DOES HOSPITAL EXPERIENCE RATHER THAN VOLUME IMPROVE OUTCOMES IN GERIATRIC TRAUMA PATIENTS?

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ABSTRACT

Background: Although high absolute hospital geriatric trauma volume (GTV) is associated with improved outcomes among geriatric trauma patients, the actual geriatric trauma proportion (GTP) may be a better predictor of outcomes.

Methods: Adult trauma admissions were identified in the California State Inpatient Database, 2007-2011. Hospital characteristics were extracted from the American Hospital Association database. The annual trauma volume of patients 65 years and older (GTV) was calculated. The GTP was derived by dividing the GTV by the overall adult trauma volume and hospitals were categorized into tertiles of GTP. Outcomes were hospital mortality, failure to rescue (FTR) and 30-day readmission in geriatric trauma patients. Independent risk factors were assessed with clustered multivariate logistic regression models adjusted for patient and hospital characteristics.

Results: There were 61,915 geriatric trauma patients included from 63 trauma centers. Hospital mortality, FTR, and 30-day readmission rates were 4.99%, 16.07% and 12.03% respectively. The adjusted Odds Ratio and 95% Confidence Intervals for in-hospital mortality and FTR per 100 patient increase in GTV were 0.91 (0.83-1.00) and 1.01 (0.90-1.14) respectively. As compared to hospitals in the lowest tertile, adjusted odds of mortality and FTR in the highest tertile were 0.71 (0.54-0.94) and 0.67 (0.48-0.92) respectively. None of the hospital factors measured was significantly associated with readmission. The Wald test revealed that GTP played a larger role than GTV in predicting hospital mortality (P=0.018 vs. P=0.048) and FTR (P=0.015 vs. P=0.985).

Conclusion: Treatment at hospitals with higher GTP is associated with lower hospital mortality and FTR among geriatric patients. These findings suggest that creation of specialized services for geriatric trauma care may improve outcomes among geriatric trauma patients.

ABBREVIATIONS

AMA, Against Medical Advice

FTR, Failure to Rescue

GTP, Geriatric Trauma Proportion

GTV, Geriatric Trauma Volume

ICD-9-CM, International Classification of Disease, 9th Revision – Clinical Modification

ICF, Intermediate Care Facility

ISS, Injury Severity Score

SNF, Skilled Nursing Facility

INTRODUCTION

Geriatric patients are responsible for a large proportion of the volume and cost of trauma care in the United States. Between 2007 and 2011, the proportion of trauma patients older than 64 years rose from 19.4% to 27.7%.(1) Injured older patients account for about 49,000 deaths annually and, in 2010 alone, the combined cost of in-patient care for geriatric trauma patients was over $39 billion.(2) Due to demographic shifts in the United States, the number of older trauma patients will continue to rise over the coming decades.(3) The causes and patterns of trauma in older patients differ significantly from younger patients. While falls account for 74% of trauma in older patients, a large proportion of traumatic injuries in patients younger than 65 years are due to motor vehicle accidents.(1) Compared to younger patients with the same injury severity, geriatric trauma patients are twice as likely to die during the index admission and have higher rates of adverse post-discharge outcomes such as readmission.(4, 5) Based on these data, it is increasingly important to identify systems and processes of care to improve outcomes for older injured patients.

A number of studies have shown that patients who receive treatment at high volume trauma centers experience lower mortality.(6-9) However, most studies do not examine how the volume-outcome relationship might be modified by age. One study that looked at age-specific data using the Pennsylvania trauma registry showed that hospitals treating higher volumes of geriatric trauma patients had lower rates of mortality and failure to rescue (FTR) among geriatric patients than similar hospitals with low geriatric trauma volumes.(10) However, the hospital non-geriatric trauma volume was not associated with outcomes among geriatric trauma patients. Meanwhile, a study using the National Trauma Data Bank, has shown that among centers with at least 500 annual trauma admissions, those with a higher proportion of geriatric trauma patients have better outcomes among geriatric patients than

centers with lower proportion of geriatric patients.(1) Together these studies, suggest that trauma centers with more experience caring for older trauma patients have better outcomes. However, no study has simultaneously assessed hospital geriatric trauma volumes and the proportion of geriatric trauma patients treated at hospitals to identify which metric is more strongly associated hospital mortality and FTR among geriatric trauma patients. In addition, the relationships between these metrics and post-discharge outcomes such as readmissions have not been assessed.

To fill these knowledge gaps we sought to compare the associations between geriatric trauma volume and the geriatric trauma proportion with in-hospital mortality, FTR and 30-day readmission rates in small and large volume trauma centers. We hypothesized that the proportion of geriatric trauma patients admitted to a trauma center would be a better predictor of outcomes than the absolute number of geriatric trauma admitted.

