JAMA Surgery | Original Investigation

Association of Practitioner Interfacility Triage Performance With Outcomes for Severely Injured Patients With Fee-for-Service Medicare Insurance

Deepika Mohan, MD, MPH; David J. Wallace, MD, MPH; Samantha J. Kerti, MS; Derek C. Angus, MD, MPH, FRCP; Matthew R. Rosengart, MD, MPH; Amber E. Barnato, MD, MPH, MS; Donald M. Yealy, MD; Baruch Fischhoff, PhD; Chung-Chou Chang, PhD; Jeremy M. Kahn, MD, MS

Supplemental content

IMPORTANCE Despite evidence that treatment of severely injured patients at trauma centers is associated with reduced mortality, nearly half of all such patients are treated at nontrauma centers (undertriaged). Little is known about whether interfacility undertriage occurs because of practitioner decision-making or institutional and regional factors.

OBJECTIVES To assess the associations between variation in triage practitioners at nontrauma centers and between practitioner-level variation and patient outcomes after injury.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study used Medicare claims data from severely injured patients presenting to nontrauma centers and the practitioners who evaluated them in the emergency department from January 1, 2010, to October 15, 2015. Data analysis was performed from January 15, 2018, to March 21, 2019.

MAIN OUTCOMES AND MEASURES Proportion of variation in undertriage associated with practitioners, practitioner rates of undertriage, practitioner characteristics associated with undertriage, and 30-day case-fatality rate.

RESULTS A total of 124 008 severely injured patients (mean [SD] age, 81 [8.4] years; 67 253 [54.2%] female) and the 25 376 practitioners (5564 [21.9%] female) who evaluated the patients in the emergency department of nontrauma centers were included in the study. Undertriage occurred among 85 403 patients (68.9%), with 40.6% of total variation associated with practitioners, 37.8% with hospitals, and 6.7% with regions. Compared with physicians with National Provider Identification (NPI) enumeration before 2007, those with an NPI enumerated between 2007 and 2010 had an undertriage risk ratio (RR) of 0.98 (95% CI, 0.97-0.99), and those with an NPI enumerated after 2010 had an undertriage RR of 0.96 (95% CI, 0.94-0.99). Hospitals with neurosurgeons had an undertriage RR of 1.51 (95% CI, 1.45-1.57) compared with those that did not; hospitals with spine surgeons had an undertriage RR of 1.10 (95% CI, 1.06-1.13); hospitals with general surgeons had an undertriage RR of 1.13 (95% CI, 1.09-1.17). Compared with practitioners who undertriaged 25% or less of patients, a statistically significant increase was found in the odds of death for patients treated by practitioners with a triage rate of less than 25% to 50% (odds ratio [OR], 1.08; 95% CI, 1.05-1.20) and less than 50% to 75% undertriage (OR, 1.12; 95% CI, 1.09-1.26) but not undertriage at greater than 75% (OR, 1.03, 95% CI, 1.00-1.18). In sensitivity analyses to adjust for unmeasured confounding, the association between triage practices and the case fatality rate became monotonic; compared with patients treated by practitioners with an undertriage rate of 25% or less, the odds of case fatality were 1.13 (95% CI, 1.05-1.21; $P = .001$) among patients treated by practitioners with undertriage rates less than 25% to 50%, 1.22 (95% CI, 1.13-1.32; $P < .001$) for patients treated by practitioners with undertriage rates less than 50% to 75%, and 1.20 (95% CI, 1.10-1.30; $P < .001$) for patients treated by practitioners with undertriage rates greater than 75%.

CONCLUSIONS AND RELEVANCE The findings suggest that individual practitioner practices are an important source of variation in triage and represent a potential locus of intervention to reduce preventable deaths after injury.

JAMA Surg. 2019;154(12):e193944. doi:10.1001/jamasurg.2019.3944
Published online October 23, 2019.

Author Affiliations: Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania (Mohan, Wallace, Kerti, Angus, Rosengart, Chang, Kahn); Department of Surgery, University of Pittsburgh, Pittsburgh, Pennsylvania (Mohan, Rosengart); Department of Emergency Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania (Wallace, Yealy); The Dartmouth Institute, Geisel School of Medicine at Dartmouth, Lebanon, New Hampshire (Barnato); Department of Engineering and Environmental Policy, Carnegie Mellon University, Pittsburgh, Pennsylvania (Fischhoff).

Corresponding Author: Deepika Mohan, MD, MPH, Department of Critical Care Medicine, University of Pittsburgh, 606D Scaife Hall, 3550 Terrace St, Pittsburgh, PA 15261 (mohand@upmc.edu).

In 2014, a total of 30 000 patients experienced preventable deaths after injury.[1] Triage of severely injured patients to designated trauma centers is associated with reduced morbidity and mortality among patients with traumatic injury.[2-5] Long-standing efforts to promote systematic triage of severely ill patients to trauma centers include the development of infrastructure necessary to support a tiered delivery system for trauma, accreditation standards that require trauma centers to perform outreach to nontrauma centers, and the development of educational programs to disseminate clinical practice guidelines.[6,7] Despite these efforts, approximately half of all severely injured patients receive definitive care at a nontrauma center rather than a trauma center.[8-11]

Factors associated with the failure to transfer patients to trauma centers (undertriage) include those related to the patient (eg, age, preferences), hospital (eg, availability of resources), and region (eg, distribution of aeromedical transport services).[9,10,12,13] The contribution of practitioners in the emergency department (ED) of nontrauma centers to undertriage is, to our knowledge, an unexplored area that could inform quality improvement efforts. The present study used patient-level claims data from the US Medicare program to quantify variation in interfacility triage associated with practitioners and to examine the association between practitioner triage practice patterns and patient outcomes.

