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Out-of-hospital and Inter-hospital Under-triage to Designated Tertiary Trauma Centers among Injured Older Adults – A 10-year Statewide Geospatial-Adjusted Analysis

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Abstract

Objective—While out-of-hospital under-triage of seriously injured older adults to tertiary trauma centers has long been acknowledged, no study has adjusted for place of injury or evaluated the extent of inter-facility under-triage. We sought to determine distance and confounder adjusted odds of treatment at a tertiary trauma center (TTC) for older adult trauma patients compared to younger trauma patients, for patients transported from the scene of injury and those transferred from a non-tertiary trauma (NTTC) center.

Methods—This was a retrospective cohort study utilizing data from a statewide trauma registry reported over a 10-year period (2005–2014). The outcome of interest was treatment at an American College of Surgeons or state-designated Level I/II trauma center (TTC). The predictor variable of interest was age group (≥ 55 years vs < 55 years). Covariates of interest included patient demographics, clinical characteristics and various distance measures calculated based on the patient's injury location.

Results—84 930 patients met study criteria. Of these 42% (35659) were 55 years and older with an average age of 74 years (SD, 11.6). Older adult patients were on average, injured slightly farther away from a TTC (median distance, 34 vs 29 miles, $p < 0.001$). Among patients initially presenting to NTTCs, older adults were significantly more likely to be transferred to another NTTC (53% vs 34%). After adjusting for confounders and distance measures, older adults were

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Declaration of Interest

The authors declare no conflict of interest.

less likely to be treated at TTCs overall (OR=0.54, 95% CI: 0.52–0.56), whether transported by EMS from the scene of injury (OR= 0.47, 95% CI: 0.44–0.50) or via inter-facility transfer (OR= 0.63, 95%CI: 0.59 – 0.68).

Conclusions—Injured older adults face significant under-triage to TTCs whether by EMS from the scene of injury or via transfer from NTTCs. Adjusting for proximity of injury to a TTC does not alter these findings.

Keywords

Inter-hospital; geriatric; under-triage; tertiary trauma center

INTRODUCTION

Older adult patients account for 25% of injury fatalities per year and consume 33% of health care resources spent on trauma.^{1, 2} Adverse outcomes following most acute events increase with age, however, age-specific mortality in patients with severe traumatic injury begins to increase as early as age of 40 years.³ The risk of mortality following trauma is on average, four (4) times greater in older patients compared to their younger counterparts.^{1, 4, 5} Moreover, the risk of in-hospital complications in older trauma patients is twice that of younger adults.⁶

Level I and II trauma centers (tertiary trauma centers) offer the most comprehensive trauma care and have the resources to manage seriously injured patients. As such, severely injured patients who are transported to or treated at a non-tertiary trauma center (NTTC) are generally considered under-triaged. Some studies have reported a survival benefit for injured older adults treated at tertiary trauma centers^{7–9} while others have reported no survival benefit.^{10–12} While research is mixed about the benefit of tertiary trauma centers (TTC) among older adults, many seriously injured older adults require specialized trauma care at these centers. However, field under-triage to these centers among older adults continues unabated.^{13–21}

The Field Triage Decision Scheme developed by American College of Surgeons Committee on Trauma (ASCOT) in 1986 forms the basis field triage guidelines for injured patients in many regions including Oklahoma. In partnership with the Centers for Disease Control and Prevention (CDC), these guidelines have been periodically revised,²² and play a critical role in ensuring that seriously injured patients are transported to tertiary trauma centers. The decision scheme has been shown to have high overall sensitivity,²³ but much lower sensitivity for seriously injured older patients.^{15, 21, 24} For patients initially transported to NTTCs but require the resources of a TTC, secondary triage and the inter-hospital transfer process acts as safety net and ensures timely definitive care. While there are ASCOT guidelines for re-triaging of patients for inter-hospital transfer, there is evidence to suggest this process is highly variable²⁵ and, it's unclear to what extent inter-facility triage rates vary by age group.

A number of studies have shown that, compared to their younger counterparts, older adults 55 years and older are under-triaged to a designated TTC from the scene of injury.^{13–18, 20} In

addition to injury severity and other associated clinical factors, distance from the scene of injury is likely to have a strong influence on whether patients are transported or transferred to a TTC. To our knowledge, only one study has additionally adjusted for distance to a TTC,²⁶ however, distance measures used in this study were determined based on patient's place of residence and are obviously less accurate than measures calculated using place of injury. Furthermore, while a few studies have included patients transferred between facilities and considered only the trauma level (TTC vs NTTC) of final definitive care regardless of initial transport destination (combined triage process),^{21, 26} no study has evaluated the extent of inter-facility under-triage separately. For predominantly rural regions trauma system effectiveness may be largely predicated on rapid identification at the initial facility and transfer of patients requiring a higher level of trauma care. Evaluating a combined triage process (field triage and inter-facility triage) generates non-specific information regarding the effectiveness of inter-facility triage.

We sought to determine the adjusted odds of treatment at a tertiary trauma center for older adult trauma patients, transported from the scene of injury and via inter-hospital transfer from a non-tertiary trauma center adjusting for the geocoded injury location, injury severity and other potentially confounding variables.