METHODS

Data Source and Study Population

We examined hospital discharge records using the California State Inpatient Database (SID), Hospital Cost and Utilization Project, Agency for Health Research and Quality, from 2007 to 2011. This database contains all hospital discharge records from up to 98% of all hospitals in the state.(11) Unique patient identifiers are assigned to individual patients making it possible to link multiple admissions during the study.

We included patients who had admitting International Classification of Disease, 9th Revision – Clinical Modification (ICD-9-CM) diagnosis codes corresponding with traumatic injuries (800 – 904, 910 – 929 and 950 – 959). We restricted our analyses to patients who were

treated at trauma centers. Trauma centers were identified by the designation assigned to each hospital in the 2011 American Hospital Association database. We excluded patients who had isolated hip fractures because their age and sex distribution, co-morbid conditions, injury severities, and treatment patterns are significantly different from the rest of the trauma population.(12) Patients that were transferred from or to other acute care facilities were also excluded from the analysis to reduce the possibility of confounding by treatment at other hospitals.

Patient Characteristics

We selected geriatric patients defined as patients age 65 years and above. We extracted demographic details such as patients' age (less than 85, 85 and older), sex, and race/ethnicity (White, Black, Hispanic, Other). Insurance type was classified as public, private, self-pay, and others. "Others" included Worker's Compensation, County Indigent Programs, Other Government aids and Other Indigent funds.(13) Median household income state quartiles for patients' zip codes were provided in the database.

We calculated the Charlson Co-morbidity Index using the CHARLSON module in Stata.(14) The Charlson Co-morbidity Index is a validated score that uses 19 possible diagnoses to predict mortality and perioperative complications in longitudinal data.(15-17) Charlson scores were classified as <2 and ≥ 2 (higher being worse). A cut-off of 2 was chosen as this was the best score to achieve roughly equal proportions of patients in each group. The severity of injury was assessed using Injury Severity Scores (ISS). The ISS is an anatomical-based method to assess the severity of injury using details of injury in three different body regions that could range from 0 to 75 (higher being worse).(18) These scores were calculated with the ICDPIC module in Stata using ICD-9-CM diagnosis codes,(19) which is a validated

method for deriving ISS from patient records.(20, 21) ISS was categorized as <9, 9 – 15, 16 – 25, >25.

Length of hospital stay was categorized as 0-3, 4-7, and >7 days. Patients' discharge dispositions were categorized within the database as Home, Home Health Care, Skilled Nursing Facility (SNF)/Intermediate Care Facility (ICF)/Other Facilities, and Against Medical Advice (AMA).

Hospital Characteristics

Hospitals were categorized based on adult trauma volume. We calculated volume of trauma admissions in three ways. First, we assessed the annual mean overall number of trauma admissions of all adults 18 years and older during the study period. Our threshold for high volume was 1200 cases per year based on the American College of Surgeons recommendation for adequate hospital trauma admission volume for Level I trauma centers.(22) Next, we assessed the mean number of trauma admissions of patients 65 years and older, which we referred to as the geriatric trauma volume (GTV). The GTV was assessed in increments of 100 patients. We then calculated the geriatric trauma volume as a proportion of the overall trauma volume and called this the geriatric trauma proportion (GTP). Hospitals were then grouped into three categories (tertiles) with the highest tertile comprising of hospitals with the highest GTP. We used tertiles because they ensured uniform distribution of the hospitals into each category and because there are no generally accepted cut-offs for GTP. Hospitals with GTPs less than 5% and hospitals that had annual overall trauma volumes less than 25 were excluded from further analysis because of the high probability of unreliable estimates associated with small sample sizes in trauma research.(23) We did not use a higher volume cut-off because we aimed to determine if GTP was

associated with better outcomes in low volume centers as well. The 2011 American Hospital Association database was linked to the California SID to ascertain additional hospital characteristics including trauma center level (Level I, II, III-IV), teaching status, and location (urban vs. rural).

Outcomes

All analyses of outcomes were limited to geriatric trauma patients. We assessed in-hospital mortality, FTR and 30-day readmission. Hospital mortality for each institution was calculated as the proportion of deaths among all the patients that were admitted. FTR was calculated as death after major in-hospital complications: myocardial infarction, acute renal failure, cerebrovascular accidents, respiratory failure, venous thromboembolism, lower respiratory tract infection, sepsis, or hemorrhage using ICD-9 codes previously described.(24) Hospital readmission was determined as the proportion of readmissions to any hospital in the state within 30-days of discharge. Planned readmissions (eg. adjustment of prosthetic devices, planned post-operative wound closure, and aftercare involving plastic surgery) were identified by V codes among the diagnosis codes. These readmissions were excluded from the analyses. Patients admitted or discharged in the last month of follow up were excluded to ensure at least 30 days of follow up for each patient included.