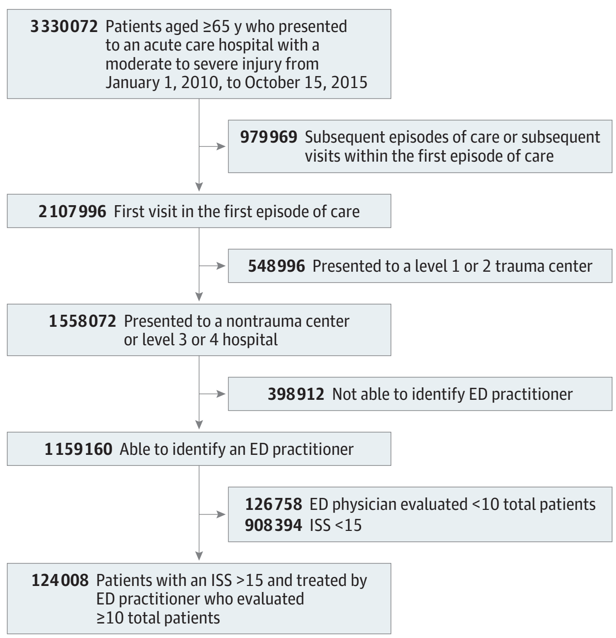
Key Points

Question Is variation in the quality of interfacility triage associated with the facility or the treating practitioner?

Findings In this cohort study of Medicare claims data from 124 008 severely injured patients, practitioners were an important source of variation in interfacility triage at nontrauma centers and practitioner triage practices were associated with and patient outcomes, such that the case-fatality rate increased in association with undertriage.

Meaning The findings suggest that practitioner variation is associated with patient outcomes and thus that efforts to eliminate preventable injuries after death should include both system-level and practitioner-based solutions.

Figure. Sample Selection



Six years of Medicare claims data included more than 3 million beneficiaries evaluated for a moderate to severe injury. After restriction of the sample to beneficiaries older than 65 years who experienced a severe injury and subjecting the data to cleaning and verification, the analytic sample included 124 008 beneficiaries. ED indicates emergency department; ISS, Injury Severity Score.

Methods

Study Design, Data, and Patients

We performed a retrospective cohort study of patients with severe traumatic injuries and the practitioners who treated them in EDs using January 1, 2010, to October 15, 2015, claims data from the Centers for Medicare & Medicaid Services (CMS). Medicare claims serve as a useful source of information for 2 reasons. First, elderly people experience high rates of undertriage and case fatality after injury, allowing analysis of the consequences of variation in care.[4,12,14] Second, Medicare claims allow the longitudinal tracking of patients and the identification of practitioners providing care. The University of Pittsburgh Institutional Review Board approved the study protocol and granted a waiver of informed consent. Data were not deidentified.

We obtained patient-level data from the 2010-2015 Medicare Beneficiary Summary Files, Inpatient and Outpatient Standard Analytic Files, and Carrier Files. These files contain the demographic characteristics and administrative health records for all fee-for-service Medicare beneficiaries and the National Provider Identification (NPI) number of the billing practitioner. We selected claims that involved a moderate to severe traumatic injury (defined as an abbreviated injury score [AIS] ≥3) using validated *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnostic codes.[15,16] Practitioner-level data came from the CMS National Plan and Provider Enumeration System, hospital-level data from the American Hospital Association Annual Survey, and the trauma center designation of hospitals from the Trauma Information Exchange Program.

Constructing Episodes of Care

We used the Inpatient and Outpatient Standard Analytic files to identify visits to acute care, nonfederal hospitals for the treatment of severe injuries by translating AISs to Injury Severity Scores (ISSs) and selected patients with an ISS greater than 15 (**Figure**). We constructed episodes of care by ordering claims by day and combined visits that occurred within 1 day of each other into a single episode. Episodes began when the beneficiary presented initially and ended (1) after 24 hours or more at an acute care hospital, (2) with discharge from the ED (assuming the beneficiary did not present to another hospital within 24 hours), or (3) with death in the ED. For episodes with multiple claims from the same day, we ordered them under the

assumption that patients would only move from nontrauma centers to trauma centers or from low-volume hospitals to high-volume hospitals (eAppendix in the Supplement).

Identifying Treating Practitioners

We identified the treating ED practitioner using unique NPI numbers and linked NPI numbers to care episodes using 2 methods. For episodes that involved a hospitalization at the same hospital as the presenting ED, we used NPIs from the professional claims in the carrier file related to that episode (eAppendix in the Supplement). For episodes that did not involve a hospitalization at the same hospital as the presenting ED, we used the performing practitioner NPI in the Outpatient Analytic File.

Variables

We abstracted patient demographics and vital status at discharge and 30 days after presentation from the Medicare Beneficiary Summary file. Information on comorbid conditions, injury characteristics, and organ failure came from *ICD-9-CM* diagnosis codes in the claims. We calculated the ISSs by mapping *ICD-9-CM* codes to AISs.

The CMS National Plan and Provider Enumeration System provided information on practitioner characteristics, including sex, type, and experience (eAppendix in the Supplement). We also determined the hospitals at which practitioners worked and categorized practitioners as working at both level 1 and 2 and nontrauma centers or working at only nontrauma centers.

We obtained the trauma center status of hospitals from the Trauma Information Exchange Program and categorized hospitals as trauma centers (level 1 and 2 centers) or nontrauma centers (level 3-5 or nondesignated centers). The American Hospital Association Annual Survey provided information on institutional characteristics (eg, number of intensive care unit beds). We used *ICD-9-CM*–specific procedure codes to identify the presence of surgical and radiographic resources at these hospitals (eAppendix in the Supplement). We also summarized the proportion of ED care at each hospital that was provided by emergency medicine (EM) physicians and described hospitals as being EM staffed if more than two-thirds of care was provided by physicians with EM certification.[9] Finally, we identified regions by their hospital referral region identifier, and we determined the number of level 1 and level 2 trauma centers in each region and categorized them as having 0, 1, or more than 1 trauma center.

