National Study of Triage and Access to Trauma Centers for Older Adults

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Study objective: To identify predictors of undertriage among older injured Medicare beneficiaries, identify any regions in which undertriage is more likely to occur, and examine additional factors associated with undertriage at a national level.

Methods: Using 2009 to 2014 Medicare claims data, we identified older adults (≥65 years) receiving a diagnosis of traumatic injury, and linked claims with trauma center designation records from the American Trauma Society. Undertriage was defined as nontrauma centers treatment with an Injury Severity Score greater than or equal to 16, consistent with the American College of Surgeons Committee on Trauma benchmark. We used multivariable logistic regression to estimate odds of undertriage by census region, adjusting for sex, race, age, Injury Severity Score, trauma center proximity, and mode of transportation.

Results: Forty-six percent of severely injured patients (n=125,731) were treated at a nontrauma center. Compared with that for patients in the Midwest, adjusted odds of undertriage were 100% higher for patients in Southern states (odds ratio [OR] 2.00; 95% confidence interval [CI] 2.00 to 2.04) and 78% higher in Western states (OR 1.78; 95% CI 1.73 to 1.82). Compared with that for patients aged 65 to 69 years, odds of undertriage gradually increased in all age groups, reaching 57% for patients older than 80 years (OR 1.57; 95% CI 1.52 to 1.61). Distance to a trauma center was associated with increasing odds of undertriage, with 37% higher odds (OR 1.37; 95% CI 1.15 to 1.40) for older adults living more than 30 miles from a trauma center compared with patients living within 15 miles.

Conclusion: Nearly half of older adult trauma patients are undertriaged; it increases with age and distance to care and is most common in Southern and Western states. Improvements to field triage and trauma center access for older patients are urgently needed. [Ann Emerg Med. 2020;75:125-135.]

Please see page 126 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Older adults (≥65 years) are the fastest-growing age group in the United States. This population is projected to increase by 105% from 2015 (47.8 million people) to 2060 (98.2 million people), which will represent nearly one quarter of the US population.[1] Traumatic injury and mortality in older adults are following the same trend, with falls representing more than half (55%) of unintentional death by injury in older adults in the United States.[2] Treating traumatic injuries in this population has intrinsic challenges because of concomitant preexisting medical conditions and polypharmacy, which have important implications for field triage, inpatient care, and long-term functional outcomes after trauma.[3] Trauma care systems need to evolve accordingly to meet the growing burden of older adult trauma, yet limited resources are currently used to better understand and improve trauma care outcomes for older adults.

The most recent Centers for Disease Control and Prevention (CDC) guidelines for field triage of injured patients,[4] updated in 2011, call for the highest level of care within the trauma system for patients meeting criteria. Level I and II trauma centers provide such care and offer definitive care for all injured patients. Moreover, the American College of Surgeons Committee on Trauma (ACS-COT) benchmarked the use of Injury Severity Score (ISS) greater than or equal to 16 nationally to define the patient population who would benefit from treatment at a Level I or II trauma center.[5] Table 1 outlines key differences among trauma center levels of designation.[6] These guidelines acknowledge undertriage as a problem and include special considerations for older adults because

Editor's Capsule Summary

What is already known on this topic

Injured older adults are less likely than younger ones to receive care in a trauma center.

What question this study addressed

What characteristics are associated with nontrauma center care (ie, undertriage) among older adults?

What this study adds to our knowledge

Among 7.8 million injured Medicare patients (2009 to 2014), 74% of all patients and 46% of severely injured ones were treated in a nontrauma center. Undertriage was more common in the South and West, among the oldest patients, and among patients living farther from trauma centers.

How this is relevant to clinical practice

Improving trauma center access for injured older adults may require both changes in out-of-hospital procedures and additional infrastructure or transportation capacity.

of elevated risk of poor injury outcomes. Such considerations include different thresholds for systolic blood pressure indicative of traumatic shock (≤90 mm Hg for adults <65 years and ≤110 for older adults) and increased priority for low-impact mechanisms (eg, ground-level falls). Trauma center care has been shown to lead to increased probability of survival in older adult trauma patients.[7] However, several studies suggest that older adults may not fully benefit from advanced trauma care systems in the United States because numerous older adult patients are undertriaged to nontrauma centers.[8-11] Reported undertriage rates are variable and range from 33% to 49.9% in regional[8] and multiregional[10,12] studies, with mixed findings on mortality and complications.[9,10,13] There are 2 national studies of undertriage to our knowledge,[11,14] 1 of them focusing on older adults.[11] Both used encounter-level data from the Nationwide Emergency Department Sample,[15] which has several key limitations related to triage decisions, including lack of information on mode of out-of-hospital transportation and the inability to determine the source of definitive care for transfer patients.

