The National Trauma Triage Protocol: Can this tool predict which patients with trauma will benefit from helicopter transport?

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BACKGROUND: Helicopter transport (HT) is an important component of American trauma care, but prospectively identifying patients that would benefit from this resource remains difficult. The objective of this study was to assess the role of the National Trauma Triage Protocol (NTTP) in selecting patients that would benefit from HT.

METHODS: Subjects transported by HT or ground transport from the scene of injury in 2007 were identified using the National Trauma Databank version 8. Criteria from the stepwise NTTP available in the data set were collected including physiologic data, anatomic injuries identified by DRG International Classification of Diseases—9th Rev. codes, and age. Subgroups of patients who met specific triage criteria were evaluated using logistic regression to determine if transport modality was an independent predictor of survival after controlling for demographics, injury severity, prehospital time, and presence of other NTTP triage criteria. Standard test characteristics were calculated for each criterion to predict trauma center need (TCN). The performance of triage criteria to predict TCN was compared between the groups using independent receiver operating characteristic area under the curve analysis.

RESULTS: There were 258,387 subjects transported either by helicopter (16%) or by ground (84%). HT subjects were more severely injured (mean [SD], Injury Severity Score, 15.9 [12] vs. 10.2 [10], $p < 0.01$). Logistic regression identified HT as an independent predictor of survival in subjects with a subset of triage criteria, including penetrating injury, GCS<14, RR<10 or >29 breaths per minute, and age>55 years. Each criterion previously mentioned was significantly more predictive of TCN in the HT group than in the ground transport group ($p < 0.01$).

CONCLUSION: Patients who meet certain triage criteria in the field seem to have an independent survival benefit if transported to a trauma center by helicopter. Furthermore, these criteria are highly specific and more reliably predict TCN in the HT group. The specific triage criteria listed previously should be carefully considered when developing policies for scene helicopter use in the trauma setting. (*J Trauma Acute Care Surg*. 2012;73: 319–325. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Prognostic study, level III.

KEY WORDS: National Trauma Triage Protocol; helicopter use; trauma systems; National Trauma Data Bank.

Rapid transport of the patient with severe injury to definitive care is a cornerstone of modern trauma care, and delay in this setting is a well-documented cause of mortality.[1] Helicopter transport (HT) in this context has become an important component of trauma systems. Recent evidence has demonstrated survival benefits for patients with trauma transported by helicopter,[2–5] but concerns about safety, cost, and overtriage have led some to question the role of HT in the trauma setting.[6,7] Prospectively identifying patients that would benefit from HT remains a significant challenge. There is little evidence to guide a development of standardized HT triage criteria, leading to wide variation among regional criteria and compliance with guidelines.[8,9]

The American College of Surgeons Committee on Trauma and the Centers for Disease Control jointly developed the National Trauma Triage Protocol (NTTP), which is based on the stepwise identification of four aspects of clinical presentation that should be readily identifiable to emergency medical service (EMS) providers at the scene of injury.[10] These include physiologic criteria (PHY), anatomic criteria (ANA), mechanism of injury criteria, and special considerations criteria that are evaluated in a sequential fashion to identify patients who should be transported to a trauma center. Although many HT triage schemes use similar criteria, the current NTTP has not been evaluated in the setting of scene HT for trauma. The objective of the current study was to determine if the criteria included in the NTTP could be used by field EMS providers to predict which patients would benefit from HT after injury.

PATIENTS AND METHODS

Subjects transported from the scene of injury by helicopter (HT) or by ground ambulance (ground transport [GT]) in 2007 were identified using the National Trauma Databank (NTDB) version 8 research data set. Subjects undergoing interfacility transfer or subjects who were dead on arrival to the trauma center were excluded. Data collected for each subject included age, sex, mechanism of injury, prehospital times (response, scene, and total times), Injury Severity Score (ISS), initial Glasgow Coma Scale (GCS) score, initial systolic blood pressure (SBP), initial respiratory rate (RR), length of stay (LOS), intensive care unit (ICU) admission and LOS, mechanical ventilation and ventilator days, emergency department disposition, hospital disposition, trauma center designation, insurance status, and DRG International Classification of Diseases—9th Rev. (ICD-9) diagnosis codes. Demographics, prehospital times, injury severity, and hospital resource use were compared between HT and GT groups.