Statistical Analysis

We excluded episodes of care that began at level 1 and 2 trauma centers (because these hospitals had the ability to provide definitive care of injuries) and episodes that began at critical access hospitals (because they would never have the ability to provide definitive care for severe injuries). We also excluded practitioners who evaluated fewer than 10 total (moderate and severely injured) beneficiaries during the 6-year period because we could not reliably generate estimates of their performance. We categorized episodes as involving moderate (ISS <15) or severe (ISS >15 [based on data calculation method, an ISS of exactly 15 was not possible]) injuries and restricted the analyses to beneficiaries' first episode of care each year that involved a severe injury. We defined *undertriage* as the failure to transfer a patient with severe injuries to a higher level of care directly from the ED or within 1 day of admission, categorizing those who died within 24 hours of arrival or who were discharged from the ED as undertriaged.

Variation in Undertriage

To determine the proportion of variation in undertriage associated with practitioners, we fit an empty mixed-effects logistic regression model, clustered at the region, hospital, and practitioner level, with the dependent variable of patient undertriage. We used a nested model with variance terms for each level and calculated their intraclass correlation coefficients.[17] In a sensitivity analysis, we tested the influence of imperfect nesting of practitioners in hospitals by excluding patients treated by practitioners who worked at more than 1 facility.

Practitioner Factors Associated With Undertriage

We began by calculating nested practitioner-specific undertriage rates, defined as the proportion of patients undertriaged by a physician at each hospital at which they worked. The American College of Surgeons (ACS) recommends less than 5% undertriage as the standard for regional triage patterns.[6] We applied a similar benchmark to the performance of hospitals and practitioners, given the high proportion of severely injured patients taken initially to nontrauma centers, but acknowledge that other standards may apply. However, because few practitioners achieved this objective, we categorized performance into 4 groups (≤25% undertriage, >25% to 50% undertriage, >50% to 75% undertriage, and >75% undertriage), an approach we selected based on the Akaike information criterion for our models. We examined practitioner-level variation graphically and compared practitioner characteristics by category of triage performance using χ^2 tests.

To understand practitioner factors associated with undertriage, we performed a multivariable analysis using random-effects Poisson regression. The dependent variable was a count of each practitioner's unsuccessfully triaged patients with severe injuries, with the total number of patients with severe injuries serving as the offset term (ie, adjusting for the number of exposures). We included practitioner-, hospital-, and regional-level covariates and specified a hospital-level random effect. We interpreted exponentiated coefficients in this model as risk ratios (RRs), controlling for the other covariates in the model.

Association Between Practitioner Triage Practices and Patient Outcomes

To determine whether practitioners influenced outcome measures in trauma, we tested the association between practitioners' triage practice patterns and the 30-day case-fatality rate. We fit a mixed-effects patient-level logistic regression model with the 30-day case-fatality rate as the dependent variable and the practitioners' undertriage rate as the primary independent variable. Covariates included patient characteristics (age [by decade], sex, selected comorbidities, maximum AIS

by body region, and organ failure), practitioner characteristics (sex, specialty, and years of experience), hospital resources (consultants [eg, neurosurgery], medical school affiliation, presence of residents, and EM staffing), and regional characteristics (number of trauma centers). In post hoc sensitivity analyses, we used the in-hospital case-fatality rate as the outcome variable to test whether time altered the strength of the association between clinician practices and patient outcome. We also excluded patients discharged from the ED, using this disposition as a surrogate method of additionally adjusting for patient robustness before injury. Finally, we tested the influence of imperfect nesting of practitioners (ie, adjusted for the correlation introduced by practitioners who worked at >1 hospital) to ensure that cross-classification would not lead to overestimation of the response variation in the different levels using Bayesian analyses.[18]

We performed data management and statistical analyses using Stata statistical software, version 12.0 (StataCorp) and MLwiN, trial version 2.36 (University of Bristol), with statistical significance set at 2-sided $P < .05$.[19,20] Data analysis was performed from January 15, 2018, to March 21, 2019.

Results

We identified 1 558 072 episodes of moderate to severe traumatic injury in patients who presented initially to a nontrauma center from January 1, 2010, to October 15, 2015. We identified a treating ED practitioner for 1 159 160 patients (74.4%), representing 132 556 unique practitioners (eTable 1 in the Supplement gives characteristics of unmatched patients). We excluded patients with only moderate injuries and those treated by practitioners who evaluated fewer than 10 total patients (eTable 2 in the Supplement gives practitioner characteristics). The final analysis included 124 008 severely injured patients (mean [SD] age, 81 [8.4] years; 67 253 [54.2%] female) treated by 25 376 practitioners (5564 [21.9%] female) (who saw at least 10 beneficiaries) at 2461 acute care hospitals. **Table 1** gives the characteristics of patients, practitioners, and hospitals in the final sample.

We observed broad variation in the triage of trauma patients: 38 605 (31.1%) were triaged successfully, and 85 403 (68.9%) were undertriaged (1337 died in the ED, 28 583 were discharged, and 55 483 were admitted to the hospital where they presented). On the basis of intraclass correlation coefficients, 40.6% of total variation was correlated with practitioners, 37.8% with hospitals, and 6.7% with regions. Our sensitivity analysis to account for imperfect practitioner nesting in hospitals produced similar results.

Practitioners who evaluated 10 or more total beneficiaries during the 6 years saw a median of 4 (interquartile range, 2-7) severely injured patients and undertriaged 75% (interquartile range, 45%-100%). Only 2388 practitioners (9.4%) met ACS-endorsed thresholds for successful triage. Practitioner characteristics by category of triage performance are given in eTable 3 in the Supplement.