PATIENTS AND METHODS

Study Design

This was a retrospective cohort study utilizing data from a statewide trauma registry reported between 2005 and 2014. The outcome of interest was treatment at a designated TTC. The predictor variable of interest was age group, dichotomously defined as older adult (age ≥ 55 years) or young adult (age < 55 years). The age cut-point of 55 years was chosen because 1) age-specific mortality in major trauma patients begins to increase as early as age of 40 years;³ 2) studies have shown that the problem of under-triage start as early as 50 years and;¹⁶ 3) the current national (CDC) triage guidelines also use an age cut-off of 55 years and older to define older adults.²² Both the Oklahoma State Department of Health (OSDH) and the University of Oklahoma Health Sciences Center Institutional Review Boards approved this study with waiver of informed consent.

Study Setting

As of December 2014, there were 80 Level IV NTTCs (primarily located in rural areas), 26 Level III NTTCs, 2 Level II TTCs, and one Level I TTC in Oklahoma. The only Level I TTC is located centrally (Oklahoma City) and is verified by the American College of Surgeons Committee on Trauma (ACS-COT), while the two Level II TTCs (of which one is ACS verified) are located in the northeastern (Tulsa) part of the state. During the study period, 6 NTTCs were re-designated from Level III to IV and 1 NTTC was re-designated from Level IV to III; there were no changes in the number of tertiary trauma centers. The State of Oklahoma has a mandatory, inclusive trauma system, and all state-licensed hospitals designated as trauma centers are required to take part in trauma system development and report data to the state trauma registry. Non-designated hospitals are not required to participate in trauma system activities and include federal facilities, Indian Health Service,

and specialty hospitals. Patients meeting the Oklahoma major trauma definition (Table 1) and all inter-facility transfers are reported on a monthly basis. Oklahoma's prehospital triage guidelines are based on the CDC's Field Triage guidelines and are periodically revised in line with the CDC's recommendations. No significant changes to the guidelines were initiated during the study period.

Study Population

To minimize measurement error (e.g. initial emergency department (ED) vital signs, intubation status, etc.) and improve data completeness and accuracy, records for patients transferred between hospitals were linked using SAS (Cary, NC) based LinkPro 3.01 (InfoSoft Inc., Winnipeg, MB Canada). Multiple iterations of deterministic and probabilistic linkage attempts were made using last name, first name, date of birth, arrival date, gender, age, and Soundex coded last name as linking variables. A majority (88%) of the records were successfully linked. Between 2005 and 2014, 120,683 unique patients were reported to the Oklahoma State Trauma Registry (OSTR) and 84,930 met study eligibility.

Geospatial Analysis

Several measures of distance were calculated for each patient and these included distance from the scene of injury to a TTC, distance to the closest Level III trauma center, and distance to the closest facility regardless of trauma level. Data sources for geocoding services included 2010 Census ZIP Code Tabulation Areas (ZCTAs), 2010 Census Counties, 2010 Census Places and 2014 ESRI U.S. ZIP Code Points. Records with Post Office Box (POB) zip codes were assigned randomly to zip code areas within 5 miles of the delivery post office address. Of all patient records, 93.3% were successfully geocoded including 75.7% geocoded based on injury zip code, 10.8% based on injury county and 6.8% based injury city. Patient injury points were located to the population weighted centroid of injury zip codes, counties or cities. ArcGIS Network Analyst extension which uses actual road networks, was used to determine distance variables of interest based on the USA Contiguous Equidistant Conic coordinate projection system (minimizes distortions while calculating distance between two points). Proportions of patients treated at TTCs were also calculated for each county for each age group by dividing the number of patients injured in the county and treated at a TTC by total number injured in that county.

Covariates

In addition to distance measures, other variables considered included injury year, gender, race, injury etiology (traffic-related, stabbing/gunshot wound, falls, other) and blunt vs penetrating, mode of arrival to initial hospital (Emergency Medical Services [EMS] vs non-EMS), inter-facility transfer status, inter-facility mode of transport, trauma level transferred to, if transferred (tertiary vs non-tertiary). Clinical factors of interest considered included initial ED vital signs (Glasgow Coma Scale (GCS), systolic blood pressure (SBP), heart rate (HR) and respiratory rate [RR]), EMS/ED intubation status, overall injury severity score (ISS), serious injury by body region (AIS ≥ 3), specific injuries based on the International Classification of Diseases–9th Revision–Clinical Modification (ICD-9) codes (flail chest, long bone fracture, skull fracture, pelvic fracture, wrist/ankle amputation and solid organ injuries) and presence of any comorbid condition (pulmonary, cardiac, diabetes,

coagulopathy, cancer, and liver/kidney disease). Hypovolemic shock was defined as SBP < 90 mm Hg and a traumatic brain injury (TBI) as GCS < 9.