Available triage criteria from the stepwise NTTP included PHY, ANA, and age. The presence of PHY (GCS score, 14; SBP, <90 mm Hg, RR, <10 or >29 breaths per minute) were determined using prehospital vital signs. Because approximately 30% of prehospital vital signs were missing in the data set, multiple imputations were performed for prehospital GCS score, SBP, and RR.[11] Multiple imputations using a fully conditional specification model based on available demographics, prehospital physiology, and prehospital time with a successive impute and predict algorithm for each variable were performed using five imputation steps to develop a complete data set. A maximum constraint for SBP of 250 mm Hg and RR of 75 breaths per minute was specified. The presence of ANA (penetrating injury, flail chest, open skull fracture, two or more proximal long-bone fractures, pelvic fracture, crush injury, amputation proximal to the ankle/wrist, and paralysis) were determined using ICD-9 diagnosis codes. Age in years was available in the data set for the special consideration age criterion (>55 years). Subjects were classified as to the presence or absence of each of the 12 available triage criteria.

To determine if transport mode was an independent predictor of survival to discharge in subjects with different triage criteria present, subjects were separately analyzed in

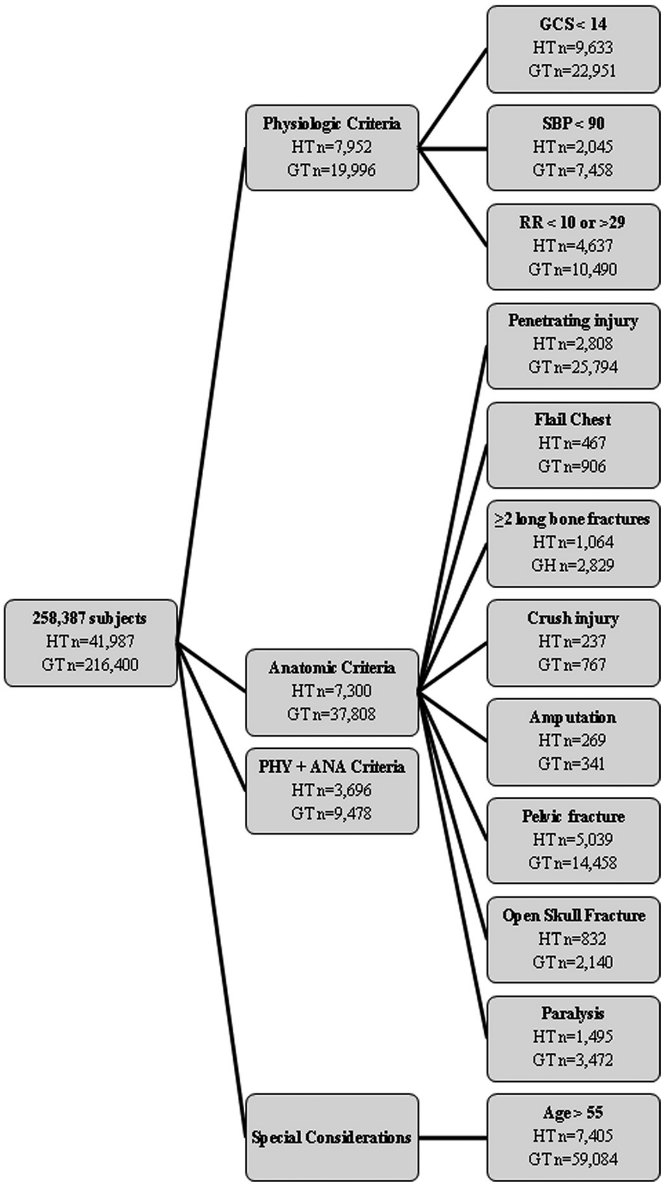

Figure 1. Study population based on transport mode and presence of 12 available NTTP criteria.

subgroups corresponding to the uniform presence of each individual triage criterion (Fig. 1). Because of the stepwise approach to decision making used by the NTTP, an analysis using the sequential approach of PHY, ANA, and PHY plus ANA was undertaken to determine if any of the NTTP steps as a whole predicted a survival benefit. Finally, individual criteria found to predict survival in the HT group were tested in combination to determine if there were additive benefits. A forward stepwise logistic regression model was used to evaluate the association of survival and transport mode in each subgroup while controlling for sex, ISS of more than 15, ICU admission, urgent operation, mechanical ventilation, trauma center designation, insurance status, total prehospital time, and presence of the remaining 11 PHY, ANA, and age criteria not defining the subgroup. Each covariate was tested in univariate analysis in a forward stepwise fashion for association with survival. Covariates were included in the model if associated with survival at a level of $p < 0.2$. The pooled data from the multiple imputations of prehospital vital signs were used in the final models.

