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How Well Do Ems Providers Predict Intracranial Hemorrhage in Head-Injured Older Adults?

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Abstract

Objective: To evaluate the accuracy of emergency medical services (EMS) provider judgment for traumatic intracranial hemorrhage (tICH) in older patients following head trauma in the field. We also compared EMS provider judgment with other sets of field triage criteria.

Methods: This was a prospective observational cohort study conducted with five EMS agencies and 11 hospitals in Northern California. Patients 55 years and older who experienced blunt head trauma were transported by EMS between August 1, 2015 and September 30, 2016, and received an initial cranial computed tomography (CT) imaging, were eligible. EMS providers were asked, "What is your suspicion for the patient having intracranial hemorrhage (bleeding in the brain)?" Responses were recorded as ordinal categories (<1%, 1–5%, >5–10%, >10–50%, or >50%) and the incidences of tICH were recorded for each category. The accuracy of EMS provider judgment was compared to other sets of triage criteria, including current field triage criteria, current field triage criteria plus multivariate logistical regression risk factors, and actual transport.

Results: Among the 673 patients enrolled, 319 (47.0%) were male and the median age was 75 years (interquartile range 64–85). Seventy-six (11.3%) patients had tICH on initial cranial CT imaging. The increase in EMS provider judgment correlated with an increase in the incidence of tICH. EMS provider judgment had a sensitivity of 77.6% (95% CI 67.1–85.5%) and a specificity of 41.5% (37.7–45.5%) when using a threshold of 1% or higher suspicion for tICH. Current field triage criteria (Steps 1–3) was poorly sensitive (26.3%, 95% CI 17.7–37.2%) in identifying tICH and current field trial criteria plus multivariate logistical regression risk factors was sensitive (97.4%, 95% CI 90.9–99.3%) but poorly specific (12.9%, 95% CI 10.4–15.8%). Actual transport was comparable to EMS provider judgment (sensitivity 71.1%, 95% CI 60.0–80.0%; specificity 35.3%, 95% CI 31.6–38.3%).

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Conclusions: As EMS provider judgment for tICH increased, the incidence for tICH also increased. EMS provider judgment, using a threshold of 1% or higher suspicion for tICH, was more accurate than current field triage criteria, with and without additional risk factors included.

Keywords

emergency medical services; head injuries; closed

Background

Approximately 2.8 million people suffer from a traumatic brain injury (TBI) per year in the United States (1). TBI contributes to 30% of all injury-related deaths with an estimated cost of $60 billion annually (1, 2). In addition, more than 50% of those who experience TBI will also develop some form of tICH (3). The presence of tICH after TBI confers an increased risk of morbidity and mortality (4–6).

EMS providers are often the first to evaluate trauma patients and must make an initial assessment that includes deciding where to transport the patient (7). This initial decision carries significant implications, because severely injured patients who receive trauma center care experience a 25% reduction in mortality versus those treated at non-trauma centers (8). Unfortunately, EMS providers often have to make decisions based on the limited information that can be immediately observed, rather than data that is precisely measured (9). Several studies have measured the effectiveness of EMS provider judgment as a way to triage trauma patients, but the results have been mixed (10, 11). Major issues with using EMS provider judgment for prehospital trauma triage include over-triaging, low specificity, and variable accuracy across multiple sites (11–14). Despite these challenges, EMS providers play an important role in identifying seriously-injured patients in need of trauma center care (11, 15–18). It is important to further explore how well EMS providers predict the immediate needs of trauma patients, particularly in the context of TBI and possible tICH.

Our objective for this study was to determine the accuracy of EMS provider judgment to predict the presence of tICH, as identified on initial cranial CT scan, in older adults with head trauma. We also compared EMS provider judgment with other sets of field triage criteria.

Methods

Study Design and Setting

This was a prospective observational cohort study conducted in Sacramento County, California, involving 5 EMS agencies and 11 hospitals (one level I trauma center, 3 level II trauma centers, and 7 non-trauma centers). We obtained Institutional Review Board approval at all sites.