Statistical Analysis

Unadjusted comparisons between older (≥ 55 years) and younger (17–54 years) patient groups were performed using the independent Student's t test or Mann-Whitney Wilcoxon test for continuous variables, and for categorical variables, the chi-square test was used. Definitive treatment was defined as final trauma care, without need for transfer for further trauma care. Logistic regression was used to determine the independent effect of age group on definitive treatment at a tertiary trauma center while adjusting for confounding/other predictor variables. The association between age group and definitive treatment at a TTC was evaluated using three separate multivariable models, determined a priori. The adjusted age group effect was evaluated for the full cohort, for subgroups of patients transported by EMS from the scene to a TTC or NTTC for definitive care and finally for patients transferred to another trauma facility for definitive care after initial transport to a NTTC. First-order statistical interactions were considered significant if they met a significance level of $p < 0.05$. Variables were considered to be important confounders/predictors if their inclusion or exclusion resulted in at least a 20% change in the estimate of the age group effect. The C statistic was used to assess how well a model discriminated between transport/transfer decisions, and the Hosmer-Lemeshow goodness-of-fit test assessed the final model's overall adequacy of fit with the data. Because several surrogate measures of injury acuity were considered for the multivariable model, we evaluated the correlation between coefficients of variables retained in final models. A crude evaluation of multicollinearity among covariates retained in final models was also performed using multiple linear regression PROC REG SAS procedure for Eigen-value analysis. In addition to multivariable analyses, the proportion of patients with an ISS ≥ 16 treated at NTTCs was used to determine under-triage rates by age group.

Attrition and sensitivity analyses

Excluded from univariate and multivariable models were 6439 patients (7.6%) due to missing data. A majority of these patients (5881, 6.8%) were excluded because their injury location could not be geocoded and therefore distance measures could not be calculated. We evaluated the potential for selection bias by comparing selected characteristics of patients included and those excluded to explore if these differed by age group. We also assessed the impact of not adjusting for distance measures on the age group estimates as a form of sensitivity analysis. All analyses were performed using SAS software version 9.3 (SAS 9.3, SAS Institute, Cary, NC).

RESULTS

Of the 120683 unique patients reported to the OSTR, 84930 met study eligibility (Figure 1). Patients were excluded from the study if they were 16 years old or younger ($n=17498$), had burn related injuries ($n=1880$), were transferred to or from an out-of-state hospital ($n=15581$). Of the remaining 84930, 58% (49271) were less than 55 years old with an average age of 34 years (SD, 11.3) and 42% were aged 55 years and older with an average

age of 74 years (SD, 11.6). About 7.6% (6439) of eligible patients were excluded from univariate and multivariable analyses. The proportion of patients excluded did not differ significantly by age group overall (8% younger vs 6% older adults). No major age group differences were observed in the proportion of excluded patients treated at TTC (6% young vs 4% older adults). Among those < 55 years old, those included had a slightly higher average ISS than those excluded (11.6 vs 9.8, $p < 0.001$), however among those ≥ 55 years, the average ISS for those included and those excluded did not vary significantly (10.7 vs 10.5, $p = 0.1219$).

Table 2 summarizes patient demographics, injury etiology and, levels of prehospital and hospital trauma care by age group. Compared to their younger counterparts, older adult patients were significantly ($p < 0.05$) more likely to be female, have fall-related injuries, to have been transported by EMS from scene of injury and less likely to have MVC-related injuries and penetrating injuries. No significant differences were noted in the average distance from the scene of injury to the closest trauma facility (any level) and closest Level III trauma center, however, older patients were on average, injured slightly farther away from a TTC (47 vs 44 miles, $p < 0.001$). Overall, disproportionately fewer older adult trauma patients were treated at a TTC (42% vs 65%, $p < 0.05$). Although there was no difference in the rate of transfer by age group among patients initially presenting to NTTCs, older adult trauma patients were significantly more likely to be transferred to a NTTC (53% vs 34%, $p < 0.05$) and less likely to be transported by helicopter EMS (14.6% vs 20%, $p < 0.05$).

Table 3 summarizes patients' clinical characteristics and outcomes by age group. Compared to their younger adult counterparts, older adults were significantly ($p < 0.05$) less likely to present in shock or to be intubated, had slightly lower overall ISS (10.7 vs 11.5), and were more likely to present with a pre-existing comorbid condition. In terms of injury severity and pattern, older adults had a higher incidence of severe head (24% vs 20%, $p < 0.05$) and extremity (35% vs 19%, $p < 0.05$) injuries including a much higher incidence (32% vs 11%, $p < 0.05$) of long bone fractures (humerus and femur) compared to younger adults. Crude in-hospital mortality was also notably higher in older adults compared to their younger adult counterparts.

Figure 2 shows patients' injury location in relation to trauma level of definitive trauma care (TTC vs NTTC) stratified by age group for patients with an ISS ≥ 9 (threshold for Oklahoma Major Trauma definition). The figure suggests that, even when older adults were injured closer to a TTC, they were disproportionately less likely to receive definitive trauma care at a TTC. In addition, 38% of injured older adults with an ISS ≥ 16 were treated at non-tertiary trauma centers compared to 18% in patients less than 55 years old.

Multivariable Analyses

Statistical interactions evaluated were determined a priori and included interactions between age group and injury time period ($p < 0.05$) and between age group and distance ($p > 0.05$). The statistical significance of the interaction between age group and injury period was largely driven by the large sample size as the point estimates' variation by injury time period was very small (0.39 to 0.43). As such, this effect modification was not deemed to be of public health significance and no stratification was done.

Table 4 summarizes results from the three multivariable models. Overall, older injured adults (≥ 55 years) were significantly ($p < 0.05$) less likely to be treated at TTCs (OR=0.54, 95% CI: 0.52–0.56) after adjusting for important confounders and predictors. The observation that patients 55 years and older were less likely to be treated at TTCs was observed both for patients transported from the scene of injury by EMS for definitive care (adjusted OR= 0.49, 95% CI: 0.47–0.52) and those patients transferred inter-facility for definitive care (adjusted OR= 0.63, 95%CI: 0.59 – 0.68). Restricting the analysis to those with an ISS ≥ 16 did not qualitatively alter the findings but resulted in attenuation of the estimated effect (overall OR 0.81, 95%CI: 0.65 – 0.98). Withholding distance measures from the models (sensitivity analysis) resulted in moderate attenuation of the age group effects and wider confidence intervals but also did not qualitatively alter the findings.