In the multivariable clustered Poisson regression analyses, EM training was associated with reduced risk of undertriage,

Table 1. Characteristics of Patients, Practitioners, and Hospitals in the Final Sample

Characteristic	Finding[a]
Patients (n = 124 008)	
Age, mean (SD), y	81 (8.4)
Female	67 253 (54.2)
Race/ethnicity	
White	112 893 (91.0)
Black	4530 (3.7)
Hispanic	1950 (1.6)
Asian	1992 (1.6)
American Indian	556 (0.5)
Other	2077 (1.7)
No. of comorbidities	
0	31 164 (25.1)
1	29 380 (23.7)
>1	63 464 (51.2)
Select comorbidities	
Arrhythmias	21 426 (17.3)
Cancer	2247 (1.8)
Cirrhosis	852 (0.7)
Chronic renal insufficiency	9303 (7.5)
Congestive heart failure	10 781 (8.7)
Chronic obstructive pulmonary disease	13 920 (11.2)
Diabetes	23 409 (18.9)
Injury Severity Score, median (IQR)	17 (16-20)
Types of injuries	
Traumatic brain injury	81 515 (65.7)
Multiple rib fractures	36 860 (29.7)
Pelvic fracture	5443 (4.4)
Spinal cord injury	13 204 (10.6)
Long bone fracture	8380 (6.8)
Severe torso injury with comorbidity	3559 (2.9)
Type of organ failure	
Circulatory	2939 (2.4)
Respiratory tract	9386 (7.6)
Renal	8605 (6.9)
Neurologic	7059 (5.7)
Hepatic	265 (0.2)
Hematologic	5323 (4.2)
Triage status	
Died in ED	1621 (1.4)
Transfer to another hospital within 24 h of initial presentation	38 605 (31.2)
Discharged home	28 583 (23.0)
Admitted	55 483 (44.7)
Disposition status	
Died during episode of care	8928 (7.2)
Discharged home	61 769 (49.8)
Discharged to another care facility[b]	53 311 (43.0)
30-d Case-fatality rate	16 747 (13.5)
Practitioners (n = 25 376)	
Female	5564 (21.9)
Credentials	
MD degree	18 855 (74.4)
DO degree	4137 (16.3)
Other[c]	2384 (9.4)

(continued)

Table 1. Characteristics of Patients, Practitioners, and Hospitals in the Final Sample (continued)

Characteristic	Finding[a]
Specialty	
Emergency medicine	20 884 (82.3)
Family practice	1528 (6.0)
Internal medicine	777 (3.1)
Other[d]	2187 (8.6)
Year NPI received	
≤2007	18 214 (71.8)
2008-2010	5963 (23.5)
>2010	1199 (5.0)
Also worked at trauma center	4316 (17.0)
Worked at >1 hospital	9897 (39.0)
Triage performance, % undertriaged	
≤25	3632 (14.3)
>25 to 50	5394 (21.3)
>50 to 75	3975 (15.7)
>75%	12 375 (48.8)
Hospitals (n = 2461)	
No. of patients with severe trauma evaluated per y, median (IQR)	75 (39-144)
Ownership	
Government, nonfederal	365 (14.8)
Nonprofit	1549 (62.9)
For profit	545 (22.1)
Teaching status	
Affiliated with medical school	588 (23.9)
Accredited for graduate medical education	391 (15.9)
No. of ICU beds, median (IQR)	10 (6-16)
Surgical and radiographic services (n = 2461)	
Neurosurgery	460 (18.5)
Orthopedic surgery	2250 (90.6)
Spine surgery	318 (12.8)
General surgery	1477 (59.5)
ENT	2 (0.08)
Vascular surgery	211 (8.5)
Cardiac surgery	425 (17.1)
Urology	543 (21.9)
MRI suite	72 (2.9)
More than two-thirds of ED care provided by physicians specializing in emergency medicine (n = 2461)	1493 (60.7)
No. of level 1 or 2 trauma centers in hospital referral region, median (IQR)	2 (1-3)
Geographic location (n = 2461)	
Northeast	371 (15.7)
South	1042 (44.1)
Midwest	514 (21.7)
West	437 (18.5)

Abbreviations: ED, emergency department; ENT, ear, nose, and throat; ICU, intensive care unit; IQR, interquartile range; MRI, magnetic resonance imaging; NPI, National Provider Identification.

[a] Data are presented as number (percentage) of individuals or hospitals unless otherwise indicated.

[b] For example, nursing home or rehabilitation facility.

[c] For example, nurse practitioner or physician assistant.

[d] For example, general surgery or physician assistants.

Table 2. Practitioner and Hospital Variables Associated With Undertriage at Nontrauma Centers

Variable	Risk Ratio[a]	*P* Value
Practitioners (n = 25 376)		
Specialty		
Emergency medicine	1 [Reference]	NA
Family practice	1.03 (1.00-1.06)	.006
Internal medicine	1.04 (1.00-1.07)	.07
Other	1.12 (1.09-1.14)	<.001
Year of NPI enumeration		
Before 2007	1 [Reference]	NA
2007-2010	0.98 (0.97-0.99)	<.001
After 2010	0.96 (0.94-0.99)	.006
Works at trauma center		
No	1 [Reference]	NA
Yes	0.97 (0.93-1.00)	.04
Volume of severely injured patients treated[b]		
Low	1 [Reference]	NA
Moderate	0.98 (0.97-1.00)	.02
High	0.98 (0.96-1.00)	.10
Hospitals (n = 2461)		
Accredited for residency education		
No	1 [Reference]	NA
Yes	0.94 (0.90-0.99)	.02
Affiliated with medical school		
No	1 [Reference]	NA
Yes	0.99 (0.95-1.03)	.54
Resources available		
Neurosurgeon	1.51 (1.45-1.57)	<.001
Spine surgeon	1.10 (1.06-1.13)	<.001
Orthopedic surgeon	1.00 (0.95-1.07)	.90
General surgeon	1.13 (1.09-1.17)	<.001
More than two-thirds of ED care provided by emergency medicine–certified physicians	0.96 (0.87-1.05)	.38
Region of country		
Northeast	1 [Reference]	NA
South	1.03 (0.99-1.07)	.15
Midwest	1.03 (0.99-1.07)	.11
West	1.09 (1.04-1.15)	.001
No. of trauma centers in hospital referral region		
0	1 [Reference]	NA
1	0.96 (0.92-0.99)	.02
>1	0.95 (0.92-0.99)	.006

Abbreviations: ED, emergency department; NA, not applicable; NPI, National Provider Identification.