Statistical Analysis

We examined the demographic, injury and admission characteristics of the patients and their distribution. We also examined differences in the patient characteristics within each tertile of GTP using Pearson Chi-square tests for categorical variables and Kruskal Wallis tests for continuous variables. We then compared mortality, FTR and readmission rates by hospital categories, using Chi-square tests to determine statistical significance. We performed

univariate logistic regression analyses to identify factors associated with the outcomes separately. Patient and hospital factors that were not marginally significantly associated with the outcomes on the univariate analysis ($P < 0.1$) were excluded from further multivariate analyses. Multivariate logistic regression models were fitted to identify independent associations with the outcomes. Patient demographic, injury, admission, and hospital characteristics were adjusted for in all models and discharge disposition was included in the models for readmission. We assessed collinearity in our models by using the default assessment which is performed when the "logistic" command is run in Stata . In order to account for possible non-independence of patients treated at the same facility, we used robust standard errors clustered at the hospital-level.

To test the null hypothesis that the variables included in our models were not contributing to the fit of the model, we used the Wald test. The *P* values from the Wald test indicate how far from the null hypothesis each parameter in the model is. Running the Wald test on variables simultaneously shows the relative contributions of each variable to the other variables being tested. We also ran sensitivity analyses to determine if the observed relationships were applicable to patients with more severe (ISS > 15) injuries. Lastly, we ran the multivariate models substituting overall hospital trauma volume for GTV to see if the overall trauma volume was associated with outcomes. All analyses were done using Stata Statistical Software: Release 13 (College Station, TX: StataCorp LP) and the significance level was set as $P < 0.05$.

RESULTS

Patient and Hospital Characteristics

Our final cohort consisted of 61,915 geriatric trauma patients who received care in 63 California Level I – IV trauma centers. The patients were predominantly White (76%), less than 85 years (67%), and female (62%). Mild injuries (defined by ISS less than 9) were found in 61% of patients and the mean hospital length of stay was 5 days. Other patient characteristics are shown in **Table 1**.

About one-third of the patients were managed at Level I trauma centers and 58% were managed at Level II trauma centers. Teaching hospitals accounted for the care of 45% of patients. High volume trauma centers (at least 1200 annual trauma admissions) admitted 23% of the patients. There were more patients managed at hospitals in the middle tertile of GTP (44%) than in the highest and lowest tertiles. Most of the patients in our cohort were treated in urban hospitals.

The tertiles of GTP had median geriatric trauma volumes of 178, 283 and 106 respectively; and median geriatric trauma proportions of 21%, 38% and 52% respectively. The demographic and clinical characteristics of patients treated at the hospitals in each tertile are shown in **Supplementary Table 1**. Patients at hospitals in the highest tertile of GTP were more likely to be White, female and live in areas with higher median income state quartiles than patients treated at hospitals in the lowest tertile of GTP. Although statistically different, the injury severity scores and Charlson Comorbidity Indices were similar across all tertiles of GTP. There were no statistically significant differences in hospital lengths of stay across tertiles of GTP.

Hospital Outcomes

The overall hospital mortality rate for geriatric trauma patients was 4.99%. In the unadjusted analyses, large hospital trauma volume was associated with higher mortality (6.25% vs. 4.61%, $P < 0.001$) (**Table 2**). However, with increasing GTP, there was reduced mortality among geriatric trauma patients. The mortality rates in the lowest, middle and highest tertiles of GTP were 7.07%, 4.59% and 3.06% respectively ($P < 0.001$). Level I trauma centers had higher mortality rates (6.37%) compared to the lower level trauma centers ($P < 0.001$). Teaching hospitals also had higher mortality rates compared to non-teaching hospitals (5.50% vs. 4.57%, $P < 0.001$).

Major complications developed in 8,668 patients and the failure to rescue rate was 16.07%. FTR was higher in large trauma volume hospitals than in smaller institutions (19.75% vs. 14.88%, $P < 0.001$). There was a progressive reduction in FTR with increasing tertiles of GTP with FTR rates of 20.52% in the lowest tertile and 11.75% in the highest tertile ($P < 0.001$). FTR occurred more frequently in higher level (Level I, 19.53%; Level II, 15.06%) than in Level III-IV trauma centers (9.99%).