DISCUSSION

Despite being at a higher risk of adverse outcomes following traumatic injury, the results of our study suggest that injured older adults in a predominantly rural region face a triage double jeopardy in that, they are more likely to be under-triaged to tertiary trauma centers whether it's from the scene of injury or via inter-facility transfer. This observation persists even after adjusting for clinically relevant factors and distance to tertiary trauma centers. Studies have shown that organized trauma care, whether provided as part of a state-wide trauma system or designated trauma centers, improves outcomes in older adult trauma patients, particularly for those patients treated at tertiary trauma centers.^{7–9} Existence of such evidence suggesting a survival benefit for older adults treated at TTCs notwithstanding, a few studies have suggested no survival benefit^{10, 11} and increased mortality¹² for older patients treated at TTCs. However, methodologic limitations preclude universal applicability of these findings; these include variation in the definition of a TTC (Level I only vs Level I and II),^{10, 11} imprecise estimates from small sample sizes, choice of statistical modeling techniques,^{10, 11} and inadequate control of confounding, especially comorbidities.^{10, 12}

A number of studies have evaluated under-triage in the older injured patient, however, most of these studies excluded patients transferred between facilities and only considered field (prehospital) under-triage^{13, 14, 16, 17} or emergency department under-triage.¹⁸ While a few studies have evaluated the combined triage process (prehospital and inter-facility) by only considering the final patient destination regardless of whether the patient was transported directly from scene or transferred from another facility,^{20, 21, 26} none of these studies quantified, separately, the extent of inter-facility under-triage among older adults. Our study quantifies inter-facility under-triage and empirically demonstrates that reasons for field under-triage of injured older adults remain operative after arrival at a NTTC. However, it should be noted that inter-facility triage patterns may vary with specific injuries; Faul et al. using data from the National Inpatient Sample (NIS) and the National Trauma Data Bank (NTDB), observed a higher proportion of inter-facility transfers to Level I/II among older adults with traumatic brain injury (TBI).²⁷

The reasons for under-triage of older adults to tertiary trauma centers are multifactorial. Proximity to a tertiary trauma center is likely to influence whether a patient is transported or transferred to a TTC for definitive treatment. To our knowledge, no prior study has taken

into account distance from the scene of injury to a TTC while evaluating under-triage in older adults. We could only identify one study which tried to circumvent this limitation by determining patient's proximity to a trauma center based on comparing the patient's resident zip code to a list of zip codes for counties with a designated tertiary trauma center.²⁶ An inherent strength of our study is that we were able to calculate various distance measures based on patient's actual injury location for the majority of the patients (93.3%), which is more accurate than distance measures calculated based on patient's residence.

Another possible reason for under-triage in older adults perhaps involves the perception that little can be done to alter outcomes in these patients (age bias).^{16, 28} A study by Chang et al. which evaluated triage rates for patients meeting prehospital priority one (1) status showed the decrease in tertiary trauma center transports to start at age 50 years with another significant decrease at age 70 years; a follow-up EMS survey ranked the top three causal factors for this under-triage in older adults as inadequate training in handling older patients, unfamiliarity with protocol and possible age bias. The authors concluded that even when trauma is recognized and acknowledged by EMS, providers are consistently less likely to consider transporting older patients to a trauma center.¹⁶ Patient preference has also been suggested as a contributing to trauma under-triage in older adults. It's been suggested that older patients may prefer non-tertiary trauma centers, given their established relationships with local physicians.

Another factor that has been attributed to under-triage of older adults, perhaps one most amenable to corrective action, is the ineffectiveness of standard trauma triage criteria, in particular the physiologic component of the triage guidelines. The national (CDC) field triage guidelines recommend an algorithm based on physiologic (hemodynamic compromise, respiratory compromise, altered mentation), anatomic (site and type of injury), and mechanism-of-injury to identify those patients requiring treatment at a TTC. Physiologic triage parameters such as tachycardia and hypotension, although typically applied in the prehospital triage of all adult patients irrespective of age, medical or pharmacologic history, are less reliable, especially in the prehospital evaluation of the older patient. Older patients are less likely to mount a tachycardic response or show signs of hypotension, given a likely history of underlying hypertension, cardiovascular disease and beta-blocker use.

The Centers for Disease Control National Expert Panel on Field Triage has made some recommendations in regards to triaging of older trauma patients, however their recommendations are ancillary to the general adult triage guidelines and fail to highlight the need for a tailored triage criteria for older adults.²² A few studies have explored specific field trauma triage criteria for older adults or ways to improve triaging of these patients. A study by Nakamura et al. showed that employing a mandatory age triage criterion would be inefficient for improving field triage. The authors estimated a number need to treat (NNT) ranging from 60 to 65 i.e. one (1) older adult patient with an ISS of 16 identified for every 60 to 65 additional patients transported to a TTC.²⁰ Newgard et al. evaluated an alternative out-of-hospital method (any positive criterion from current guidelines, GCS $\leq$ 14 or abnormal vital signs) for identifying older adults ($\geq$ 65 years) with an ISS of 16 and showed the alternative triage guidelines to have increased sensitivity (92% vs 76%) but decreased