Across the United States, Medicare covers approximately 46 million Americans aged 65 years or older,[16] regardless of income or health status, and therefore provides a unique analytic vantage point to better understand traumatic injury in a national sample of older adults.[17] Studying undertriage among Medicare beneficiaries allows validation of previous estimates of undertriage and identifies potential determinants of undertriage, including mode of transportation and transfer status. These factors may be sensitive to policy interventions designed to ensure quality and efficiency of care as trauma health care systems grow and adapt to meet the increasing demand for services.

Our objective was to identify predictors of undertriage for older injured patients at a national level, identify any regions in which undertriage is more likely to occur, and examine additional factors associated with undertriage. We hypothesized that patient, injury severity, and geographic characteristics independently predict treatment by trauma center level.

MATERIALS AND METHODS

Data Collection and Processing

Using Medicare claims data for inpatient and emergency department (ED) encounters from 2009 to 2014, we identified trauma patients aged 65 years or older in accordance with *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* diagnosis codes for traumatic injury (800.0 to 959.9,

Table 1. Trauma center designation and patient care criteria by level of designation.*

TC Level	Minimum Patient Threshold	Continuous Trauma Surgeon Presence	Continuous Anesthesia Services	Continuous Neurosurgeon Presence	Continuous Orthopedic Surgeon Presence	Continuous Operating Room	PT, OT, and Rehabilitation Available	Transfer Patients With Complex Disease
I	Yes	In house	In house	On call	On call	Yes	Yes	No
II	No	On call†	In house	On call	On call	Yes	Yes	Possibly
III	No	On call	On call	No	On call	Yes	PT only	Yes
IV/V/NTC	No	No	No	No	No	No	No	Yes

TC, Trauma center; *PT*, physical therapists; *OT*, occupational therapists; *NTC*, nontrauma center.
*Level I and II TCs have far more resources than lower-level TCs and NTCs.
†Senior resident in house with a trauma surgeon available in less than 15 minutes.

excluding 905 to 909, 910 to 924, and 930 to 939). Medicare data were obtained from the Centers for Medicare & Medicaid Services through virtual access to the Virtual Research Data Center, managed by the Research Data Assistance Center.[18] We linked Medicare claims with hospital and trauma center identification information from the American Trauma Society Trauma Information Exchange Program[19] (2016) and the American Hospital Association Annual Survey (2012), using the association's unique number identifier, which is included in Medicare claims data for all beneficiaries treated at an American Hospital Association–member hospital.[20] The Trauma Information Exchange Program maintains a database of hospital characteristics for trauma centers in the United States and shares data with institutional members of the American Trauma Society. The American Hospital Association conducts an annual survey of hospitals in the United States, including characteristics of nontrauma centers not included in the Trauma Information Exchange Program data. This allowed us to determine the facilities where older patients (≥65 years) with traumatic injury received care in the United States from 2009 to 2014 and identify factors associated with undertriage. This study was reviewed and determined to meet criteria for institutional review board exemption by Partners Human Research Committee.

We included the following variables, derived from Medicare patient characteristics and claims data in our analyses: trauma center characteristics, demographic characteristics, census region, distance to a trauma center (miles), mode of transportation (ambulance versus private), injury severity, and fall as a mechanism of injury. Treatment was considered definitive when a patient was admitted for treatment of his or her injury (as determined with claims codes) and discharged from the ED without same-day claims at a different hospital or ED. To account for patients dead on arrival, we excluded those who died in the ED before inpatient admission. Trauma center care was defined as definitive treatment at a hospital designated as Level I or II, based on verification from the ACS-COT or from a state agency responsible for trauma system oversight. Nontrauma center care was defined as definitive treatment at a designated Level III, IV, or V trauma center or at a hospital without trauma center verification. Demographic variables included age (65 to 69, 70 to 75, 76 to 80, and >80 years), sex, race (white, black, Asian, North American Native, and other), census region (Midwest, Northeast, South, and West), and mode of transport (ambulance versus private vehicle). Trauma center proximity was measured according to estimated driving distance from the population-weighted centroid of each patient's residential zip code to the nearest trauma center. Driving distances were estimated with road network data from OpenStreetMap (OpenStreetMap, Cambridge, UK)[21] and a proprietary algorithm developed by Redivis, Inc,[22] and were categorized as less than or equal to 15 miles, 15 to 30 miles, or greater than or equal to 30 miles. Driving distances based on population-weighted centroids have been validated as a measure of access to tertiary medical care.[23] Moreover, we have validated estimated driving distance according to reported ambulance miles driven in Medicare claims and found that georaphic information systems based estimates of ambulance driving distance based on residential zip codes produce highly correlated estimates of ambulance miles driven.[24] ISS was calculated according to *ICD-9-CM* codes, using an adapted version of the validated[25] ICD Programs for Injury Categorization[26] for SAS, and categorized as less than or equal to 9, 10 to 15, 16 to 25, or greater than or equal to 25. ISS is calculated as the sum the squares of the Abbreviated Injury Scale score for the 3 most severely injured body regions. Falls were identified with *ICD-9-CM* codes E880.0 to E899 (unintentional); motor vehicle crashes were identified with *ICD-9-CM* codes E810.0 to E819.