To identify patients who would potentially benefit from trauma center care, the outcome of trauma center need (TCN) was defined as a composite of ISS more than 15, ICU admission of 24 hours or more, or the need for urgent surgery defined as emergency department disposition to the operating room. This outcome was used to assess the predictive ability of the 12 triage criteria. Standard diagnostic test characteristics were calculated for each of the triage criteria to predict TCN in the HT and GT groups including sensitivity, specificity, positive predictive value (PPV), negative predictive value, undertriage, and overtriage. Receiver operating characteristic (ROC) curves were constructed for each individual triage criterion to predict TCN in the HT and GT groups. Again, combinations of criteria as described previously were evaluated to determine if there was any incremental increase in predictive ability. The area under the curve (AUC) for each triage criterion was compared using methodology described by Hanley and McNeil[12] to determine if each triage criterion had a different performance in predicting TCN between HT and GT subjects. For determining triage characteristics, prehospital SBP and RR were available in 68%, and GCS score in 78%. In subjects where prehospital vital signs were not available, first admission vital signs were available and used for determining triage criteria predictive value for TCN in an additional 28% of the subjects. There was no significant difference in triage diagnostic test characteristics or ROC AUC comparisons when incorporating the admission vital signs or evaluating only the available prehospital vital signs for PHY.

Data analysis was conducted using SAS JMP version 7.0 (Cary, NC) and SPSS version 19 (Chicago, IL). χ^2 tests were used to compare categorical variables, and Mann-Whitney *U* tests were used to compare continuous variables. Continuous data are presented as mean (SD). A $p \leq 0.05$ was considered significant.

RESULTS

The NTDB version 8 identified 333,768 subjects transported by either helicopter or ground ambulance. Of these, 74,779 were interfacility transfers and 602 were dead on arrival, leaving 258,387 subjects for the final analysis (Fig. 1). HT subjects were younger, had longer prehospital times, higher injury severity, and used more hospital resources (Table 1).

In regression analysis, HT was an independent predictor of survival to discharge when compared with GT in the presence of penetrating injury, GCS score of less than 14, RR of less than 10 breaths per minute or more than 29 breaths per minute, and age of more than 55 years (Table 2). In addition, subjects that had any one PHY plus any one ANA had a survival advantage if transported by helicopter when compared with GT. In the presence of the remaining triage criteria, transport mode was not associated with survival after adjusting for covariates. When evaluating combinations of individual criteria in which HT was associated with a survival benefit, four

TABLE 1. Comparison of HT and GT Group Characteristics

	HT	GT	p
Age, mean (SD), y	36 (19)	42 (22)	<0.01
Male sex, %	70	65	<0.01
Blunt mechanism, %	93	88	<0.01
Prehospital time, mean (SD), min	59.9 (23.5)	43.4 (21.5)	<0.01
ISS, mean (SD)	15.9 (12.3)	10.2 (9.5)	<0.01
ISS > 15, %	43	21	<0.01
SBP < 90 mm Hg, %	4.8	3.4	<0.01
LOS, mean (SD), d	8.5 (12.6)	5.4 (8.6)	<0.01
ICU admission, %	44	23	<0.01
ICU LOS, mean (SD), d	7.3 (10.3)	5.4 (8.6)	<0.01
Mechanical ventilation, %	21	7	<0.01
Urgent operation, %	18.9	12.7	<0.01

additional combinations were associated with an enhanced survival benefit. These included GCS score of less than 14 with abnormal RR (odds ratio [OR], 1.26; 95% confidence interval [CI], 1.10–1.45; $p < 0.01$), penetrating injury with GCS score of less than 14 (OR, 2.00; 95% CI, 1.52–2.64; $p < 0.01$), penetrating injury with abnormal RR (OR, 1.51; 95% CI, 1.06–2.17; $p = 0.02$), and penetrating injury with GCS score of less than 14 plus abnormal RR (OR, 1.94; 95% CI, 1.29–2.91; $p < 0.01$). The same triage criteria demonstrated an independent association between HT and survival when using the pooled multiple imputation data and the original data set with missing prehospital physiologic data excluded.