specificity (42% vs 78%).²⁹ A similar study by Newgard et al. that evaluated a revised physiologic criteria for prehospital identification of seriously injured older adults also concluded that the revised criteria would increase sensitivity, reduce specificity, and increase the proportion of patients without serious injuries transported to TTCs by 60%.³⁰ Wasserman et al. has also proposed a new algorithm to detect older adult patients with TBI derived from previously established scales (GCS, level of alertness, etc.), however this algorithm needs further evaluation before it can be adopted.³¹ The Trauma Committee of the Ohio Emergency Medical Services (EMS) Board also developed a specific triage criteria for older adult trauma victims and showed improved sensitivity and moderate decrease in specificity in those 70 years or older and minimal increase in sensitivity and substantial decrease in specificity in those less than 70 years.^{32,24} A major limitation of the Ohio criteria is the high age cut-off (≥ 70 years); studies have shown that the problem of under-triage start as early as 50 years old.¹⁶

While studies that have explored specific field trauma triage criteria for older adults are an important step forward in an effort to improve triaging of injured older adults, more work still needs to be done to formulate criteria that can be universally applied as done with the current national adult triage guidelines. Our study results support previous research attributing age bias as a major contributing factor to the problem of under-triage in older adults.¹⁶ Our study further highlights that this bias persists beyond the prehospital environment and influences the secondary triage of older adult trauma patients requiring tertiary trauma care. Furthermore, our results show that adjusting for proximity to a tertiary trauma center does not mitigate this bias; in our study even when older adults were injured closer to a tertiary trauma center, they were disproportionately less likely to receive definitive trauma care at a Level I/II. In addition to formulating specific criteria for field triage for older adult patients, trauma systems should also focus on formulating or improving criteria for secondary triage of older patients. However, it should be noted that the existence of specific field and secondary triage criteria for older adults alone is unlikely to reduce under-triage of older adults to tertiary trauma centers without further trauma triage educational efforts focused on older adults. Educational efforts should be focused on both prehospital and hospital providers to reduce under-triage of older adults.

Our study has limitations that warrant a discussion. The retrospective nature of the study precluded us from considering additional information that could alter our study estimates. To that point, we were not able to take into account patient preference in our adjustment. Still, we were able to improve upon previous methodology by adjusting for distance from the scene of injury. Because we excluded patients with missing data (7.6%), it is possible that selection bias remains unmitigated in our study and that, inclusion of excluded patients would alter our age group estimates. However, our attrition analysis found no major differences between those included and those excluded by age group. Furthermore, our sensitivity analysis suggests adjusting for distance measures is beneficial as reflected by the attenuation of the age group estimates and wider confidence intervals in models without distance. Our study was conducted within a predominantly rural state and as such, may not be generalizable to regions that have an urban prominence. Aforementioned limitations notwithstanding, the major strength of our study is that it is the first study to quantify the extent of inter-facility under-triage separately and adjust for patient's injury location

Conclusions

Injured older adults are under- triaged to tertiary trauma centers both from the scene of injury and non-tertiary trauma centers. Furthermore, our study results suggest that age bias rather than distance to a TTC, is major contributory factor to the problem of under-triage in older adult trauma patients. Efforts should be focused on improving both field triage and inter-facility triage of injured older adults if outcomes in this high risk population are to be improved.

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References

- Schwab CW, Kauder DR. Trauma in the geriatric patient. *Arch Surg.* 1992; 127(6):701–706. [PubMed: 1596171]
- Lane P, Sorondo B, Kelly JJ. Geriatric trauma patients-are they receiving trauma center care? *Acad Emerg Med.* 2003; 10(3):244–250. [PubMed: 12615590]
- Knudson MM, Lieberman J, Morris JA Jr, Cushing BM, Stubbs HA. Mortality factors in geriatric blunt trauma patients. *Arch Surg.* 1994; 129(4):448–453. [PubMed: 8154972]
- Victorino GP, Chong TJ, Pal JD. Trauma in the elderly patient. *Arch Surg.* 2003; 138(10):1093–1098. [PubMed: 14557126]
- Dechert TA, Duane TM, Frykberg BP, Aboutanos MB, Malhotra AK, Ivatury RR. Elderly patients with pelvic fracture: interventions and outcomes. *Am Surg.* 2009; 75(4):291–295. [PubMed: 19385287]
- Bochicchio GV, Joshi M, Knorr KM, Scalea TM. Impact of nosocomial infections in trauma: does age make a difference? *J Trauma.* 2001; 50(4):612–617. [PubMed: 11303154]
- Smith JS Jr, Martin LF, Young WW, Macioce DP. Do trauma centers improve outcome over non-trauma centers: the evaluation of regional trauma care using discharge abstract data and patient management categories. *J Trauma.* 1990; 30(12):1533–1538. [PubMed: 2258968]
- Meldon SW, Reilly M, Drew BL, Mancuso C, Fallon W Jr. Trauma in the very elderly: a community-based study of outcomes at trauma and nontrauma centers. *J Trauma.* 2002; 52(1):79–84. [PubMed: 11791055]
- Pracht EE, Langland-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]
- 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):569–576. [PubMed: 24054408]
- 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):366–378. [PubMed: 16436768]
- Scheetz LJ. Differences in survival, length of stay, and discharge disposition of older trauma patients admitted to trauma centers and nontrauma center hospitals. *J Nurs Scholarsh.* 2005; 37(4):361–366. [PubMed: 16396410]
- Ma MH, MacKenzie EJ, Alcorta R, Kelen GD. Compliance with prehospital triage protocols for major trauma patients. *J Trauma.* 1999; 46(1):168–175. [PubMed: 9932702]
- Phillips S, Rond PC III, Kelly SM, Swartz PD. The failure of triage criteria to identify geriatric patients with trauma: results from the Florida Trauma Triage Study. *J Trauma.* 1996; 40(2):278–283. [PubMed: 8637079]