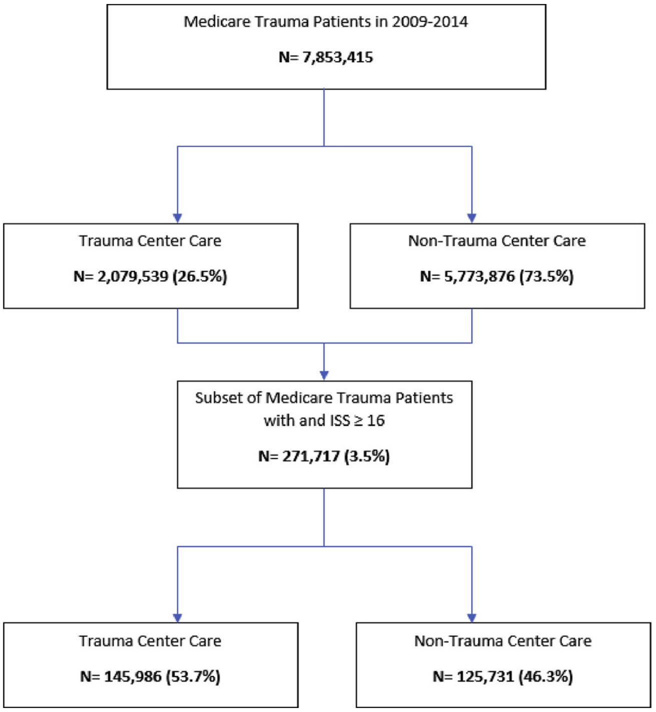

Figure 1. Medicare patients (≥65 years) with traumatic injury by facility, 2009 to 2014.

Outcome Measures

The primary outcome of interest was undertriage, defined as nontrauma center care for patients with an ISS

Table 2. Trauma center demographics and characteristics for Medicare patients (≥65 years) overall and severely injured patients (ISS ≥16), 2009 to 2014.

	All Medicare Trauma Patients			Subset of Medicare Trauma Patients With ISS ≥16 (3.5%)		
	Total, N=7,853,415	**TC, N=2,079,539 (26.5%), %**	**NTC, N=5,773,876 (73.5%), %**	**Total ISS ≥16, N=271,717**	**TC ISS ≥16, N=145,986 (53.7%), %**	**NTC ISS ≥16, N=125,731 (46.3%), %**
Age, mean (SD), y	80.2	80.3 (8.4)	80.0 (8.4)	80.9	80.9 (8.0)	82.2 (7.9)
Age group, y						
65–69	1,046,584	25.5	74.5	23,070	62.2	37.8
70–75	1,559,099	25.6	74.4	43,984	58.0	42.0
76–80	1,382,806	26.3	73.7	49,324	55.1	44.9
>80	3,864,926	27.2	72.8	155,339	50.8	49.2
Sex						
Women	5,185,636	26	74.0	145,898	52.2	47.8
Men	2,667,779	27.4	72.6	125,819	55.5	44.5
Race						
White	7,130,383	26.2	73.8	244,121	54.0	46.0
Black	427,058	29.9	70.1	13,234	54.2	45.8
Hispanic	118,783	25.4	74.6	4,699	44.5	55.5
Asian	77,854	29.1	70.9	4,968	47.2	52.8
North American Native	27,291	23.4	76.6	1,143	53.0	47.0
Other	58,288	29.5	70.5	3,088	53.0	47.0
Missing	13,758	28.3	71.7	464	54.3	45.7
Region						
Midwest	1,782,608	38.1	61.9	63,044	63.5	36.5
Northeast	1,538,525	29.6	70.4	54,802	59.6	40.4
South	3,309,973	19.1	80.9	110,109	46.8	53.2
West	1,222,309	25.6	74.4	43,762	49.7	50.3
Distance to TC, miles						
0–15	5,344,297	32.1	67.9	185,880	55.5	44.5
15–30	1,386,028	16.7	83.3	47,396	51.5	48.5
>30	1,123,090	11.7	88.3	38,441	48.1	51.9
Transportation						
Private vehicle	5,070,038	25.2	74.8	144,001	55.8	44.2
Ambulance	2,783,377	28.8	71.2	127,716	51.3	48.7