[a] Estimates obtained from a Poisson regression model. The risk ratio can be interpreted so that for a 1-U change in the variable, the risk of undertriage is expected to change by the respective regression coefficient (presented in exponentiated form).

[b] Low is fewer than 4 patients; moderate, 4 to 9 patients; and high, more than 9 patients.

whereas greater experience and lower volumes of patients were associated with increased risk of undertriage (**Table 2**). Practitioners at hospitals with neurosurgical services (RR, 1.51; 95% CI, 1.45-1.57), spine surgeons (RR, 1.10; 95% CI, 1.06-1.13), and

general surgeons (RR, 1.13; 95% CI, 1.09-1.17) were significantly more likely to undertriage patients.

After adjustment for patient, practitioner, and hospital characteristics, there was a U-shaped association between treatment by a practitioner who undertriaged more patients and odds of 30-day case fatality (**Table 3**). In sensitivity analysis in which patients discharged from the ED (who may have been systematically less frail) were excluded, compared with patients treated by practitioners with a triage rate of 25% or less, a statistically significant increase was found in the odds of case fatality for patients treated by practitioners with a triage rate of 26% to 50% (odds ratio [OR], 1.13; 95% CI, 1.05-1.21), 51% to 75% (OR, 1.22; 95% CI, 1.13-1.32), and greater than 75% (OR, 1.20; 95% CI, 1.10-1.30) (**Table 4**). The use of Bayesian analysis to adjust for imperfect nesting of practitioners within hospitals produced similar point estimates and credible intervals to the main analysis.

Discussion

In a retrospective cohort study of Medicare fee-for-service patients, we found that 41% of the total variation in triage at nontrauma centers was associated with practitioners. Few practitioners met the ACS threshold of less than 5% undertriage. Practitioners who undertriaged fewer patients tended to have less experience and were less likely to work at hospitals with the resources necessary to manage injured patients definitively. In sensitivity analyses, treatment by a practitioner with low rates of undertriage was associated with a small mortality benefit.

Prior studies[21-23] have found variation in patterns of care and outcomes associated with individual practitioners in other clinical domains, including discretionary spending in the intensive care unit, length of stay for general surgical patients, and mortality after acute myocardial infarction. However, in trauma, debate still exists about the significance of clinician decision-making during triage. An argument against the role of practitioner decision-making as a mediator is that mortality is associated with many nonmodifiable variables (eg, the injury complex, the patient's preexisting physiologic status).[24] The alternative argument stresses the importance of early intervention in altering the trajectory of the condition in the patient, and the institution and practitioners who first provide care are responsible for the outcome.[25-27] Our study supports the latter view. Specifically, our results suggest that the quality of the practitioners' decision-making, as manifested by their triage patterns, is associated with the case-fatality rate. Interventions that address practitioner judgment (ie, their ability to assess accurately the probability of a severe injury) and decisional thresholds (ie, their preferences for erring on the side of undertriage or overtriage in the context of diagnostic uncertainty) have the potential to reduce variation in undertriage. These results may therefore have policy implications by informing the distribution of resources intended to improve the quality of trauma regionalization, such as those authorized by legislation such as the Patient Protection and Affordable Care Act.[3]

The association between practitioner-level variability in triage practices and case-fatality rates may have several explanations. Patients treated by practitioners with higher

Table 3. Association Between Patient, Practitioner, Hospital, and Regional Variables and the 30-Day Case-Fatality Rate

Variable	Odds Ratio (95% CI)	*P* Value
Patients		
Age, y		
65-70	1 [Reference]	NA
71-80	1.49 (1.37-1.61)	<.001
81-90	2.88 (2.67-3.11)	<.001
>90	5.45 (5.02-5.92)	<.001
Sex		
Male	1 [Reference]	NA
Female	0.77 (0.74-0.80)	<.001
Race/ethnicity		
White	1 [Reference]	NA
Black	0.80 (0.72-0.89)	<.001
Hispanic	0.76 (0.65-0.89)	.001
Asian	0.74 (0.63-0.87)	<.001
Native American	0.97 (0.73-1.28)	.81
Other/unknown	0.78 (0.66-0.92)	.003
Comorbidities		
Arrhythmias	1.31 (1.25-1.36)	<.001
COPD	1.22 (1.15-1.29)	<.001
Cancer	3.01 (2.70-3.34)	<.001
Chronic kidney disease	1.30 (1.22-1.39)	<.001
Cirrhosis	2.03 (1.67-2.47)	<.001
CHF	1.58 (1.49-1.67)	<.001
Abbreviated Injury Scores		
Head	1.41 (1.38-1.43)	<.001
Face	0.68 (0.65-0.72)	<.001
Chest	1.09 (1.07-1.11)	<.001
Abdomen	1.05 (1.02-1.08)	<.001
Extremity	1.10 (1.08-1.12)	<.001
External	0.84 (0.82-0.87)	<.001
Organ failure		
Respiratory tract	8.85 (8.38-9.36)	<.001
Circulatory	1.29 (1.17-1.43)	.009
Neurologic	2.69 (2.53-2.86)	<.001
Hematologic	1.16 (1.08-1.26)	<.001
Liver	3.64 (2.68-4.95)	<.001
Renal	1.30 (1.22-1.38)	<.001
Practitioners		
Sex		
Male	1 [Reference]	NA
Female	0.98 (0.94-1.03)	.55
Practitioner specialty		
Emergency medicine	1 [Reference]	NA
Internal medicine	0.92 (0.84-1.00)	.06
Family practice	0.99 (0.88-1.12)	.89
Other	0.81 (0.71-0.94)	.005
Year of NPI enumeration		
2007 or earlier	1 [Reference]	NA
2008-2010	0.95 (0.91-1.00)	.05
After 2010	0.92 (0.81-1.05)	.21