The 30-day readmission rate in the overall cohort was 12.03%. Unadjusted analyses showed significant variations in readmission rates based on demographic and injury characteristics. However, hospital factors measured were not significantly associated with 30-day readmission.

On multivariate analyses adjusting for the patient and hospital characteristics in individual hospitals, there was no significant reduction in hospital mortality per 100 increase in GTV (Adjusted Odds Ratio: 0.91, 95% Confidence Interval: 0.83 – 1.00) (**Table 3**). Compared to

the lowest tertile of GTP, hospitals in the highest tertile had significantly lower hospital mortality (0.71, 0.54 – 0.94) and FTR (0.67, 0.48 – 0.92). Trauma center level and teaching status were not associated with hospital mortality after adjusting for volume characteristics of the hospitals, and GTV was not associated with FTR. No hospital characteristics were associated with 30-day readmission rates.

Sensitivity Analyses and Comparison of Hospital Metrics

Sensitivity analyses evaluating the performance of our models on outcomes among patients with more severe injuries (ISS > 15) generally showed similar patterns to that seen in the overall cohort (**Table 4**). However, there was a significant decrease in hospital mortality per 100 increase in GTV (0.89, 0.82 – 0.97). Additionally, Level II trauma centers were associated with significant reductions in mortality compared to Level I trauma centers (0.73, 0.57 – 0.93). Models substituting GTV with overall hospital trauma volume showed no significant differences in the patterns seen with the main analyses (**Supplementary Table 2**).

The Wald test to evaluate the hierarchy of predictive capacities of each variable in our mortality model showed that GTP was more significantly predictive of hospital mortality than the GTV in the overall cohort (P= 0.018 vs. P= 0.048) (**Table 5**). However, the two volume metrics were of nearly equal importance when only patients with severe injuries were examined (P= 0.019 vs. P= 0.013). For the FTR models, GTP was the only volume metric that contributed to the fit of the model in the overall cohort (P= 0.015). However it was not a significant variable in the model fit for patients with severe injuries only (P= 0.098). None of the hospital volume metrics we assessed contributed to the fit of the hospital readmission models.

DISCUSSION

This study of a large state inpatient database reveals that the proportion of geriatric trauma patients treated at a trauma center is a greater contributor to better outcomes than the geriatric trauma volume at that same center. Hospitals in this study with high GTP had significantly lower mortality rates than those with low GTP. These data indicate that, among hospitals with similar geriatric volumes, hospitals that treat relatively greater numbers of older trauma patients have lower mortality compared with those that treat high proportions of younger patients. This trend was also seen when FTR was examined and in sensitivity analyses that only included the most severely injured patients. Our study corroborates other studies which have shown a unique volume-outcome relationship in geriatric trauma.(1, 10)

Unlike previous studies where absolute or relative geriatric trauma volumes have been examined in isolation of each other, this study compared the contribution of both measures in the same patient population and showed that proportion of overall cases account for some of the differences in mortality and FTR rates among older patients treated at different level of trauma centers. Better outcomes at higher GTP hospitals may reflect practices and systems in hospitals with more relative experience in preventing or mitigating the consequences of complications frequently experienced by older patients such as delirium and aspiration.(25-27) There are varied reports on the effect of trauma center level on outcomes among geriatric trauma patients. While a study examining GTP alone showed lower level trauma centers out-perform Level I trauma centers in the treatment of older patients,(1) another study that looked specifically at effects of GTV showed no difference in the outcomes based on trauma center designation.(28) Our study showed that geriatric volumes (both in quantity and in proportion of overall cases) account for some of the differences in mortality and FTR rates seen between levels of trauma center designation.

Interestingly, the hospital trauma volume metrics were not associated with 30-day readmissions among the patients we studied. This may mean that the structures we assume are in place at hospitals with high GTP may not be associated with the prevention of readmissions among these patients. Understanding appropriate care structures that could reduce readmissions among geriatric trauma patients will become increasingly important as hospitals become accountable for healthcare utilization linked to the index admission.(29)

The findings from this study suggest that beyond the skill acquisition that comes with treating large numbers of patients with similar characteristics, adaptation of processes of care may play significant roles in improving mortality. There is growing evidence supporting the need for specialized care for geriatric trauma patients. A study among geriatric patients that assessed the effect of reducing thresholds for activating trauma teams showed that, compared with the patients treated conventionally, early intensive monitoring of severely injured geriatric patients led to 36% reduction in mortality.(30) An analysis of a state's triage system also showed that using the same triage criteria, older patients had an under-triage rate of 71% compared with younger patients at 36%, indicating the need for age-specific triage criteria.(31) Creation of special geriatric trauma wards in some institutions supervised by surgeons, internists, physical therapists, geriatricians and nurses familiar with the care of older patients have been associated with improvements in triage, better management of chronic illnesses and lower morbidity.(32) Other institutions have included geriatric consultations in routine care and have seen lower rates of delirium, earlier initiation of end of life discussions, and better long-term functional outcomes.(33, 34) The creation of specialized geriatric trauma centers has also been suggested.(1) However, the economic viability of this system has not been assessed. Studies among orthopedic trauma services

suggest that such stand-alone centers can only be profitable to the system if they have very high patient volumes.(35) The results of our study appear to support the notion that specialty geriatric trauma services could lead to lower mortality and failure to rescue rates among geriatric trauma patients.