ISS, median (IQR)		4.0 (8.00)	4.0 (4.00)		17 (4.00)	16.0 (1.00)
≤9	7,363,477	25.0	75.0	—*	—	—
10–15	218,221	41.2	58.8	—	—	—
16–25	258,657	52.4	47.6	258,657	52.4	47.6
>25	13,060	79.0	21.0	13,060	79.0	21.0
ISS ≥16						
No	7,581,698	25.5	74.5	—	—	—
Yes	271,717	53.7	46.3	271,717	53.7	46.3
Motor vehicle crash						
No	7,694,824	26.1	73.9	251,285	51.5	48.5
Yes	158,591	44.7	55.3	20,432	81.3	18.7
Fall						
No	3,870,658	25.0	75.0	94,721	56.9	43.1
Yes	3,982,757	27.9	72.1	176,996	52.0	48.0

*Dashes indicate data not available.

greater than or equal to 16, aligned with the field triage guidelines[4] for injured patients and the American College of Surgeons Committee on Trauma[5] benchmark. Patients who were initially treated at a nontrauma center and subsequently transferred to a trauma center were considered properly triaged in our analyses. We identified transfers and the presumed order of encounters as follows: transfers were assumed to move from lower levels of care (ie, nontrauma centers and Level III or IV centers) to higher ones (eg, Level I and II centers); if trauma center level was the same at both hospitals, the hospital with the earliest claim end date was considered the transferring hospital; and if a patient was treated at 2 hospitals with the same trauma center designation and the same claim end date, disputes were resolved by differences in hospital bed size (eg, the hospital with smallest bed size was assumed to be the transferring hospital). Secondary outcomes included census region, distance to trauma center care, and mode of transportation.

Primary Data Analysis

We used descriptive statistics (χ^2 for categoric variables and t tests, ANOVA or Kruskal-Wallis's test for continuous variables) to examine demographic, geographic, transport, and injury characteristics overall, and to compare trauma centers and nontrauma centers. We used multivariable logistic regression to estimate odds of undertriage, adjusting for sex, race, age, ISS, trauma center proximity, and mode of transportation. We also conducted subgroup analysis to examine patterns of undertriage by trauma center proximity and mode of transportation. Statistical analyses were performed in SAS (version 9.4; SAS Institute, Inc., Cary, NC).

RESULTS

Among 7.8 million (n=7,853,415) trauma patients identified, 26.5% were treated at a trauma center and the rest at a nontrauma center (73.5%); 3.5% (n=271,717) had an ISS greater than or equal to 16, and of those, 46.3% were considered undertriaged (treated at a nontrauma center) (Figure 1). Approximately one quarter of older adults were treated at a trauma center and three quarters were treated at a nontrauma center, consistently with slight variations across age groups, sex, race, ambulance transport, and injury mechanism (falls) for all Medicare trauma patients (Table 2). Trauma center treatment was most common in the Midwest (38%; n=678,369) and least common in the South (19%; n=633,523). Twenty five percent of patients (n=1,843,609) with an ISS less than or equal to 9, 41% (n=89,944) of those with an ISS of 10 to 15, 52% (n=135,663) of those with an ISS of 16 to 25, and 79% (n=10,323) of those with an ISS greater than 25 were treated at a trauma center. Of all injury patients identified in Medicare claims, 3.5% (n=271,717) had an ISS greater than or equal to 16 and were the focus of this study. Two percent of patients (158,591) had been involved in a motor vehicle crash. Falls were the mechanism of injury for half of our patient population (n=3,982,757).

