i>		
Fall	4,177	(83.2%)
Motor vehicle crash	284	(5.7%)
Motor vehicle vs. pedestrian	120	(2.4%)
Penetrating injury (gunshot wound or stabbing)	44	(0.9%)
Other	397	(7.9%)
<i>Initial hospital and subsequent inter-hospital transfers:</i>		
Level I	427	(8.5%)
Level II	376	(7.5%)
Level III	1,056	(21.0%)
Level IV	781	(15.6%)
Level V	59	(1.2%)
Non-trauma hospital	2,322	(46.3%)
Inter-hospital transfer	434	(8.7%)
<i>Injury severity and injury patterns:</i>		
Mean ISS	6.6	
ISS 0 – 8	3,117	(62.1%)
ISS 9 – 15	1,656	(33.0%)
ISS 16 – 24	212	(4.2%)
ISS > 24	36	(0.7%)
Head AIS 3	243	(4.9%)
Chest AIS 3	137	(2.7%)
Abdominal-pelvic AIS 3	86	(1.7%)
Extremity AIS 3	819	(16.3%)
<i>Hospital interventions:</i>		
Major surgery – non-orthopedic	101	(2.0%)
Orthopedic surgery	808	(16.1%)
Packed red blood cell transfusion (any)	358	(7.1%)
Cardiac procedures	31	(0.6%)
<i>Outcomes:</i>		
30-day mortality	234	(4.7%)
90-day mortality	458	(9.1%)
1-year mortality	1,047	(20.9%)

* There were 2,639 patients with Medicare Part D records for medication use within 90 days prior to 911 contact; 18 patients filled more than one anticoagulation medication during this time period. EMS = emergency medical services; SBP = systolic blood pressure; GCS = Glasgow Coma Scale score; ISS = Injury Severity Score; AIS = Abbreviated Injury Scale score.

Table 2.

Stepwise accuracy metrics for the field triage of injured older adults using current field triage guidelines and additional triage criteria (n = 5,021).

	Sensitivity	95% CI	Specificity	95% CI	Sensitivity	95% CI	Specificity	95% CI
	Outcome: ISS 16, major non-orthopedic surgery, or early death				Outcome: ISS 16			
Current triage guidelines	36.6%	(31.2-42.0%)	90.1%	(89.2-91.0%)	39.9%	(33.7-46.0%)	89.9%	(89.0-90.7%)
Add: GCS 14	59.2%	(53.3-65.0%)	65.2%	(63.6-66.7%)	63.8%	(57.5-70.1%)	65.1%	(63.5-66.6%)
Add: Geriatric-specific vital signs	70.5%	(65.2-75.9%)	47.6%	(46.1-49.2%)	74.4%	(68.5-80.2%)	47.5%	(46.0-49.0%)
Add: Comorbidity count 2	90.3%	(86.8-93.7%)	17.0%	(15.8-18.1%)	91.3%	(87.7-94.9%)	16.9%	(15.7-18.1%)
Add: Oral anticoagulant use*	94.1%	(90.1-98.1%)	14.0%	(12.6-15.4%)	95.6%	(91.7-99.5%)	14.0%	(12.6-15.4%)
	Outcome: Head AIS 3				Outcome: Head, Chest, or Abdominal-Pelvic AIS 3			
Current triage guidelines	33.9%	(24.8-43.0%)	89.5%	(88.6-90.4%)	28.0%	(21.9-34.1%)	89.9%	(89.0-90.7%)
Add: GCS 14	61.5%	(51.6-71.3%)	64.9%	(63.4-66.4%)	51.4%	(44.5-58.3%)	65.0%	(63.4-66.5%)
Add: Geriatric-specific vital signs	73.2%	(63.9-82.5%)	47.4%	(45.9-49.0%)	65.3%	(59.2-71.4%)	47.5%	(45.9-49.1%)
Add: Comorbidity count 2	89.3%	(80.9-97.6%)	16.8%	(15.5-18.0%)	82.5%	(77.3-87.7%)	16.4%	(15.2-17.6%)
Add: Oral anticoagulant use*	94.2%	(87.5-100%)	13.9%	(12.5-15.3%)	89.2%	(83.3-95.1%)	13.7%	(12.3-15.2%)
	Outcome: 30-day mortality				Outcome: 1-year mortality			
Current triage guidelines	15.7%	(11.0-20.4%)	88.6%	(87.8-89.5%)	11.3%	(9.3-13.2%)	88.3%	(87.3-89.3%)
Add: GCS 14	54.1%	(47.2-61.0%)	64.5%	(63.0-66.1%)	45.0%	(41.7-48.2%)	65.9%	(64.1-67.6%)
Add: Geriatric-specific vital signs	71.1%	(65.1-77.2%)	47.3%	(45.7-48.8%)	63.2%	(60.1-66.2%)	49.0%	(47.2-50.7%)
Add: Comorbidity count 2	94.4%	(91.4-97.4%)	17.0%	(15.9-18.2%)	93.5%	(92-95.1%)	19.1%	(17.8-20.5%)
Add: Oral anticoagulant use*	96.0%	(92.3-99.7%)	13.9%	(12.5-15.3%)	95.0%	(93.1-96.9%)	15.7%	(14.1-17.3%)

* When use of anticoagulant medication replaces comorbidity count in the decision rule, sensitivity and specificity are: 78.9% and 40.8% for ISS 16 or major non-orthopedic surgery; 83.3% and 40.8% for ISS 16; 82.1% and 40.7% for head AIS 3; 74.7% and 40.7% for head, chest, or abdominal-pelvic AIS 3; 80.1% and 40.5% for 30-day mortality; and 69.9% and 42.1% for 1-year mortality.