There are a number of limitations to this study. Although we assume that the beneficial effect of high GTP on mortality is related to processes of care in these hospitals, we do not know the actual care structures of the individual hospitals included in our study. It is possible that there are other inherent practices and structures in these hospitals that are associated with improved mortality. Further studies that individually examine these hospitals and identify characteristics common to them may provide more evidence for best practices in the care of older trauma patients. In addition, we did not have access to physiological data such as admission systolic blood pressure, which are associated with trauma outcomes and could be a source of residual confounding.(36) However, we did account for both injury severity and co-morbidities in our analyses. We therefore have a reasonable, though not perfect, assessment of the clinical status of the patients included.

In conclusion, geriatric trauma patients have disproportionately high rates of mortality and long-term complications. This study shows that hospitals that routinely treat older trauma patients have lower hospital mortality and FTR rates than those with higher proportions of younger trauma patients. Creation of age-appropriate protocols in such centers, better understanding of geriatric-specific injury response patterns, and the development of structures that are geared towards improving outcomes in older patients, may be factors that mediate the mortality benefit of these centers. Understanding the practices and characteristics

of hospitals with high GTP may be beneficial in bolstering efforts to improve outcomes among geriatric trauma patients.

References

1. Zafar SN, Obirieze A, Schneider EB, et al. Outcomes of trauma care at centers treating a higher proportion of older patients: The case for geriatric trauma centers. Journal of trauma and acute care surgery. 2015;78(4):852-9.

2. Centers for Disease Prevention and Control. Cost of Injury Reports. Data and Statistics (WISQARS). Available at: https://wisqars.cdc.gov:8443/costT/cost_Part1_Intro.jsp. Accessed October 22, 2015.

3. Etzioni DA, Liu JH, Maggard MA, Ko CY. The aging population and its impact on the surgery workforce. Annals of surgery. 2003;238(2):170.

4. Moore L, Stelfox HT, Turgeon AF, et al. Rates, patterns, and determinants of unplanned readmission after traumatic injury: a multicenter cohort study. Annals of surgery. 2014;259(2):374-80.

5. van der Sluis CK, Klasen H, Eisma W, Ten Duis H. Major trauma in young and old: what is the difference? Journal of Trauma and Acute Care Surgery. 1996;40(1):78-82.

6. Bennett KM, Vaslef S, Pappas TN, Scarborough JE. The volume-outcomes relationship for United States Level I trauma centers. Journal of Surgical Research. 2011;167(1):19-23.

7. Freeman J, Nicholl J, Turner J. Does size matter? The relationship between volume and outcome in the care of major trauma. Journal of health services research & policy. 2006;11(2):101-5.

8. Nathens AB, Jurkovich GJ, Maier RV, et al. Relationship between trauma center volume and outcomes. Jama. 2001;285(9):1164-71.

9. Yaghoubian A, Lewis RJ, Putnam BA, De Virgilio C. Impact on patient outcomes after closure of an adjacent trauma center. The American surgeon. 2008;74(10):930-4.

10. Matsushima K, Schaefer EW, Won EJ, Armen SB, Indeck MC, Soybel DI. Positive and negative volume-outcome relationships in the geriatric trauma population. JAMA surgery. 2014;149(4):319-26.

11. Healthcare Cost and Utilization Project. Overview. Available at: http://www.hcup-us.ahrq.gov/sidoverview.jsp. Accessed June 15, 2015.

12. Gomez D, Haas B, Hemmila M, et al. Hips can lie: impact of excluding isolated hip fractures on external benchmarking of trauma center performance. Journal of Trauma and Acute Care Surgery. 2010;69(5):1037-41.

13. Healthcare Cost and Utilization Project. SID Documentation. Available at: http://www.hcup-us.ahrq.gov/db/vars/siddistnote.jsp?var=pay1. Accessed June 15, 2015.

14. Stagg V. CHARLSON: Stata module to calculate Charlson index of comorbidity. Statistical Software Components. 2006.

15. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of chronic diseases. 1987;40(5):373-83.

16. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. Journal of clinical epidemiology. 1994;47(11):1245-51.

17. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. Journal of clinical epidemiology. 1992;45(6):613-9.

18. Baker SP, o'Neill B, Haddon Jr W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. Journal of Trauma and Acute Care Surgery. 1974;14(3):187-96.

19. Clark DE, Osler TM, Hahn DR. ICDPIC: Stata module to provide methods for translating International Classification of Diseases (Ninth Revision) diagnosis codes into standard injury categories and/or scores. Statistical Software Components. 2010.

20. Osler T, Rutledge R, Deis J, Bedrick E. ICISS: an international classification of disease-9 based injury severity score. Journal of Trauma and Acute Care Surgery. 1996;41(3):380-8.

21. Rutledge R, Osler T, Emery S, Kromhout-Schiro S. The end of the Injury Severity Score (ISS) and the Trauma and Injury Severity Score (TRISS): ICISS, an International Classification of Diseases, ninth revision-based prediction tool, outperforms both ISS and TRISS as predictors of trauma patient survival, hospital charges, and hospital length of stay. Journal of Trauma and Acute Care Surgery. 1998;44(1):41-9.

22. American College of Surgeons. Committee on Trauma. Resources for optimal care of the injured patient 2006: American College of Surgeons; 2006.

23. Hashmi ZG, Dimick JB, Efron DT, et al. Reliability adjustment: a necessity for trauma center ranking and benchmarking. The journal of trauma and acute care surgery. 2013;75(1):166.

24. Menendez ME, Ring D. Failure to Rescue After Proximal Femur Fracture Surgery. Journal of orthopaedic trauma. 2015;29(3):e96-e102.

25. Inouye SK, Westendorp RG, Saczynski JS. Delirium in elderly people. The Lancet. 2014;383(9920):911-22.

26. Dasgupta M, Dumbrell AC. Preoperative risk assessment for delirium after noncardiac surgery: a systematic review. Journal of the American Geriatrics Society. 2006;54(10):1578-89.

27. Kozlow JH, Berenholtz SM, Garrett E, Dorman T, Pronovost PJ. Epidemiology and impact of aspiration pneumonia in patients undergoing surgery in Maryland, 1999–2000. Critical care medicine. 2003;31(7):1930-7.

28. Pandya SR, Yelon JA, Sullivan TS, Risucci DA. Geriatric motor vehicle collision survival: the role of institutional trauma volume. Journal of Trauma and Acute Care Surgery. 2011;70(6):1326-30.

29. Centers for Medicare and Medicaid Services. Readmissions Reduction Program Baltimore, MD. Available at: http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html. Accessed February 15, 2015.

30. Demetriades D, Karaiskakis M, Velmahos G, et al. Effect on outcome of early intensive management of geriatric trauma patients. British journal of surgery. 2002;89(10):1319-22.

31. Phillips S, Rond PC, Kelly SM, Swartz PD. The failure of triage criteria to identify geriatric patients with trauma: results from the Florida Trauma Triage Study. Journal of Trauma and Acute Care Surgery. 1996;40(2):278-83.

32. Mangram AJ, Mitchell CD, Shifflette VK, et al. Geriatric trauma service: a one-year experience. Journal of Trauma and Acute Care Surgery. 2012;72(1):119-22.

33. Fallon Jr WF, Rader E, Zyzanski S, et al. Geriatric outcomes are improved by a geriatric trauma consultation service. Journal of Trauma and Acute Care Surgery. 2006;61(5):1040-6.

34. Tillou A, Kelley-Quon L, Burruss S, et al. Long-term postinjury functional recovery: outcomes of geriatric consultation. JAMA surgery. 2014;149(1):83-9.

35. Clement RC, Mehta S, Bernstein J. Economic viability of geriatric hip fracture centers. Orthopedics (Online). 2013;36(12):e1509.

36. Brown JB, Gestring ML, Forsythe RM, et al. Systolic blood pressure criteria in the National Trauma Triage Protocol for geriatric trauma: 110 is the new 90. Journal of trauma and acute care surgery. 2015;78(2):352-9.