(continued)

Table 3. Association Between Patient, Practitioner, Hospital, and Regional Variables and the 30-Day Case-Fatality Rate (continued)

Variable	Odds Ratio (95% CI)	*P* Value
Undertriage, %		
≤25	1 [Reference]	NA
>25 to 50	1.08 (1.05-1.20)	.001
>50 to 75	1.12 (1.09-1.26)	<.001
>75	1.03 (1.00-1.18)	.05
Hospitals		
Accredited for residency education		
No	1 [Reference]	NA
Yes	1.11 (1.02-1.21)	.01
Affiliated with medical school		
No	1 [Reference]	NA
Yes	1.04 (0.96-1.12)	.37
Resources		
Neurosurgery	0.91 (0.85-0.98)	.01
Spine surgery	1.08 (1.01-1.15)	.02
Orthopedic surgery	1.06 (0.89-1.26)	.51
General surgery	0.90 (0.84-0.96)	.001
Proportion of ED care provided by emergency medicine-certified practitioners		
<67%	1 [Reference]	NA
≥67%	0.92 (0.88-0.96)	.001
Regions		
No. of trauma centers in region		
0	1 [Reference]	NA
1	1.01 (0.93-1.09)	.83
>1	0.89 (0.83-0.96)	.003

Abbreviations: CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ED, emergency department; NA, not applicable; NPI, National Provider Identification.

triage rates are more likely to be transferred to a trauma center, where treatment is associated with a range of benefits.[2,28,29] Alternatively, triage practices may serve as a marker for other types of care that are also associated with mortality benefits (eg, early and aggressive resuscitation, appropriate use of antibiotics for patients with open fractures).[30,31] As indicated in Table 4, we also found that the association between triage practices and case fatality attenuated over time, which is consistent with a conceptual model of triage as having the greatest effect on early outcomes.

In the present study, the association between practitioner triage practices and patient outcome was U-shaped. In post hoc sensitivity analyses, this observation was shown to likely be secondary to residual unmeasured confounding. Specifically, the exclusion of patients discharged from the ED had a monotonic association between practitioner triage practices and odds of death. Patients that we identified as severely injured who were discharged from the ED may have been misclassified in our analysis. However, a study previously validated,[32] through medical record review, the observation that practitioners frequently discharge severely injured patients from the ED. We consequently speculated that these discharges offered an indirect method of assessing patient robustness. Better risk adjustment allowed us to assess the association between practitioner performance and patient outcomes.

Limitations

Our study has several limitations. First, although the use of Medicare fee-for-service claims allowed us to evaluate triage patterns in a national sample of practitioners, it constrained the analysis to adults older than 65 years with fee-for-service Medicare. Our observations may not be generalizable to younger patients or those with Medicare Advantage. Second, we excluded a large proportion of patients; 26% of the cohort remained unmatched—a common problem in claims-based research about ED practice.[33,34] As indicated in eTable 1 in the Supplement, the case-fatality rate was increased among these patients, and they were less likely to be transferred to a trauma center. We speculate that this exclusion would therefore bias our estimates toward the null (if unmatched patients occurred systematically among specific practitioners) or would have no effect (if unmatched patients occurred randomly). We also excluded patients treated by practitioners who treat low volumes of patients to ensure the stability of our estimates of performance. As indicated in eTable 2 in the Supplement, these practitioners were less likely to be EM board certified and more likely to work at smaller hospitals with fewer resources. Our observations may therefore have limited generalizability to this population.

Third, our analysis attributed responsibility for triage to ED physicians. We speculate that our failure to capture the informal and formal contributions of other practitioners to the decision-making process biases our results toward the null, underestimating the differences among practitioners. Fourth, we used *ICD-9-CM*–derived ISS to identify the cohort, which is an imperfect process. However, we have no reason to believe that this misspecification varied systematically. Fifth, our study is subject to survivorship bias. Specifically, patients who died before arrival to the initial triage hospital were excluded from the analysis; those who died shortly after arrival at the initial hospital were included but were treated as triage failures. A recent article by Bardes et al[35] reported that of the patients in the National Trauma Data Bank who died on the first day, 33% died in the first 4 hours. Other studies[36,37] reported estimates of 20% to 25%. We could not adjust for the inclusion of this cohort of patients; thus, bias may have inflated our point estimates. Related to this issue, our primary outcome variable (transfer within 24 hours of presentation) was subject to misspecification because we had only date stamps and not date and time stamps. However, misspecification was likely to be nondifferential among hospitals and practitioners and for injury severity.[38] Sixth, we generated estimates of hospital resources using claims filed for moderately and severely injured patients, possibly resulting in an underestimate of resources available at hospitals with high transfer rates. To mitigate this problem, we included not only claims from patients with severe injuries during their index hospitalization (n = 124 008) but also those from patients who presented with a moderate to severe injury from January 1, 2010, to October 15, 2015 (n = 3 330 072). In addition, we set a low threshold to distinguish between the presence or absence of resources (number of claims required was 10).

Table 4. Sensitivity Analyses of Practitioner Triage Practices and Patient Outcomes[a]

Undertriage Rate, %	Odds Ratio (95% CI) In-Hospital Death	30-d Death Excluding Patients Discharged From ED	In-hospital Death Excluding Patients Discharged From ED
≤25	1 [Reference]	1 [Reference]	1 [Reference]
>25 to 50	1.10 (1.00-1.20)	1.13 (1.05-1.21)	1.18 (1.08-1.30)
>50 to 75	1.14 (1.03-1.26)	1.22 (1.13-1.32)	1.34 (1.22-1.48)
>75	1.10 (1.00-1.22)	1.20 (1.10-1.30)	1.36 (1.23-1.52)

Abbreviation: ED, emergency department.