Incidence of undertriage varied by census region, trauma center proximity, and ISS category. Of the severely injury patients (ISS ≥16) identified in Medicare claims, 54% (n=145,986/271,717) were treated at a trauma center and 46% (n=125,731/271,717) at a nontrauma center (Table 2). The distribution of severely injured older adults treated at either a trauma or nontrauma center was split approximately equally across most categories. Differences were observed by age group, census region, private transportation, and ISS as follows. Incidence of undertriage was lowest among patients aged 65 to 69 years (38%; n=8,718) and highest among those older than 80 years (49%; n=76,394). Similarly, undertriage was lowest in the Midwest (37%; n=23,006) and highest in the South (53%; n=58,606). Twenty-one percent of older adults (n=2,612) with an ISS greater than 25 were treated at a nontrauma center. Compared with that for patients in the Midwest, adjusted odds of undertriage were 100% higher for older patients in Southern states (odds ratio [OR] 2.00; 95% confidence interval [CI] 2.00 to 2.04) (Table 3) and 78% higher in Western states (OR 1.78; 95% CI 1.73 to 1.82). Older patients in the Northeast had 18% higher odds of being undertriaged (OR 1.18; 95% CI 1.15 to 1.21). Odds of undertriage were higher for female patients (OR 1.09; 95% CI 1.07 to 1.11). Hispanic patients (OR 1.33; 95% CI 1.25 to 1.41) and Asian patients (OR 1.28; 95% CI 1.21 to 1.35) also had higher odds of undertriage compared with white patients. Compared with that for patients aged 65 to 69 years, odds of undertriage gradually increased in all age groups (Figure 2), reaching 57% for patients older than 80 years (OR 1.52; 95% CI 1.52 to 1.61). The odds of undertriage increased by 240% (OR 3.4; 95% CI 3.28 to 3.58) for severely injured patients (ISS 16 to 25) compared with very severely injured patients (ISS >25).

Among patients who lived within 15 miles of a trauma center, 32% (n=1,716,578) were treated at a trauma center, whereas 17% (n=231,447) of those who lived 15 to 30 miles from a trauma center and 12% (n=131,514) of those who lived more than 30 miles from a trauma center received trauma center treatment (Table 2). Distance to a trauma center was associated with increasing odds of undertriage, with 37% higher odds (OR 1.37; 95% CI 1.15 to 1.40) for older adults living more than 30 miles from a trauma center compared with patients within 15 miles (Table 2).

In multivariable subgroup analysis of older adults with an ISS greater than or equal to 16, stratified by distance to trauma center care, the association between patient age and undertriage was more pronounced for patients who lived more than 30 miles from a trauma center, with odds of undertriage increasing by 64% for patients older than 80 years (OR 1.64; 95% CI 1.53 to 1.76) (Table 4). Similarly, the odds of treatment at a nontrauma center increased to 69% (OR 1.69; 95% CI 1.62 to 1.76) for patients who were transported by private vehicle and lived more than 30 miles from a trauma center. Conversely, the association between census region and undertriage was attenuated for patients who lived within 30 miles from a trauma center, with 119% higher odds of undertriage in Southern states (OR 2.19; 95% CI 2.14 to 2.24) and 83% higher odds of undertriage in Western states (OR 1.83; 95% CI 1.78 to 1.89). Northeastern states had 21% higher odds of undertriage (OR 1.21; 95% CI 1.18 to 1.24) compared with Midwestern ones for patients living within 30 miles of a trauma center. Severely injured patients (ISS 16 to 25) had increased odds of undertriage in both groups in regard to distance to trauma center, 242% (OR 3.42; 95% CI 3.26 to 3.59) within 30 miles and 237% (OR 3.37; 95% CI 3.05 to 3.73) at more than 30 miles, compared with very severely injured older adults with ISS greater than 25.

Twenty-nine percent (n=802,176) and 71% (n=1,981,201) of older adults were transported by ambulance to a trauma center and nontrauma center, respectively. Fifty-six percent (n=80,414) and 44% (n=63,587) of severely injured older adults were transported by private vehicle to a trauma center and nontrauma center, respectively (Table 2). Compared with that for older adults transported by ambulance, the odds of receiving treatment at a nontrauma center were 19% higher for patients using private transportation (OR 1.19; 95% CI 1.17 to 1.20) (Table 3). Similarly, in multivariable subgroup analysis of older adults with an ISS greater than or equal to 16, stratified by distance to trauma center, the association between private transport and undertriage was more pronounced for patients who lived more than 30 miles from a trauma center, with odds of undertriage increasing by 69% (OR 1.69; 95% CI 1.62 to 1.76) (Table 4) compared with that for older adults transported by ambulance. In multivariable subgroup analysis of patients with an ISS greater than or equal to 16, stratified by mode of transportation (ambulance versus private vehicle), the estimated effects of ISS were more pronounced for patients transported by private vehicle (Table 5). Among private vehicle transports, ISS 16 to 25 was

Table 3. Multivariable logistic regression for undertriage in Medicare patients with ISS greater than or equal to 16.