Table 1: Distribution of Geriatric Trauma Patients Included in Study Analyses

Characteristics		Percentage of total population, % [N = 61,915]
Patient-level Characteristics		
Age (years)	65 – 84	67.18
	85 and older	32.82
Sex	Female	61.98
	Male	38.02
Race	White	76.49
	Black	3.03
	Hispanic	11.77
	Other	8.71
Median Household Income for zip code	1st quartile	23.30
	2nd quartile	25.93
	3rd quartile	26.53
	4th quartile	24.24
Injury Severity Score Category	<9	60.47
	9 – 15	21.45
	16 – 24	15.95
	≥25	2.14
Length of Stay (days)	0 – 3	51.20
	4 – 7	32.16
	>7	16.64
Charlson Score	<2	73.58
	≥2	26.42
Discharge disposition	Home	32.25
	Home Health Care	47.70
	SNF, ICF, other facility	14.01
	Against Medical Advice	0.45
Hospital-level Characteristics		
Trauma Center Level	Level I	30.46
	Level II	58.19
	Level III – IV	11.35
Overall Trauma Volume Category	< 1200	76.83
	≥ 1200	23.17
Geriatric Trauma Proportion	Lowest tertile	31.22
	Middle tertile	44.33
	Highest tertile	24.45
Urbanicity	Rural	0.35
	Urban	99.65
Teaching Status	Non-teaching	54.63
	Teaching	45.37

ICF, Intermediate Care Facility; SNF, Skilled Nursing Facility

Table 2: Hospital Characteristics and Associated Unadjusted Outcomes among Geriatric Trauma Patients

Hospital Characteristics	No. of hospitals	In-hospital Mortality, %	*P* value	Failure to Rescue Rate, %	*P* value	Readmission Rate, %	*P* value
Overall	**63**	**4.99**		**16.07**		**12.03**	
Trauma Center Level							
Level I	13	6.37	<0.001	19.53	<0.001	12.38	0.190
Level II	34	4.70		15.06		11.83	
Level III – IV	16	2.82		9.99		12.11	
Teaching Status							
Non-teaching	38	4.57	< 0.001	14.56	<0.001	12.10	0.563
Teaching	25	5.50		17.99		11.94	
Overall Trauma Volume							
<1200	54	4.61	<0.001	14.88	<0.001	12.00	0.677
≥1200	9	6.25		19.75		12.13	
Geriatric Trauma Proportion							
Lowest tertile	21	7.07	<0.001	20.52	<0.001	12.19	0.383
Middle tertile	21	4.59		14.41		12.10	
Highest tertile	21	3.06		11.75		11.71	

Table 3: Multivariate Analysis of Hospital Factors associated with In-hospital Mortality, Failure to Rescue and 30-day Hospital Readmission among Geriatric Trauma Patients

Hospital Characteristics	Adjusted Odds Ratio (95% Confidence Interval)		
	In-hospital Mortality*	Failure to Rescue*	30-day Readmission**
Trauma Center Level			
Level I	REF	REF	REF
Level II	0.78 (0.60 – 1.00)	1.02 (0.79 – 1.31)	0.99 (0.84 – 1.16)
Level III – IV	0.74 (0.43 – 1.25)	1.00 (0.50 – 2.01)	1.11 (0.83 – 1.49)
Geriatric Trauma Volume			
Per 100 increase	0.91 (0.83 – 1.00)	1.01 (0.90 – 1.14)	1.03 (0.98 – 1.08)
Teaching Status			
Non-teaching	REF	REF	REF
Teaching	0.98 (0.79 – 1.21)	1.09 (0.90 – 1.33)	1.00 (0.90 – 1.11)
Geriatric Trauma Proportion			
Lowest tertile	REF	REF	REF
Middle tertile	0.87 (0.69 – 1.08)	0.73 (0.57 – 0.95)	0.95 (0.82 – 1.08)
Highest tertile	0.71 (0.54 – 0.94)	0.67 (0.48 – 0.92)	0.90 (0.76 – 1.06)

*Adjusted for hospital characteristics: trauma center level, geriatric trauma volume, teaching status, geriatric trauma proportion; and for patient characteristics: age, sex, race, Charlson Co-morbidity Index, Injury Severity Scores, hospital length of stay

**Adjusted for all characteristics in the mortality model and for discharge disposition

Table 4: Multivariate Analysis of Hospital Factors associated with In-hospital Mortality, Failure to Rescue and 30-day Hospital Readmission among Severely Injured (ISS > 15) Geriatric Trauma Patients