15. Scheetz LJ. Effectiveness of prehospital trauma triage guidelines for the identification of major trauma in elderly motor vehicle crash victims. *J Emerg Nurs.* 2003; 29(2):109–115. [PubMed: 12660691]
16. Chang DC, Bass RR, Cornwell EE, MacKenzie EJ. Undertriage of elderly trauma patients to state-designated trauma centers. *Arch Surg.* 2008; 143(8):776–781. [PubMed: 18711038]
17. Lehmann R, Beekley A, Casey L, Salim A, Martin M. The impact of advanced age on trauma triage decisions and outcomes: a statewide analysis. *Am J Surg.* 2009; 197(5):571–574. [PubMed: 19393350]
18. 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]
19. Hsia RY, Kellermann AL, Shen YC. Factors associated with closures of emergency departments in the United States. *JAMA.* 2011; 305(19):1978–1985. [PubMed: 21586713]
20. Nakamura Y, Daya M, Bulger EM, Schreiber M, Mackersie R, Hsia RY, Mann NC, Holmes JF, Staudenmayer K, Sturges Z, Liao M, Haukoos J, Kuppermann N, Barton ED, Newgard CD, and the WESTRN Investigators. Evaluating age in the field triage of injured persons. *Ann Emerg Med.* 2012; 60(3):335–345. [PubMed: 22633339]
21. Newgard CD, Zive D, Holmes JF, Bulger EM, Staudenmayer K, Liao M, Rea T, Hsia RY, Wang NE, Fleischman R, Jui J, Mann NC, Haukoos JS, Sporer KA, Gubler KD, Hedges JR. WESTRN investigators. 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):709–721. [PubMed: 22107917]
22. Sasser SM, Hunt RC, Sullivent EE, Wald MM, Mitchko J, Jurkovich GJ, Henry MC, Salomone JP, Wang SC, Galli RL, Cooper A, Brown LH, Sattin RW. National Expert Panel on Field Triage, Centers for Disease Control and Prevention (CDC). Guidelines for field triage of injured patients: recommendations of the National Expert Panel on Field Triage, 2011. *MMWR Recomm Rep.* 2012; 61(RR-1):1–20.
23. Lerner EB. Studies evaluating current field triage: 1966–2005. *Prehosp Emerg Care.* 2006; 10(3):303–306. [PubMed: 16801265]
24. 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. [PubMed: 24908590]
25. Newgard CD, Hedges JR, Adams A, Mullins RJ. Secondary triage: early identification of high-risk trauma patients presenting to non-tertiary hospitals. *Prehosp Emerg Care.* 2007; 11(2):154–163. [PubMed: 17454801]
26. Hsia RY, Wang E, Saynina O, Wise P, Perez-Stable EJ, Auerbach A. Factors associated with trauma center use for elderly patients with trauma: a statewide analysis, 1999–2008. *Arch Surg.* 2011; 146(5):585–592. [PubMed: 21242421]
27. Faul M, Xu L, Sasser SM. Hospitalized Traumatic Brain Injury: Low Trauma Center Utilization and High Interfacility Transfers among Older Adults. *Prehosp Emerg Care.* 2016; 20(5):594–600. [PubMed: 26986195]
28. Utter GH, Victorino GP, Wisner DH. Interhospital transfer occurs more slowly for elderly acute trauma patients. *J Emerg Med.* 2008; 35(4):415–420. [PubMed: 17933480]
29. Newgard CD, Holmes JF, Haukoos JS, Bulger EM, Staudenmayer K, Wittwer L, Stecker E, Dai M, Hsia RY. the Western Emergency Services Translational Research Network (WESTRN) Investigators. Improving early identification of the high-risk elderly trauma patient by emergency medical services. *Injury.* 2016; 47(1):19–25. [PubMed: 26477345]
30. Newgard CD, Richardson D, Holmes JF, et al. Physiologic Field Triage Criteria for Identifying Seriously Injured Older Adults. *Prehosp Emerg Care.* 2014; 18(4):461–470. [PubMed: 24933614]
31. Wasserman EB, Shah MN, Jones CM, et al. Identification of a Neurologic Scale that Optimizes EMS Detection of Older Adult Traumatic Brain Injury Patients who Require Transport to a Trauma Center. *Prehosp Emerg Care.* 2015; 19(2):202–212. [PubMed: 25290953]
32. Werman HA, Erskine T, Caterino J, Riebe JF, Valasek T. Development of statewide geriatric patients trauma triage criteria. *Prehosp Disaster Med.* 2011; 26(3):170–179. [PubMed: 22107767]

Fig 1.
Study Population

Figure 2. Injury location in relation to level of definitive trauma care by age group for patients with an ISS ≥ 9