Parameter	OR	95% CI
Region		
Midwest	Reference	1 [Reference]
Northeast	1.18	(1.15–1.21)
South	2.00	(2.00–2.04)
West	1.78	(1.73–1.82)
Sex		
Men	Reference	1 [Reference]
Women	1.09	(1.07–1.11)
Race		
White	Reference	1 [Reference]
Black	1.00	(0.96–1.03)
Hispanic	1.33	(1.25–1.41)
Asian	1.28	(1.21–1.35)
North American Native	0.95	(0.84–1.07)
Other	1.10	(1.03–1.19)
Age group, y		
65–69	Reference	1 [Reference]
70–75	1.18	(1.14–1.23)
76–80	1.32	(1.28–1.37)
>80	1.57	(1.52–1.61)
ISS		
>25	Reference	1 [Reference]
16–25	3.43	(3.28–3.58)
Distance to TC, miles		
0–15	Reference	1 [Reference]
15–30	1.17	(1.15–1.20)
>30	1.37	(1.15–1.40)
Transported by ambulance		
Yes	Reference	1 [Reference]
No	1.19	(1.17–1.20)

associated with a 3.9-fold increase in odds of treatment at a nontrauma center (OR 3.89; 95% CI 3.64 to 4.14) compared with that for very severely injured older adults with ISS greater than 25. The association between trauma center proximity and undertriage was more pronounced among patients transported by ambulance, with a 38% increase in odds of undertriage for patients who lived within 15 to 30 miles of a trauma center (OR 1.38; 95% CI 1.34 to 1.43) and 79% increase in odds of treatment at a nontrauma center for patients who lived more than 30 miles from a trauma center (OR 1.79; 95% CI 1.73 to 1.86). Conversely, the association between trauma center proximity and treatment at a nontrauma center was attenuated for patients transported by private vehicle. The associations between census region, sex, race, and age group were similar for both modes of transportation.

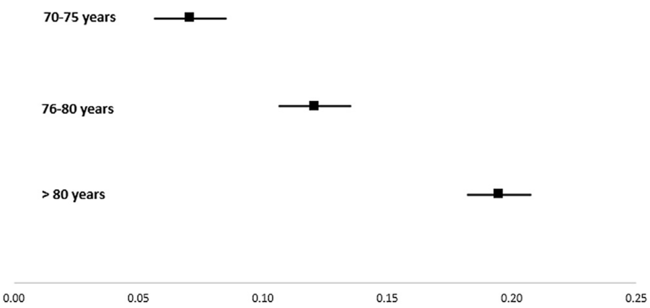

Figure 2. Odds for undertriage in severely injured Medicare patients (ISS ≥16) by age group compared with those aged 65 to 69 years.

LIMITATIONS

There are several limitations in our study. First, it was based on a retrospective review of Medicare claims data. The most relevant limitations to our study include confounding, missing data, lack of timestamps, lack of vital signs or ancillary test results reported, and that data were obtained from billing data; a more extensive description on limitations associated with this study design has been described elsewhere.[17,27,28] Moreover, race and ethnicity information is self-reported, and as such the quality of the data varies considerably.[29] Second, we determined whether an older adult was "adequately triaged" according to Medicare claims postfactually. In other words, we did not have access to out-of-hospital–level data that could have provided further insights about the rationale of emergency medical services (EMS) personnel or family members to seek care. Unfortunately, no reliable out-of-hospital databases that would allow national analyses of this magnitude exist. Standardized collection of out-of-hospital trauma care is urgently needed to improve quality of care and outcomes for injured patients. Third, we relied on ISS, CDC guidelines, and the ACS-COT benchmark to determine undertriage of older adults, but these criteria have not been validated in this population and could inappropriately categorize need for trauma center care. Older adults present with well-documented differences in physiologic response to injury,[30,31] preexisting medical conditions, polypharmacy,[3,32] and mechanisms of injury. These known differences have led to an ad hoc geriatric trauma committee,[33] which calls for reassessment and standardization of triage criteria for geriatric trauma patients.[34] Fourth, additional threats to validity and confounding factors might exist, such as systematic differences between trauma centers and nontrauma centers, including diagnosis coding and transfer protocols. Fifth, although we excluded patients who died in the ED and considered older adults transferred from nontrauma centers to trauma centers to be appropriately triaged, it is possible

Table 4. Multivariable logistic regression for undertriage in Medicare patients with ISS greater than or equal to 16, and distance to trauma center.