Hospital Characteristics	**Adjusted Odds Ratio (95% Confidence Interval)**		
	In-hospital Mortality*	**Failure to Rescue***	**30-day Readmission****
Trauma Center Level			
Level I	REF	REF	REF
Level II	0.73 (0.57 – 0.93)	1.00 (0.70 – 1.43)	1.05 (0.88 – 1.25)
Level III – IV	0.75 (0.43 – 1.33)	0.82 (0.26 – 2.54)	1.38 (0.76 – 2.52)
Geriatric Trauma Volume			
Per 100 increase	0.89 (0.82 – 0.97)	1.01 (0.86 – 1.18)	1.02 (0.94 – 1.11)
Teaching Status			
Non-teaching	REF	REF	REF
Teaching	1.02 (0.82 – 1.26)	1.17 (0.87 – 1.58)	1.05 (0.88 – 1.25)
Geriatric Trauma Proportion			
Lowest tertile	REF	REF	REF
Middle tertile	0.91 (0.73 – 1.14)	0.69 (0.49 – 0.97)	1.00 (0.77 – 1.31)
Highest tertile	0.72 (0.55 – 0.93)	0.72 (0.48 – 1.08)	0.97 (0.72 – 1.31)

* Adjusted for hospital characteristics: trauma center level, geriatric trauma volume, teaching status, geriatric trauma proportion; and for patient characteristics: age, sex, race, Charlson Co-morbidity Index, Injury Severity Scores (ISS), hospital length of stay

**Adjusted for all characteristics in the mortality model and for discharge disposition

Table 5: Relative Contributions of Hospital Volume Parameters to Multivariate Analyses of Outcomes among Geriatric Trauma Patients

Volume	**In-hospital Mortality**		**Failure to Rescue**		**30-day Readmission**	
Parameter	Overall	ISS > 15	Overall	ISS > 15	Overall	ISS > 15
GTV	**0.048**	**0.013**	0.985	0.793	0.345	0.606
GTP	**0.018**	**0.019**	**0.015**	0.098	0.223	0.858

Estimates are based on *P* values generated from Wald test. Significant values are in bold
ISS, Injury Severity Score; GTP, Geriatric Trauma Proportion; GTV, Geriatric Trauma Volume

Supplementary Table 1: Characteristics of Geriatric Patients treated at Hospitals based on Tertiles of Geriatric Trauma Proportion

Characteristics		Geriatric Trauma Proportion, %			*P* value*
		Lowest Tertile	Middle Tertile	Highest Tertile	
Sex	Female	55.24	63.47	67.03	<0.001
	Male	44.76	36.55	32.97	
Race	White	60.55	83.02	83.94	<0.001
	Black	5.56	1.99	1.99	
	Hispanic	21.21	7.81	7.74	
	Other	12.68	7.17	6.33	
Median Household Income for zip code	1st quartile	30.38	20.64	19.04	<0.001
	2nd quartile	30.80	24.91	22.49	
	3rd quartile	20.68	29.40	28.49	
	4th quartile	18.15	25.06	29.98	
Injury Severity Score†		5 [4 – 13]	4 [4 – 9]	4 [4 – 9]	<0.001
Length of Stay (days)†		4 [2 – 7]	3 [2 – 6]	3 [2 – 6]	0.264
Charlson Score†		1 [0 – 2]	1 [0 – 2]	1 [0 – 2]	<0.001

**P* values are calculated using Pearson Chi square tests for categorical variables and Kruskal-Wallis tests for continuous variables

†Median [interquartile range]

Supplementary Table 2: Multivariate Analysis of Hospital Factors associated with In-hospital Mortality, Failure to Rescue and 30-day Hospital Readmission among Geriatric Trauma Patients using alternative model

Hospital Characteristics	**Adjusted Odds Ratio (95% Confidence Interval)**		
	In-hospital Mortality*	**Failure to Rescue***	**30-day Readmission****
Trauma Center Level			
Level I	REF	REF	REF
Level II	0.78 (0.60 – 1.00)	1.09 (0.89 – 1.35)	0.96 (0.82 – 1.13)
Level III – IV	0.74 (0.43 – 1.25)	1.13 (0.62 – 2.07)	
Overall Trauma Volume			
Per 100 increase	0.91 (0.83 – 1.00)	1.02 (0.99 – 1.04)	1.00 (0.99 – 1.02)
Teaching Status			
Non-teaching	REF	REF	REF
Teaching	0.98 (0.79 – 1.22)	1.13 (0.93 – 1.36)	1.00 (0.89 – 1.11)
Geriatric Trauma Proportion			
Lowest tertile	REF	REF	REF
Middle tertile	0.86 (0.69 – 1.08)	0.76 (0.64 – 0.89)	0.99 (0.86 – 1.13)
Highest tertile	0.71 (0.54 – 0.94)	0.71 (0.57 – 0.89)	0.95 (0.81 – 1.11)

* Adjusted for hospital characteristics: trauma center level, geriatric trauma volume, teaching status, geriatric trauma proportion; and for patient characteristics: age, sex, race, Charlson Co-morbidity Index, Injury Severity Scores, hospital length of stay

**Adjusted for all characteristics in the mortality model and for discharge disposition