Study Participants

Inclusion and exclusion criteria regarding participants for this study has been outlined previously (19, 20). Briefly, our participants were patients 55 years and older who experienced head trauma and were transported by EMS between August 1, 2015 and September 30, 2016. Participants were excluded if they experienced penetrating head trauma, inter-facility transport, or did not undergo cranial CT imaging at their index ED visit. In addition, patients who did not consent to a follow-up telephone call or those who did not have a reliable means for follow-up were also excluded. EMS providers were given standardized data collection forms that included information pertaining to demographics, anticoagulant usage, and other clinical variables.

Study Protocol and Measurements

The data collection method has been described previously (19, 20). In summary, a standardized prehospital patient care report (PCR) form was completed for each patient by participating EMS agencies. Information collected included the patient's demographics, vital signs, medical history, and history of present illness (e.g., vomiting, headache, loss of consciousness, amnesia, seizure after head injury), mechanism of injury, initial GCS score, and EMS provider judgment for tICH. EMS providers were asked "What is your suspicion for the patient having intracranial hemorrhage (bleeding in the brain)?" Responses were recorded as ordinal categories (<1%, 1–5%, >5–10%, >10–50%, or >50%).

Each patient's EMS record was then linked to hospital electronic medical records (EMR) using patient name, date of birth, and date of EMS transport. A trained research coordinator then summarized the data from the PCR and EMR. This included patient name, date of birth, mechanism of injury, detail regarding EMS transport, initial GCS score, history of vomiting, headache, loss of consciousness, amnesia, or seizure after head injury, EMS suspicion for tICH, antiplatelet and anticoagulant use, and initial cranial CT results. All tests, including cranial CT imaging, were ordered at the discretion of the treating physician.

Outcome Measure

The primary outcome measured was the presence of tICH on initial cranial CT imaging. tICH included subarachnoid hemorrhage, subdural hemorrhage, epidural hemorrhage, intraparenchymal hemorrhage/contusion, or intraventricular hemorrhage.

Primary Analysis

We formatted and de-identified the data and recoded the variables using STATA 14.0 statistical software (STATA Corp, College Station, TX). Descriptive statistics were used to characterize the study population. Non-normal interval data were reported with medians and quartiles 1 (Q1) and 3 (Q3). The incidence of tICH was stratified by EMS provider judgment ordinal categories (<1%, 1–5%, >5–10%, >10–50%, or >50%).

We compared the sensitivity and specificity of EMS provider judgment to identify tICH to other sets of triage criteria, including current field triage criteria, current field triage criteria plus additional risk factors identified using a multivariate logistical regression model, and actual transport. EMS provider judgment was stratified as <1% judgment for tICH vs. 1% or higher judgment for tICH. Current field triage criteria included physiologic criteria (Step 1), anatomic criteria (Step 2), and mechanism of injury criteria (Step 3) (7).

Multivariate logistical regression risk factors were identified using a regression model that included a parsimonious set of covariates, comprised of age 85 years or older (ideal cut-point based on receiver operating curve), loss of consciousness or amnesia, history of vomiting, abnormal initial EMS GCS score (dichotomized where abnormal equals GCS score less than 15), evidence of trauma above the clavicles, mechanism of injury other than a fall from standing height or less, any anticoagulant or antiplatelet use, and the presence of any Step 1 to 3 field triage criteria. Anticoagulant or antiplatelet use included the use of warfarin, direct oral anticoagulants (dabigatran, rivaroxaban, apixaban, or edoxaban), aspirin, and other antiplatelet medications (clopidogrel, ticlopidine, prasugrel, dipyridamole, cilostazol, or ticagrelor). To identify the ideal cut-point for age, we explored various age cut-points using a receiver operating curve for nonparametric data and chose the cut-point that maximized sensitivity and specificity (Youden Index) (21). Significance was defined as a p value <0.05 and the results of the multivariate logistic regression model were presented as adjusted OR with 95% CIs. We used complete-case analysis to handle missing data due to the infrequency of missing data (<1%) and model fit was evaluated using the c-statistic (22, 23).

Sensitivity Analysis

To evaluate for potential selection bias, we compared age, male sex, EMS GCS score, Injury Severity Score (ISS), and incidence of tICH between those who did and did not have an EMS provider judgment recoded. Because a higher risk threshold for EMS provider judgment might be tolerated, we also evaluated the sensitivity and specificity of EMS provider judgment stratified as 5% or lower judgment for tICH vs. >5% judgment for tICH.