All triage criteria studied demonstrated a high specificity and relatively low sensitivity to predict TCN (Table 3). The PPV for predicting TCN was uniformly higher in the HT group, including criteria in which a survival benefit was identified (Table 2). In ROC AUC analysis, there was a significantly different performance to predict TCN in nine criteria (Table 3). Presence of any one PHY plus any one ANA, any PHY, any ANA, GCS score of less than 14, RR of less than 10 breaths per minute or more than 29 breaths per minute, two or more long-bone fractures, paralysis, and pelvic fracture better predicted TCN in the HT group than in the GT group. In all criteria studied, only penetrating injury had a better predictive ability for TCN in the GT group. There was no significant difference in the predictive ability for TCN between the HT and GT groups for the remaining triage criteria. Of the criteria combinations demonstrating a survival benefit in the HT group identified previously, GCS score of less than 14 with RR of less than 10 breaths per minute or more than 29 breaths per minute better predicted TCN in the HT group than in the GT group (Table 3). These combinations increased specificity (98.7–99.9%) at the expense of sensitivity (1.0–12.1%) when compared with individual criteria.

DISCUSSION

Aeromedical transport of injured patients has grown in the United States; however its role in the civilian trauma system continues to be debated. Overtriage remains a significant problem, acknowledged even in studies supporting HT.[4,5] Trauma triage in general is inexact, with current guidelines relying heavily on consensus and expert opinion.[10] Gathering evidence for HT triage has proven even more challenging, leaving trauma systems little guidance in developing triage criteria for helicopter use.[9]

Triage of patient with trauma and aeromedical triage address fundamentally different questions. The former seeks to determine what level of care the injured patient requires and helps to identify those that would benefit from transport to a trauma center. The latter seeks to identify those patients requiring a trauma center that would benefit from HT. Many patients may benefit from trauma center care without requiring the resources of HT. It is flawed to assume existing trauma triage guidelines serve as adequate surrogates for identifying patients that benefit from HT.

The current study represents the largest evaluation of triage criteria for scene HT to date, examining both predictive ability as well as outcomes among patients meeting individual triage criteria. Patients that meet a subset of the NTTP PHY, ANA, and age triage criteria have an independent survival benefit if transported by helicopter after adjusting for patient, injury, and hospital level factors. Patients that have GCS score less than 14, an RR of less than 10 breaths per minute or more than 29 breaths per minute, penetrating injury, or age of more than 55 years had improved survival if transported by helicopter. In addition, patients with any one of the three PHY plus any one of the eight ANA had improved survival if transported by helicopter. Furthermore, these criteria have high PPV and specificity, and four of the five criteria perform better in the HT group than in the GT group to predict the need for trauma center care.

Specificity and PPV to determine TCN was uniformly higher in the HT group among all criteria where a difference in predictive ability was identified between HT and GT patients. Ideal criteria for HT triage have high specificity and PPV, whereas a high sensitivity is less important. These patients can still require trauma center care, but not all may benefit from

TABLE 2. Adjusted OR of Survival in HT Versus GT for Triage Criteria With PPV for TCN

	Adjusted OR Survival HT vs. GT (95% CI)	p	PPV HT, %	PPV GT, %
Penetrating injury	1.40 (1.13–1.74)	<0.01	70	53
RR <10 or >29 breaths per min	1.32 (1.12–1.55)	<0.01	87	69
Any PHY + ANA	1.28 (1.22–1.34)	<0.01	95	85
GCS score < 14	1.22 (1.10–1.35)	<0.01	90	76
Age > 55 y	1.15 (1.03–1.30)	0.01	68	37
Paralysis	1.20 (0.95–1.52)	0.13	93	84
Crush injury	1.07 (0.28–5.07)	0.93	68	54
SBP < 90 mm Hg	1.13 (0.95–1.34)	0.18	89	73
Any PHY	0.98 (0.79–1.01)	0.07	87	71
Pelvic fracture	0.95 (0.81–1.12)	0.54	82	56
Any ANA	0.95 (0.81–1.11)	0.49	81	57
Open skull fracture	0.88 (0.65–1.18)	0.39	98	95
2 long-bone fractures	0.86 (0.61–1.20)	0.36	88	53
Flail chest	0.78 (0.57–1.08)	0.13	99	98
Amputation	0.71 (0.33–1.50)	0.37	95	90