	TC ≤30 Miles		TC >30 Miles	
Parameter	**OR**	**95% CI**	**OR**	**95% CI**
Region				
Midwest	Reference	1 [Reference]	Reference	1 [Reference]
Northeast	1.21	1.18–1.24	1.12	1.03–1.19
South	2.19	2.14–2.24	1.30	1.23–1.36
West	1.83	1.78–1.89	1.49	1.39–1.59
Sex				
Men	Reference	1 [Reference]	Reference	1 [Reference]
Women	1.08	1.06–1.10	1.15	1.10–1.20
Race				
White			Reference	1 [Reference]
Black	0.97	0.94–1.01	1.15	1.03–1.28
Hispanic	1.31	1.23–1.39	1.17	0.94–1.45
Asian	1.24	1.17–1.32	1.61	1.16–2.24
North American Native	1.12	0.97–1.29	0.70	0.57–0.87
Other	1.07	0.99–1.15	1.38	1.05–1.81
Age group, y				
65–69	Reference	1 [Reference]	Reference	1 [Reference]
70–75	1.18	1.14–1.23	1.16	1.07–1.25
76–80	1.31	1.27–1.36	1.33	1.23–1.44
>80	1.55	1.50–1.60	1.64	1.53–1.76
ISS (≥16)				
>25	Reference	1 [Reference]	Reference	1 [Reference]
16–25	3.42	3.26–3.59	3.37	3.05–3.73
Transported by ambulance				
Yes	Reference	1 [Reference]	Reference	1 [Reference]
No	1.12	1.10–1.14	1.69	1.62–1.76

that some patients were not stable enough to be transferred to trauma center care or died as inpatients at a nontrauma center. Despite these limitations, this study used a comprehensive data set that enabled us to examine national patterns of undertriage, including examination of several factors that were not assessed in previous studies, to our knowledge. Medicare data used in this study are the best available data to examine undertriage of older adults in the absence of nationally standardized out-of-hospital data collection.

DISCUSSION

To our knowledge, this is the first national analysis to quantify the magnitude and identify predictors of undertriage among injured Medicare beneficiaries. Our results echo findings from previous national, regional, and state[8-12,14] analyses. This study offers unique subanalyses on distance traveled to receive care and mode of transportation used (ambulance versus private vehicle). Almost half of severely injured patients in our study (46%) received care at a nontrauma center despite the CDC recommendation that older injured patients be triaged to the highest level of trauma care available.[4] We also found higher odds of undertriage in Southern and Western states, with increased age, higher injury severity, and increased distance to trauma center care.

Our results suggest that incidence of undertriage is highest in Southern and Western states, a pattern that persists across injury severity categories. One explanation for this pattern could be the increased older population living in the South[35] versus the Midwest and the geographic distribution of the population[3] relative to trauma center and nontrauma center locations.[36] Undertriage, or treatment at a nontrauma center, could reflect lack of access to a Level I or II center. In fact, 69.2% of the US population lives within 45 minutes from a

Table 5. Multivariable logistic regression for undertriage in Medicare patients with ISS greater than or equal to 16, and means of transportation to a trauma center.

	Transported by Ambulance		Private Vehicle	
Parameter	**OR**	**95% CI**	**OR**	**95% CI**
Region				
Midwest	Reference	1 [Reference]	Reference	1 [Reference]
Northeast	1.19	1.15–1.24	1.15	1.11–1.19
South	2.03	1.97–2.09	1.95	1.90–2.01
West	1.77	1.70–1.83	1.79	1.73–1.85
Sex				
Men	Reference	1 [Reference]	Reference	1 [Reference]
Women	1.11	1.08–1.13	1.07	1.05–1.10
Race				
White	Reference	1 [Reference]	Reference	1 [Reference]
Black	0.99	0.94–1.05	0.99	0.95–1.05
Hispanic	1.32	1.21–1.45	1.33	1.23–1.44
Asian	1.19	1.09–1.30	1.34	1.24–1.45
North American Native	1.14	0.93–1.40	0.88	0.76–1.02
Other	1.05	0.94–1.18	1.14	1.03–1.23
Age group, y				
65–69	Reference	1 [Reference]	Reference	1 [Reference]
70–75	1.17	1.11–1.24	1.18	1.13–1.23
76–80	1.34	1.27–1.41	1.31	1.25–1.36
>80	1.62	1.54–1.69	1.53	1.47–1.59
ISS (≥16)				
>25	Reference	1 [Reference]	Reference	1 [Reference]
16–25	3.04	2.86–3.23	3.89	3.64–4.14
Distance to TC, miles				
0–15	Reference	1 [Reference]	Reference	1 [Reference]
15–30	1.38	1.34–1.43	1.01	0.98–1.04
>30	1.79	1.73–1.86	1.11	1.08–1.15