Results

Characteristics of the Patients

Our initial cohort included 1,304 patients, of which 673 patients (51.6%) had an EMS provider judgment for tICH documented. These 673 patients had a median age of 75 years (interquartile range 64–85) and 319 (47.0%) were male. Most (72.8%) of these patients had a GCS score of 15 and the majority(73.8%) had experienced a fall from standing height or less. Following emergency department evaluation, most patients (57.9%) were later discharged home. The complete description of patients included in this study is documented in Table 1. There were no differences in age, male sex, GCS score, ISS, and the presence of tICH in patients with and without an EMS provider judgment recorded (Table 2).

Main Results

Overall, 76 (11.3%) patients enrolled in the study had a tICH on initial cranial CT imaging. EMS providers most commonly had a low suspicion for tICH and rated 265 patients (39.4%) as <1% risk and 201 patients (29.9%) as 1–5% risk. In general, as EMS provider judgment for tICH increased, the incidence of tICH also increased (Table 3).

Adjusted analysis demonstrated a history of vomiting (OR 4.70, 95% CI 1.58–13.97), evidence of trauma above the clavicle (OR 2.41, 95% CI1.09–5.32), an abnormal initial EMS GCS score (OR2.23, 95% CI 1.26–3.96), Step 1 to 3 field triage criteria (OR 2.04, 95% CI 1.05 to 3.98), and loss of consciousness or amnesia (OR 2.02, 95% CI 1.14 to 3.59) as predictive of the incidence of tICH on initial cranial CT (Table 4).

Using a threshold of 1% or higher suspicion for tICH, EMS provider judgment had a sensitivity of77.6% (95% CI 67.1–85.5%) and a specificity of 41.5% (95% CI 37.7–45.5%). Using a threshold of >5% suspicion for tICH, EMS provider judgment had a sensitivity of 53.9% (95% CI 42.8–64.7%) and a specificity of 72.2% (95% CI 68.5–75.6%).

Steps 1 to 3 of the field triage criteria was poorly sensitive (26.3%, 95% CI 17.7–37.2%) in identifying tICH and Steps 1 to 3 of the field triage criteria plus multivariate logistical regression risk factors was sensitive (97.4%, 95% CI 90.9–99.3%) but poorly specific (12.9%, 95% CI 10.4–15.8%). Actual transport had similar accuracy as EMS provider judgment (sensitivity 71.1%, 95% CI 60.0–80.0%; specificity35.3%, 95% CI 31.6–38.3%) (Table 5). The c-statistic for the logistic regression model was 0.73, which indicates an overall good model fit.

Discussion

Our study demonstrated that in general, as EMS provider judgment for tICH increased, the incidence for tICH also increased. Most patients were considered in the two lowest risk categories (<1% and 1 to 5%), however, the incidence of tICH in these categories was higher than predicted by EMS providers (6.4% in the <1% risk category and 9.0% in the 1 to 5% risk category). This suggests that many of these patients were well-appearing but ultimately had a tICH on initial cranial CT. This is consistent with prior literature demonstrating the difficulty in accurately identifying tICH in this patient population (24).

EMS provider judgment, using a threshold of 1% or higher suspicion, demonstrated similar accuracy compared to actual transport. Current field triage criteria using Step 1 to 3 criteria was not sensitive while the addition of the additional risk factors included in the multivariate model proved to be highly sensitive but not specific, limiting its utility as triage criteria. All sets of triage criteria failed to meet the American College of Surgeons – Committee on Trauma (ACS-COT) benchmark of a sensitivity ≥95% and a specificity ≥50% for field age criteria (20, 25).

Several studies have been conducted to evaluate EMS prehospital triage capabilities, such as determining patient ambulance usage, severity of injuries to specific body regions, and hospital admissions (10, 12, 13). While some studies support the use of EMS provider judgment in prehospital triage, others have cautioned against such usage (10–18).

While none of the sets of triage criteria met the ACS-COT benchmark for sensitivity and specificity, there are questions as to whether this benchmark can be realistically achieved (25). In particular, this patient population of older adults with head trauma are difficult to risk stratify. They often have minor, low energy mechanisms of injury and have minimal evidence of trauma but are at increased risk for tICH compared to younger patients due to anatomical differences, comorbid conditions, and frequent use of anticoagulant or antiplatelet agents. Prior decision rules have included older age as a risk factor for clinically important TBI (26–29). However, in practice, injured older adults are also under-triaged to trauma centers more frequently than younger injured patients (30–32).