Table 1

Oklahoma's Major Trauma Definition

Inclusion Criteria (Must meet at least one criteria in each category)		Exclusion Criteria	
1	International Classification of Disease 9th Revision Clinical Modification code of 800.00 – 959.9	1	Persons who died at the scene, or
2	Abbreviated Injury Scale value of 3 or higher; or <ul style="list-style-type: none"> • Injury Severity Score (ISS) of 9 or higher; or • RISS Survival Probability less than *.50; or • Dead on arrival or died while in hospital 	2	Any of the following as the sole type of injury <ul style="list-style-type: none"> • Overexertion injuries; • Submersions; • Poisonings; • Asphyxiation; • Injuries caused by a pre-existing condition (e.g., osteoporosis, etc).
3	Length of hospital stay > 48 hours; or <ul style="list-style-type: none"> • Transferred from a lower level to a higher level trauma center with major trauma; or • Dead on arrival or died while in hospital • Admitted to intensive care unit; or • Admitted to operating room for major surgery (head, chest, abdomen, vascular). 		

Table 2

Patient and Injury Characteristics by Age Group, Oklahoma State Trauma Registry, 2005–2014

	Age < 55 Years n=49271	Age >=55 Years n=35659	p-value
Variable			
Injury Year, n (%)			
2005	4599 (9)	2395 (6.7)	<0.001
2006	4941 (10)	2691 (7.6)	
2007	4963 (10)	2983 (8.4)	
2008	5168 (10)	3216 (9)	
2009	4946 (10)	3463 (9.7)	
2010	4891 (9.9)	3555 (10)	
2011	5022 (10)	3763 (11)	
2012	5060 (10)	4128 (11.6)	
2013	5002 (10)	4742 (13)	
2014	4626 (9.4)	4656 (13)	
Mean Age (±SD)	34 (11.3)	74 (11.6)	
Male, n (%)	36272 (74)	16351 (46)	<0.0001
Race, n (%)			
White	36621 (74)	32171 (90)	<0.0001
Black	5339 (11)	1128 (3.2)	
AI/AN/PI	3330 (7)	1112 (3)	
Asian	299 (0.6)	169 (0.5)	
Other	3682 (7.5)	1079 (3)	
Penetrating Injury, n (%)	9202 (19)	1238 (3.5)	<0.0001
MOI, n (%)			
MVC	16052 (33)	5574 (16)	<0.0001
Motorcycle	3789 (7.7)	968 (2.7)	
Pedestrian	1397 (2.8)	486 (1.4)	
GSW/Stabbing	7741 (15.7)	762 (2.1)	
Falls	7802 (16)	24116 (68)	
Other/Unspecified	12490 (25)	3753 (10.5)	
Prehospital EMS Transport, n (%)	32953 (67)	25504 (72)	<0.0001
Level of final * definitive trauma care, n (%)			<0.001
I/II	32173 (65)	15019 (42.4)	
III	14031 (29)	17453 (49.3)	
IV	2881 (6)	2924 (8.3)	
Mean distance to closest (±SD), miles			
Any Level trauma facility	6.4 (5.7)	6.4 (5.7)	0.6904
Level III trauma facility	19.4 (24)	19.7 (24)	0.1147

	Age < 55 Years n=49271	Age >=55 Years n=35659	p-value
Level I/II trauma facility	43.7 (45)	47 (45)	<0.0001
Mean distance to definitive care facility	35 (41)	30 (36)	<0.0001
Transferred, n (%)	17808 (36)	12935 (36)	0.6946
Inter-facility. EMS Transport, n (%)	14821 (30)	11938 (33.5)	<0.0001
HEMS Inter-facility Transport, n (%)	3563 (7.2)	1888 (5.3)	<0.0001
Trauma Level Transferred To, n (%)			<0.0001
I/II	11696 (23.7)	6086 (17.1)	
III	5887 (12)	6533 (18.3)	
IV	149 (0.3)	204 (0.6)	

* definitive care – final trauma care provided (without need for further transfer) regardless of facility's trauma level

% = column %

Table 3

Clinical Characteristics and Outcomes by Age Group, Oklahoma State Trauma Registry, 2005–2014