TABLE 3. Test Characteristics for Triage Criteria With Different Predictive Ability for TCN Between HT and GT Subjects

	HT			GT			
	Sensitivity, %	Specificity, %	AUC	Sensitivity, %	Specificity, %	AUC	ROC AUC *p*
GCS score < 14*†	32.9	93.5	0.63	20.8	95.7	0.58	<0.01
SBP < 90 mm Hg	8.3	98.2	0.53	7.9	98.1	0.53	0.50
RR < 10 or > 29 breaths per min*†	15.3	95.9	0.56	8.6	97.5	0.53	<0.01
Penetrating injury*†	7.4	94.5	0.51	16.8	90.2	0.54	<0.01
Flail chest	1.8	100	0.51	1.1	100	0.51	0.31
2 long-bone fractures*	3.5	99.2	0.51	1.8	99.0	0.50	<0.01
Crush injury	0.6	99.5	0.50	0.5	99.7	0.50	0.86
Amputation	1.0	99.9	0.50	0.4	100	0.50	0.41
Pelvic fracture*	15.6	94.1	0.55	9.6	95.1	0.52	<0.01
Open skull fracture	3.1	99.9	0.52	2.4	99.9	0.51	0.31
Paralysis*	5.3	99.3	0.52	3.5	99.6	0.51	0.02
Any PHY*	38.4	89.9	0.64	26.3	92.8	0.60	<0.01
Any ANA*	33.8	86.7	0.60	32.9	83.5	0.58	<0.01
Any PHY + ANA*†	13.4	98.9	0.56	9.7	98.9	0.54	<0.01
Age > 55 y†	19.2	84.4	0.52	26.3	70.0	0.52	0.87
GCS score < 14 + abnormal RR*	12.1	98.7	0.55	5.5	99.4	0.52	<0.01

*$p < 0.05$.
†HT associated with survival benefit if criterion is present.

HT. A low sensitivity for these criteria lead to "undertriage;" however, the question is not whether the patient should go to a trauma center, but how they should arrive. Patients who would be "undertriaged" by HT triage criteria can still be transported by ground to a trauma center. A more restrictive set of criteria with high specificity and PPV as well as a measurable benefit is warranted for HT. Although testing the ability of the criteria to predict TCN is important, identifying patients who may have a survival benefit is more compelling for selecting HT triage criteria.

Penetrating injury was the strongest predictor of survival in the HT group and was the only criteria that performed better in the GT group for predicting TCN. Penetrating injury is commonly thought of in an urban setting where HT offers little or no benefit.[13,14] Thus, this group was analyzed further. Sixty percent of HT penetrating injuries were gunshot wounds compared with 54% in the GT group ($p < 0.01$). In the HT group, 42.2% of penetrating injuries were accidental or self inflicted versus 18.8% in the GT group ($p < 0.01$). The mean (SD) transport time in the HT group was 21.4 (11.1) minutes compared with 13.8 (10.7) minutes in the GT group ($p < 0.01$). This suggests that penetrating injuries undergoing HT come from much farther and are more likely to be hunting accidents, suicide attempts, and accidental shootings. This appears to be a different population when compared with the urban penetrating trauma that is associated with violent crime and is historically represented in the GT group. This caveat must be kept in mind when considering these data in the context of HT triage.

Current HT triage guidelines have been adapted from trauma triage guidelines. The National Association of EMS Physicians published a national guideline for aeromedical dispatch criteria in 2003.[15] The authors note the paucity of research on which to base their recommendations. Most of the criteria from these guidelines are similar to the contemporary American College of Surgeons Committee on Trauma (ACS-COT) trauma triage guideline. A recent study surveyed HT dispatch criteria across 55 aeromedical organizations in Europe, finding wide variation in criteria and significant discretionary helicopter dispatch based on providers' judgment of the need for HT.[16] Moreover, compliance with established guidelines varies as well, as one study found HT patients met regional criteria for aeromedical dispatch between 50% and 94% of transports depending on EMS agency.[8]

Ringburg et al.[9] performed a systematic review finding only five studies addressing accuracy of helicopter triage criteria against measures of need for trauma center care. Of 49 dispatch criteria, only altered level of consciousness was identified as a potential valid criterion. Rhodes et al.[17] demonstrated abnormal vital signs and entrapment predicted severe injury with a lower observed-to-expected mortality in HT patients. Wuerz et al.[18] evaluated a previous ACS-COT trauma triage protocol to predict ISS of more than 15, noting high specificity and low sensitivity for PHY, similar to the current study. King et al.[19] determined that prehospital heart rate variability predicted base excess and life-saving operating room procedures better than standard trauma triage criteria and could be used to avoid unnecessary HTs.