The results of our study have potential clinical and policy implications. Our results support the most recent field triage guidelines that include special considerations criteria (Step 4) (7). These criteria highlight the higher risk for potentially serious injuries in older adults despite minor mechanisms of injury. Our results also support the field triage guidelines recommendation to consider EMS provider judgment in the decision to transport injured patients to a trauma center. Particularly in well-appearing older adults with head trauma, EMS provider judgment may be more accurate to predict trauma center need than any specific set of physiologic, anatomical, or mechanistic criteria. Additional research is needed to determine the best possible triage criteria to use in evaluating these patients.

Our results should be evaluated in the context of some limitations. First, our study was conducted in a single EMS system and as such, the results may not be applicable in other EMS settings. Second, we set a low threshold for EMS provider judgment (≥1% suspicion) to suggest transport to a trauma center. We conducted a sensitivity analysis to evaluate a higher threshold (>5% suspicion) and the sensitivity to predict tICH decreased while the specificity increased. These, and the other, ordinal cutoff values were sensible, but were not based on any scientific evidence. Third, almost half of the subjects did not have an EMS provider judgment reported and this could lead to potential selection bias. However, there were no differences in age, sex, EMS GCS score, and the incidence of tICH in subjects with and without an EMS provider judgment reported. Fourth, EMS providers may not accurately identify anticoagulants or antiplatelet use (33). Knowledge of anticoagulant or antiplatelet use may influence EMS provider judgment. Finally, EMS providers typically do not have the medical experience to assess and diagnose tICH and, thus, this may limit the accuracy of their clinical judgment.

Conclusions

In summary, our results suggest that increasing EMS provider judgment for tICH is consistent with an increasing incidence of tICH in head injured older adults. EMS provider judgment, using a threshold of 1% or higher suspicion for tICH, was more accurate than current field triage criteria, with and without additional risk factors included.

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TABLE 1.

Characteristics of the patient population, $n = 673$

Characteristic	*N* (%)
Age, median (Q1, Q3)	75 (64, 85)
Male sex	319 (47)
Race*	
• White	484 (71.9)
• Black	50 (7.4)
• Asian	59 (8.8)
• American Indian/Alaskan Native	6 (0.9)
• Pacific Islander/Native Hawaiian	8 (1.2)
• Other	65 (9.7)
• Unknown	1 (0.1)
Ethnicity†	
• Hispanic	57 (8.5)
• Not Hispanic	603 (89.6)
EMS provider was a paramedic	664 (98.7)
Initial prehospital Glasgow Coma Scale (GCS) score‡	
• GCS score 15	490 (72.8)
• GCS score 14	125 (18.6)
• GCS score 13	16 (2.4)
• GCS score < 13	37 (5.5)
Mechanism of injury	
• Direct blow to head	39 (5.8)
• Fall from greater than standing height	30 (4.5)
• Fall from standing height or less	497 (73.8)
• Motor vehicle collision >35 miles per hour	26 (3.9)
• Motor vehicle collision ≤ 35 miles per hour	24 (3.6)
• Auto versus pedestrian/bicyclist	17 (2.5)
• Other mechanism of injury	27 (4.0)
• Unknown mechanism	13 (1.9)
Trauma above the clavicles	533 (79.2)
History of vomiting	18 (2.7)
History of headache	41 (6.1)
History of loss of consciousness or amnesia	192 (28.5)
Anticoagulant/antiplatelet medication use	
• Warfarin alone	66 (9.8)
• Direct oral anticoagulant alone	28 (4.2)
• Aspirin alone	115 (17.1)
• Other antiplatelet alone	30 (4.5)
• More than one anticoagulant or antiplatelet medication	32 (4.8)
• None	402 (59.7)