	Age < 55 Years n=49271	Age >=55 Years n=35659	p-value
Variable			
Initial ED, Mean ($\pm$ SD)			
SBP	131 (29)	144 (33)	<0.0001
GCS	13.6 (3.5)	14.2 (2.4)	<0.0001
HR	91.7 (25)	82.7 (20)	<0.0001
RR	18.3 (6.7)	18.5 (4.8)	<0.0001
Shock (SBP <90 mmHg), n (%)	2468 (5)	1245 (3.5)	<0.0001
TBI (GCS <9), n (%)	4831 (10)	1568 (4.7)	<0.0001
EMS/ED Intubation, n (%)	4632 (9.4)	1668 (4.7)	<0.0001
Mean ISS ($\pm$ SD)	11.5 (9.4)	10.7 (7.8)	<0.0001
ISS Group, n (%)			<0.0001
0–8	19238 (39)	9867 (28)	
9–15	17001 (34)	18247 (51)	
16–24	7120 (15)	4643 (13)	
>=25	5620 (11.5)	2744 (7.7)	
Severe Injury (AIS >=3), n (%)			
Head	10090 (20)	8614 (24)	<0.0001
Chest	10502 (21)	4859 (13.6)	<0.0001
Abdomen	4012 (8)	1083 (3)	<0.0001
Extremity	9509 (19)	12530 (35)	<0.0001
Anatomic Injury Triage Criteria, n (%)			
Flail chest	6030 (12)	4278 (12)	0.2875
Long bone fracture (hum/fem)	5182 (10.5)	11386 (32)	<0.0001
Skull fracture/Intracranial	17307 (35)	10851 (30)	<0.0001
Pelvic	3702 (7.5)	2642 (7.5)	0.5676
Wrist/Ankle amputation	43 (0.09)	16 (0.04)	0.0206
Other GI/Abdominal			
GI Tract	1445 (3)	250 (0.7)	<0.001
Spleen	2141(4)	523 1.5)	<0.0001
Liver	1997 (4)	337 (1)	<0.0001
Kidney	874 (2)	194 (0.5)	<0.0001
Pelvic organs	115 (0.2)	17 (0.05)	<0.0001
Other abdominal organs	1207 (2.5)	308 (0.9)	<0.0001
Pre-existing Comorbidity, n (%)	4549 (9)	13289 (37)	<0.0001
Pulmonary Disease, n (%)	1381 (3)	3032 (8.5)	<0.0001
Cardiac Disease, n (%)	1703 (3.5)	8242 (23)	<0.0001

	Age < 55 Years n=49271	Age >=55 Years n=35659	p-value
Diabetes, n (%)	1445 (3)	5371 (15)	<0.0001
Coagulopathy, n (%)	370 (0.8)	828 (2)	<0.0001
Cancer, n (%)	44 (0.1)	332 (1)	<0.0001
Liver/Kidney, n (%)	312 (0.6)	1439 (4)	<0.0001
Mean LOS ($\pm$ SD)	5.9 (16)	6.4 (15)	<0.0001
In-hospital Mortality, n (%)	2508 (5)	2494 (7)	<0.0001

% = column %

Table 4

Adjusted ORs for Predictors of Definitive Treatment at a Tertiary Trauma Center

Variable	Overall OR (95% CI) N=78292	Direct Transport from Scene and not further transferred OR (95% CI) n=50007	Inter-facility Transferred OR (95% CI) n=28285
Age < 55 years	ref	ref	ref
Age ≥55 years	0.54 (0.52–0.56)	0.49 (0.47 – 0.52)	0.63 (0.59 – 0.68)
Male Gender	1.24 (1.20 – 1.28)	1.24 (1.18 – 1.30)	1.20 (1.14 – 1.28)
Mechanism of Injury			
Traffic-related	ref	ref	ref
Stabbing/GSW	0.89 (0.83 – 0.95)	0.79 (0.73 – 0.86)	0.91 (0.82 – 1.02)
Falls	0.30 (0.28 – 0.31)	0.24 (0.22 – 0.25)	0.40 (0.37 – 0.44)
Other	0.45 (0.43 – 0.47)	0.34 (0.32 – 0.37)	0.63 (0.58 – 0.68)
Injury Period			
2005 – 2006	ref	ref	ref
2007–2008	1.16 (1.10–1.23)	1.26 (1.17 – 1.36)	1.06 (0.97 – 1.16)
2009–2010	1.32 (1.25 – 1.39)	1.49 (1.39 – 1.61)	1.16 (1.06 – 1.27)
2011–2012	1.75 (1.66 – 1.85)	2.00 (1.86 – 2.16)	1.56 (1.43 – 1.71)
2013–2014	2.25 (2.13 – 2.38)	2.44 (2.27 – 2.63)	2.18 (1.99 – 2.38)
Prehospital EMS Transport	2.14 (2.05 – 2.23)	3.95 (3.71 – 4.20)	1.10 (1.04 – 1.17)
Distance to Closest TTC (10 mile interval)	0.813 (0.809 – 0.818)	0.65 (0.64 – 0.66)	0.965 (0.96 – 0.971)
Distance to Closest Lev 3 (10 mile interval)	1.14 (1.13 – 1.16)	1.48 (1.45 – 1.51)	Dropped from model, p >0.05
SBP (10 mmHg interval)	1.016 (1.01–1.022)	1.03 (1.02 – 1.033)	Dropped from model, p > 0.05
ED/EMS Intubation	4.03 (3.70 – 4.39)	5.34 (4.75 – 6.00)	3.48 (3.03 – 4.00)
Severe Injury (AIS ≥3)			
Head	1.72 (1.65 – 1.80)	1.86 (1.75 – 1.97)	1.47 (1.37 – 1.57)
Chest	1.81 (1.72 – 1.90)	1.69 (1.59 – 1.79)	2.89 (2.60 – 3.21)
Abdomen	2.80 (2.56 – 3.06)	2.80 (2.50 – 3.13)	3.19 (2.69 – 3.80)
* Long bone fracture	0.66 (0.63 – 0.69)	0.77(0.73 – 0.82)	0.45 (0.41 – 0.49)
Pelvic fracture	2.67 (2.47 – 2.85)	2.12(1.93 – 2.32)	4.77 (4.13 – 5.51)
Pre-existing Comorbidity	1.29 (1.23 – 1.35)	1.20 (1.13 – 1.27)	1.39 (1.29 – 1.49)
Model AUC (95% CI)	0.81 (0.803 – 0.809)	0.87 (0.867 – 0.873)	0.745 (0.739 – 0.751)

* humerus/femur; OR: odds ratio