The limited available evidence suggests that PHY tend to perform best as HT triage criteria. This is similar to the current study findings, as three of the five criteria in which HT patients have a survival benefit are PHY with high specificity and PPV. Furthermore, patients with combinations of these PHY demonstrated an enhanced survival benefit if transported by helicopter.

Although the current study could not address mechanism of injury and many special considerations in the NTTP, previous evidence suggests these criteria perform poorly. The PPV for mechanism of injury ranges from 27% to 32%.[18,20] These studies evaluated criteria to predict the need for trauma center care, which does not necessarily translate into the need for HT. Thus, it is unclear if patients with a subset of mechanism of injury or special consideration criteria may have improved outcomes when transported by helicopter. The current study did find age more than 55 years in the current NTTP to be associated with a survival benefit if transported by helicopter, warranting further study of these criteria subgroups.

Logistic factors such as time and distance also play a crucial role in the decision to use HT.[9,15,21] These factors cannot be evaluated using traditional outcome measures but, nonetheless, must be incorporated into HT triage protocols. Diaz et al.[22] were able to show that HT was faster than GT if requested by scene personnel for a patient who is 45 miles from the trauma center, making patients in this distance range the most likely to benefit from more rapid transport to definitive care by helicopter. In addition, ground EMS capabilities likely influence the role of HT. Aeromedical crews may provide a higher level of care in some systems than ground crews. First, helicopter providers may be trained and authorized to perform potentially life-saving interventions such as rapid sequence intubation, cricothyroidotomy, or blood product administration that ground crews cannot.[23] In addition, helicopter crews have exposure to a larger volume of patients with trauma, affording them more experience and comfort with management of the patient with severe injury. This can be seen in one study demonstrating a 98% success rate for airway interventions among aeromedical crews.[2]

This study must be interpreted in light of its limitations. First are those inherent to a retrospective design. Second are those outlined by ACS-COT for use of the NTDB.[24] The main advantage is access to a large number of patients in a national sample; however, there are a limited number of variables accessible for analysis. This limits the data that can be used to evaluate outcomes and control for confounders. A substantial amount of prehospital physiologic data were missing; however, multiple imputations was used to mitigate this limitation. Moreover, using admission vital signs in a subset of patients whose prehospital vital signs were missing to determine triage criteria ability to predict TCN did not substantially affect the diagnostic test characteristics. All other data were missing less than 5% of values. Furthermore, mechanism of injury and special considerations in the NTTP could not be evaluated but are an important piece of the triage scheme. ICD-9 codes were used to determine anatomic injuries, relying on complete coding. In addition, it is not possible to evaluate the factors that resulted in individual decisions to transport a patient by helicopter or ground. Finally, the heterogeneity of the data requires careful application in individual trauma systems.

This large, national study suggests that certain criteria that are currently part of the NTTP can help predict which patients with trauma may benefit from HT. Specifically, patients with GCS score of less than 14, RR of less than 10 breaths per minute or more than 29 breaths per minute, penetrating injury, age of more than 55 years, or any PHY plus any ANA have an independent survival benefit if transported by helicopter. Furthermore, these criteria perform better in helicopter patients for predicting need for trauma center care. This study is the first to evaluate HT triage criteria based on the benefit of HT rather than accuracy for predicting TCN alone. The use of HT for patients with these specific criteria is justified by the need for trauma center care and validated by improved outcomes in this study population. These findings demonstrate the need for objectively verifiable triage criteria for HT and warrant further study in a prospective setting. These criteria should be considered when developing national and regional protocols for the scene HT of the injured patient.

AUTHORSHIP

J.B.B., M.L.G., and R.M.F. designed the study. J.B.B. and M.L.G. performed the literature search and data collection. J.B.B. performed the data analysis. All authors contributed to data interpretation, manuscript preparation, and critical revision of the manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

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