Characteristic	*N* (%)
International normalized ratio, median (Q1, Q3)[§]	2.3 (1.8, 2.8)
Platelet count, median (Q1, Q3)	215 (173.3, 262)
ED disposition	
• Discharged home	390 (57.9)
• Admitted to observation unit	19 (2.8)
• Admitted to the floor	161 (23.9)
• Admitted to the intensive care unit	73 (10.8)
• Death in the ED	2 (0.3)
• Operating room	8 (1.2)
• Transferred to another hospital	11 (1.6)
• Left against medical advice	6 (0.9)
• Other	3 (0.4)
Hospital length of stay, median (Q1, Q3)[e]	3 (2, 6)
Injury severity score, median (Q1, Q3)[e]	0 (0, 1)
Isolated head injury[#]	635 (94.5)

Abbreviations: ED = *emergency department*; EMS = *emergency medical services*; Q1 = *first quartile*; Q3 = *third quartile*.

[*] May have more than one rac.

[†] Missing in 13 patients.

[‡] Missing in five patients.

[§] In patients taking warfarin.

[e] Calculated in admitted patients only.

[#] If Abbreviated Injury Scale score for all non-head body regions is less than 3.

TABLE 2.

Comparison of characteristics and outcomes in patients with and without EMS clinical impression provided

Characteristic	EMS gestalt, *n* = 673	No EMS gestalt, *n* = 474
Age, median (IQR)	75 (64 to 85)	72 (62 to 84)
Male sex, *n* (%)	319 (47.4)	227 (47.9)
EMS GCS score, median (IQR)	15 (14 to 15)	15 (15 to 15)
ISS, median (IQR)	6 (4 to 14)	5 (2 to 12)
HCH, n (%)	76 (11.3)	36 (7.6)

Abbreviations: EMS = *emergency medical services*; IQR = *interquartile range*; GCS = *Glasgow Coma Score*; ISS = injury severity score; tICH = *traumatic intracranial hemorrhage*.

TABLE 3.

Incidence of traumatic intracranial hemorrhage by EMS provider judgment

EMS provider judgment*	Traumatic intracranial hemorrhage, *n* (%)
<1%	17/265 (6.4)
1–5%	18/201 (9.0)
>5–10%	7/92 (7.6)
>10–50%	23/90 (25.6)
>50%	11/25 (44.0)

*EMS providers were asked, "What is your suspicion for the patient having intracranial hemorrhage (bleeding in the brain)?" (choices <1%, 1–5%, >5–10%, >10–50%, >50%).

TABLE 4.

Adjusted analysis to predict the incidence of traumatic intracranial hemorrhage on initial cranial CT scan, $n = 668$ [*]

Variable	OR (95% CI)
History of vomiting	4.70 (1.58 to 13.97)
Evidence of trauma above the clavicles	2.41 (1.09 to 5.32)
Abnormal EMS GCS score, initial	2.23 (1.26 to 3.96)
Step 1 to 3 criteria	2.04 (1.05 to 3.98)
Loss of consciousness or amnesia	2.02 (1.14 to 3.59)
Any anticoagulant or antiplatelet use	1.61 (0.94 to 2.75)
Age 85 years or older	1.43 (0.78 to 2.60)
Mechanism of injury other than a fall from standing height or less	1.37 (0.74 to 2.55)

Abbreviations: CT = *computed tomography*; EMS = *emergency medical services*; GCS = *Glasgow Coma Scale*; OR =. *odds ratio*; CI = *confidence interval*.

[*] Five patients were not included in the regression model due to missing data

TABLE 5.

Test characteristics for various combinations of triage criteria to identify traumatic intracranial hemorrhage (n = 76)

	Sensitivity		Specificity	
Triage criteria	***n***	**% (95% CI)**	***n***	**% (95% CI)**
EMS provider judgment*	59/76	77.6% (67.1–85.5%)	248/597	41.5% (37.7–15.5%)
Step 1–3 criteria	20/76	26.3% (17.7–37.2%)	527/597	88.3% (85.4–90.6%)
Step 1–3 criteria and multivariate logistic regression risk factors†	74/76	97.4% (90.9–99.3%)	77/597	12.9% (10.4–15.8%)
Actual transport	54/76	71.1% (60.0–80.0%)	211/597	35.3% (31.6–39.3%)

*If EMS provider judgment was <1% suspicion for the patient having intracranial hemorrhage.

†Loss of consciousness or amnesia OR abnormal initial EMS GCS score OR history of vomiting OR evidence of trauma above the clavicles.