[a] Estimates derived from mixed-effects logistic regression model clustered at the practitioner and hospital levels.

Conclusions

The findings suggest that variation in triage patterns persists despite best-practice quality improvement efforts by major stakeholders. Using Medicare claims, we found variation in practitioner interfacility triage practices and an association with patient outcomes. We believe that interventions designed to reduce undertriage by EM practitioners should be evaluated in future studies.

ARTICLE INFORMATION

Accepted for Publication: July 29, 2019.

Published Online: October 23, 2019. doi:10.1001/jamasurg.2019.3944

Author Contributions: Dr Mohan had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Mohan, Angus, Rosengart, Barnato, Fischhoff, Chang, Kahn.
Acquisition, analysis, or interpretation of data: Mohan, Wallace, Kerti, Barnato, Yealy, Chang, Kahn.
Drafting of the manuscript: Mohan, Angus, Rosengart, Yealy, Chang.
Critical revision of the manuscript for important intellectual content: Mohan, Wallace, Kerti, Angus, Rosengart, Barnato, Fischhoff, Chang, Kahn.
Statistical analysis: Mohan, Kerti, Angus, Rosengart, Chang.
Obtained funding: Mohan.
Administrative, technical, or material support: Mohan, Wallace, Angus.
Supervision: Angus, Rosengart, Barnato, Yealy.

Conflict of Interest Disclosures: Drs Mohan, Wallace, Angus, Barnato, and Kahn reported receiving grants from the National Institutes of Health during the conduct of the study. Dr Angus reported receiving personal fees from Ferring Pharmaceuticals Inc, Bristol-Myers Squibb, Bayer AG, and GenMark Diagnostics; receiving stock options from Alung Technologies Inc outside the submitted work; and having a patent to Selepressin compounds, compositions, and methods for treating sepsis pending and a patent to Proteomic biomarkers of sepsis in elderly patients pending. No other disclosures were reported.

Funding/Support: This study was supported by grants DP2 LM012339 (Dr Mohan) and NHLBI-K08-HL122478 (Dr Wallace) from the National Institutes of Health.

Role of the Funder/Sponsor: The funding agencies reviewed the study but played no role in its design, collection, analysis, or interpretation.

Additional Contributions: The Biostatistics and Data Management Core, Clinical Research, Investigation, and Systems Modeling of Acute Illness Center, Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania, provided statistical support. No compensation was provided for the work.

REFERENCES

1. National Academies of Sciences, Engineering, and Medicine. *A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury*. Washington, DC: National Academies Press; 2016.

2. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med*. 2006;354(4):366-378. doi:10.1056/NEJMsa052049

3. Eastman AB, Mackenzie EJ, Nathens AB, Sustaining A. Sustaining a coordinated, regional approach to trauma and emergency care is critical to patient health care needs. *Health Aff (Millwood)*. 2013;32(12):2091-2098. doi:10.1377/hlthaff.2013.0716

4. Calland JF, Ingraham AM, Martin N, et al; Eastern Association for the Surgery of Trauma. Evaluation and management of geriatric trauma: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg*. 2012;73(5)(suppl 4):S345-S350. doi:10.1097/TA.0b013e318270191f

5. Institute of Medicine. *Regionalizing Emergency Care: Workshop Summary*. Washington, DC: National Academies Press; 2010.

6. Committee on Trauma, American College of Surgeons. *Resources for Optimal Care of the Injured Patient*. Chicago, IL: American College of Surgeons; 2014.

7. US Department of Health and Human Services. Model trauma system planning and evaluation. https://www.socialtext.net/acs-demo-wiki/index.cgi?regional_trauma_systems_optimal_elements_integration_and_assessment_systems_consultation_guide. Accessed February 14, 2006.

8. Delgado MK, Yokell MA, Staudenmayer KL, Spain DA, Hernandez-Boussard T, Wang NE. Factors associated with the disposition of severely injured patients initially seen at non–trauma center emergency departments: disparities by insurance status. *JAMA Surg*. 2014;149(5):422-430. doi:10.1001/jamasurg.2013.4398

9. Gomez D, Haas B, de Mestral C, et al. Institutional and provider factors impeding access to trauma center care: an analysis of transfer practices in a regional trauma system. *J Trauma Acute Care Surg*. 2012;73(5):1288-1293. doi:10.1097/TA.0b013e318265cec2

10. Zhou Q, Rosengart MR, Billiar TR, Peitzman AB, Sperry JL, Brown JB. Factors associated with nontransfer in trauma patients meeting American College of Surgeons' criteria for transfer at nontertiary centers. *JAMA Surg*. 2017;152(4):369-376. doi:10.1001/jamasurg.2016.4976

11. Lale A, Krajewski A, Friedman LS. Undertriage of firearm-related injuries in a major metropolitan area. *JAMA Surg*. 2017;152(5):467-474. doi:10.1001/jamasurg.2016.5049

12. 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. doi:10.1001/archsurg.143.8.776

13. Brown JB, Gestring ML, Guyette FX, et al. Helicopter transport improves survival following injury in the absence of a time-saving advantage. *Surgery*. 2016;159(3):947-959. doi:10.1016/j.surg.2015.09.015

14. Goodmanson NW, Rosengart MR, Barnato AE, Sperry JL, Peitzman AB, Marshall GT. Defining geriatric trauma: when does age make a difference? *Surgery*. 2012;152(4):668-674. doi:10.1016/j.surg.2012.08.017