trauma center.[37] In our study, 14.3% of older adults lived more than 30 miles from a trauma center, indicating that a considerable number of older adults, likely from rural areas, lack access to trauma center care. Living more than 50 miles away from a trauma center has been described as a predictor of not receiving trauma center care, although our results suggest that trauma center distances as short as 15 miles affect the likelihood of receiving trauma center care.[38] Further research is needed to better understand driving factors of undertriage at local and state levels, as well as distance to a trauma center and access to trauma center care in rural regions.

Other potential determinants of undertriage include the high incidence of fall-related injuries in older adults and the influence of patient or family preferences in hospital destination. Out-of-hospital providers and caregivers making triage decisions might underestimate the severity of fall-related injuries, a mechanism that is highly prevalent and especially worrisome for older adults because of increased risk of death associated with aspirin use and intracranial bleeding for older patients with ground-level falls.[32] Patient or family choice has also been shown to influence hospital selection by EMS providers after accounting for field triage protocols, particularly as age increases, up to 75.8% among patients older than 90 years.[39]

There are important implications of these findings. First, although the revised field triage guidelines[4] have incorporated special considerations for older adults, evidence suggests that geriatric-specific EMS triage guidelines might be needed in this population.[34] Having specific geriatric field triage guidelines might help reduce undertriage driven by patient or family choice. Some of the above-mentioned factors, such as patient or family choice, previous treatment at a nontrauma center, or initial ISS, might be contributing to the increasing undertriage rates by distance for older adults transported by ambulance. Moreover, analyses of outcomes by mechanism of injury and within trauma center levels are beyond the scope of this article. Ciesla et al[40] showed that severely injured patients do not necessarily require trauma center treatment for optimal care, whereas Flottemesch et al[41] showed that older adults with severe head trauma faced disparities despite increased trauma center treatment after the release of the updated field triage guidelines. Further research is needed to better understand outcomes of different injury mechanisms in these patients. Nevertheless, a national public health intervention to raise awareness about the implications of ground-level falls in older adults could lead to an informed adequate level of care selection, thus reducing morbidity and mortality in severely injured older adults. The relationship between mode of transportation, triage decisions, and patient preference warrants further investigation to support improved triage protocols.

Undertriage in older adults is a complex multilayered issue that cannot be explained by one factor alone, but rather by an interconnection of factors at a patient level (eg, comorbid conditions, polypharmacy, frailty, mechanism of injury) and at a system level (eg, out-of-hospital: access; inhospital: capacity; posthospital: rehabilitation). Assessing out-of-hospital outcomes, inhospital outcomes, and long-term outcomes for severely injured older adults is greatly needed to better understand the factors behind these results.

This analysis confirms the previously noted patterns of undertriage for older injured patients in a national sample. Nationally, nearly half of severely injured older adult trauma patients aged 65 years or older are undertriaged to a nontrauma center. This problem appears to be particularly worse in the Southern United States, despite that field triage guidelines[4] currently call for expedited transport of older trauma patients to a trauma center. Severely injured older adults are less likely to be undertriaged if they live within 30 miles of a trauma center and are transported by ambulance. Tools that improve field triage and enhance access to trauma centers for older patients are urgently needed.

In summary, reducing fatal injuries continues to be an increasing public health concern, as was outlined by Healthy People 2020.[42] Although progress has been made to advance the areas of specific research established in the field triage guidelines,[4] our results highlight the need for ongoing assessment and policy interventions. Our findings offer important information for stakeholders, with health policy implications to improve trauma systems. Limited resources can be targeted to improving access to trauma center care in the Southern and Western states and improving field triage and access to quality care, particularly for patients with falls.

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