15. Mohan D, Rosengart MR, Farris C, Cohen E, Angus DC, Barnato AE. Assessing the feasibility of the American College of Surgeons' benchmarks for the triage of trauma patients. *Arch Surg*. 2011;146(7):786-792. doi:10.1001/archsurg.2011.43

16. MacKenzie EJ, Steinwachs DM, Shankar B. Classifying trauma severity based on hospital discharge diagnoses: validation of an *ICD-9CM* to AIS-85 conversion table. *Med Care*. 1989;27(4):412-422. doi:10.1097/00005650-198904000-00008

17. Seymour CW, Iwashyna TJ, Ehlenbach WJ, Wunsch H, Cooke CR. Hospital-level variation in the use of intensive care. *Health Serv Res*. 2012;47(5):2060-2080. doi:10.1111/j.1475-6773.2012.01402.x

18. Huang H, Chin HC, Haque MM. Severity of driver injury and vehicle damage in traffic crashes at intersections: a Bayesian hierarchical analysis. *Accid Anal Prev*. 2008;40(1):45-54. doi:10.1016/j.aap.2007.04.002

19. Charlton C, Rasbash J, Browne WJ, Healy M, Cameron B. *MLwiN Trial* [computer program]. Version 2.36. *Epi Info* [computer program]. Bristol, UK: Centre for Multilevel Modeling, University of Bristol; 2018.

20. Browne WJ. *MCMC Estimation in MLwiN* [computer program]. Version 2.25. Bristol, UK: Centre for Multilevel Modeling, University of Bristol; 2018.

21. Garland A, Shaman Z, Baron J, Connors AF Jr. Physician-attributable differences in intensive care unit costs: a single-center study. *Am J Respir Crit Care Med*. 2006;174(11):1206-1210. doi:10.1164/rccm.200511-1810OC

22. Tu JV, Austin PC, Chan BTB. Relationship between annual volume of patients treated by admitting physician and mortality after acute myocardial infarction. *JAMA*. 2001;285(24):3116-3122. doi:10.1001/jama.285.24.3116

23. Greenfield S, Nelson EC, Zubkoff M, et al. Variations in resource utilization among medical specialties and systems of care. Results from the medical outcomes study. *JAMA*. 1992;267(12):1624-1630. doi:10.1001/jama.1992.03480120062034

24. Burns LR, Wholey DR. The effects of patient, hospital, and physician characteristics on length of stay and mortality. *Med Care*. 1991;29(3):251-271. doi:10.1097/00005650-199103000-00007

25. Lerner EB, Moscati RM. The golden hour: scientific fact or medical "urban legend"? *Acad Emerg Med*. 2001;8(7):758-760. doi:10.1111/j.1553-2712.2001.tb00201.x

26. Howell GM, Peitzman AB, Nirula R, et al. Delay to therapeutic interventional radiology postinjury: time is of the essence. *J Trauma*. 2010;68(6):1296-1300. doi:10.1097/TA.0b013e3181d990b5

27. Härtl R, Gerber LM, Iacono L, Ni Q, Lyons K, Ghajar J. Direct transport within an organized state trauma system reduces mortality in patients with severe traumatic brain injury. *J Trauma*. 2006;60(6):1250-1256. doi:10.1097/01.ta.0000203717.57821.8d

28. Haas B, Jurkovich GJ, Wang J, Rivara FP, Mackenzie EJ, Nathens AB. Survival advantage in trauma centers: expeditious intervention or experience? *J Am Coll Surg*. 2009;208(1):28-36. doi:10.1016/j.jamcollsurg.2008.09.004

29. Prada SI, Salkever D, Mackenzie EJ. Level-I trauma center effects on return-to-work outcomes. *Eval Rev*. 2012;36(2):133-164. doi:10.1177/0193841X12442674

30. Sperry JL, Guyette FX, Brown JB, et al; PAMPer Study Group. Prehospital plasma during air medical transport in trauma patients at risk for hemorrhagic shock. *N Engl J Med*. 2018;379(4):315-326. doi:10.1056/NEJMoa1802345

31. Patzakis MJ, Wilkins J. Factors influencing infection rate in open fracture wounds. *Clin Orthop Relat Res*. 1989;(243):36-40. doi:10.1097/00003086-198906000-00006

32. Kulkarni SS, Dewitt B, Fischhoff B, et al. Defining the representativeness heuristic in trauma triage: A retrospective observational cohort study. *PLoS One*. 2019;14(2):e0212201. doi:10.1371/journal.pone.0212201

33. Venkatesh AK, Mei H, Kocher KE, et al. Identification of emergency department visits in Medicare administrative claims: approaches and implications. *Acad Emerg Med*. 2017;24(4):422-431. doi:10.1111/acem.13140

34. Bartee S. *Medicare Fee-For-Service Provider Utilization & Payment Data Physician and Other Supplier Public Use File: A Methodological Overview*. Baltimore, MD: Centers for Medicare & Medicaid Services; 2018:1-26.

35. Bardes JM, Inaba K, Schellenberg M, et al. The contemporary timing of trauma deaths. *J Trauma Acute Care Surg*. 2018;84(6):893-899. doi:10.1097/TA.0000000000001882

36. Callcut RA, Kornblith LZ, Conroy AS, et al; Western Trauma Association Multicenter Study Group. The why and how our trauma patients die: A prospective Multicenter Western Trauma Association study. *J Trauma Acute Care Surg*. 2019;86(5):864-870. doi:10.1097/TA.0000000000002205

37. Demetriades D, Murray J, Charalambides K, et al. Trauma fatalities: time and location of hospital deaths. *J Am Coll Surg*. 2004;198(1):20-26. doi:10.1016/j.jamcollsurg.2003.09.003

38. Søreide K. Temporal patterns of death after trauma: evaluation of circadian, diurnal, periodical and seasonal trends in 260 fatal injuries. *Scand J Surg*. 2010;99(4):235-239. doi:10.1177/145749691009900411