Accuracy of prehospital triage protocols in selecting severely injured patients: A systematic review

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BACKGROUND: Prehospital trauma triage ensures proper transport of patients at risk of severe injury to hospitals with an appropriate corresponding level of trauma care. Incorrect triage results in undertriage and overtriage. The American College of Surgeons Committee on Trauma recommends an undertriage rate below 5% and an overtriage rate below 50% for prehospital trauma triage protocols. To find the most accurate prehospital trauma triage protocol, a clear overview of all currently available protocols and corresponding outcomes is necessary.

OBJECTIVES: The aim of this systematic review was to evaluate the current literature on all available prehospital trauma triage protocols and determine accuracy of protocol-based triage quality in terms of sensitivity and specificity.

METHODS: A search of Pubmed, Embase, and Cochrane Library databases was performed to identify all studies describing prehospital trauma triage protocols before November 2016. The search terms included "trauma," "trauma center," or "trauma system" combined with "triage," "undertriage," or "overtriage." All studies describing protocol-based triage quality were reviewed. To assess the quality of these type of studies, a new critical appraisal tool was developed.

RESULTS: In this review, 21 articles were included with numbers of patients ranging from 130 to over 1 million. Significant predictors for severe injury were: vital signs, suspicion of certain anatomic injuries, mechanism of injury, and age. Sensitivity ranged from 10% to 100%; specificity from 9% to 100%. Nearly all protocols had a low sensitivity, thereby failing to identify severely injured patients. Additionally, the critical appraisal showed poor quality of the majority of included studies.

CONCLUSION: This systematic review shows that nearly all protocols are incapable of identifying severely injured patients. Future studies of high methodological quality should be performed to improve prehospital trauma triage protocols. (*J Trauma Acute Care Surg.* 2017;83: 328–339. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic review, level III.

KEY WORDS: Triage; prehospital; severely injured; trauma system.

The impact of severely injured trauma patients is a significant global concern, causing over 5 million deaths each year and leaving even more patients with lifelong injury-related disabilities.[1] Prehospital trauma triage is essential in providing appropriate care for patients at risk for severe injury to improve their chance of survival and to avert disabilities.[2–4]

Incorrect triage results in undertriage and overtriage.[5–8] Undertriage refers to patients with severe injuries not transported to a high-level trauma center by emergency medical services (EMS) providers. Overtriage occurs when patients without severe injuries are taken to a high-level trauma center. It has previously been shown that undertriage results in increased mortality and morbidity.[2,3,9] In other words, correct prehospital triage can save lives. In addition, undertriage causes delay in diagnosis and treatment, missed injuries, and decreased functional outcome.[2,3] The American College of Surgeons' Committee on Trauma (ACS COT) recommends aiming for an undertriage rate below 5%.[10] Overtriage, on the other hand, results in unnecessary burden on high-level trauma center resources and high trauma care costs.[11,12] Prehospital trauma triage protocols have been developed to improve triage rates. To assess protocol-based triage quality sensitivity and specificity are used, which are the same as 1-undertriage and 1-overtriage, respectively.

Prehospital trauma triage protocols have been studied extensively over the last few decades.[13,14] However, a clear overview of the quality of all currently available protocols and corresponding outcomes is lacking. It is unclear which prehospital trauma triage protocol is most effective. The aim of this systematic review was to determine quality of currently available prehospital trauma triage protocols for trauma patients transported by ground ambulance in terms of sensitivity and specificity.

MATERIALS AND METHODS

Search

A systematic review of all published literature according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines was conducted. A search of Pubmed, Embase, and Cochrane Library databases was performed to identify all studies investigating prehospital trauma triage protocols before November 2016. The search terms included "trauma," "trauma center," or "trauma system" combined with "triage," "undertriage," or "overtriage."

Study Selection

Studies describing the accuracy of prehospital triage protocols in identifying severely injured patients, regardless of actual destination facility, were included. All articles, regardless of year of publication, or language, were eligible for inclusion. Exclusion criteria were grey literature (i.e., conference abstracts, editorials, and dissertations), articles describing only helicopter transport or including only pediatric patients. Studies on prehospital protocols seek to identify patients in need of high-level trauma center care, whereas articles on helicopter transport use a separate protocol to identify patients requiring helicopter transport among the patients in need of high-level trauma center care.[15,16] Estimation of pediatric trauma injury severity and triaging these patients is a challenging task. Protocols for pediatric trauma patients usually differ significantly from the protocols for adults and require a separate review, in our opinion.[17–20]

Critical Appraisal

Due to the specific design of the included studies, most available critical appraisal tools were not fully applicable. Criteria from the critical appraisal tools from the Centre for Evidence Based Medicine of the University of Oxford were used for the assessment of the risk of bias.[21] The critical appraisal tool consists of five items that were designed to evaluate the quality of the included studies (Table 1). An accurate assessment of a prehospital triage protocol should include prehospital parameters collected on scene and all trauma patients transported to all levels of trauma the centers in a specific geographic region, without a substantial amount

TABLE 1. Items, Importance, and Score Used for the Critical Appraisal

Items	Importance	Score
1. Study setting	A study setting including all levels of trauma centers guarantees a realistic analysis of triage rates, eliminating selection bias.	+ Regional study, including high-level trauma center(s) as well as lower-level trauma centers − One type of trauma center or not reported
2. Domain	Including all trauma patients ensures a true representation of the trauma population, eliminating selection bias.	+ All trauma patients or adults only − A specific group
3. Collection of data	Prehospital parameters scored by EMS providers give a valid depiction of the actual use of a prehospital trauma triage protocol.	+ Data acquired and scored on the scene by EMS providers − Data acquisition based on records and scored by data managers or collection method not described
4. Timing of measurements	Measuring prehospital data on the scene and at the same time for all included trauma patients represents the actual situation, for prehospital parameters, such as vital signs, can change due to interventions or over time.	+ Parameters measured at the same (prehospital) time − Not measured at the same time (for example the use of a combination of pre- and in-hospital data or the use of in-hospital data only) or timing of measurements not reported
5. Missing data	Including missing data in analyses results in a possibly unreliable outcome.	+ No missing data +/− 0–15% missing data − >15% missing data
Total score	Good quality	Total score of 5 +
	Intermediate quality	Total score of 4 +
	Poor quality	Total score of ≤ 3 +

of missing data. Therefore, the critical appraisal consisted of the items: study setting, domain, collection of data, timing of measurements, and missing data.

Data Extraction

Before the selection of relevant articles, all duplicates were excluded. Two reviewers (E.v.R. and M.v.H.) assessed titles, abstracts, and subsequently full texts. All studies were assessed for methodological design and quality by two reviewers (E.v.R. and M.v.H.), using the critical appraisal as described. There were no discrepancies between the two reviewers. References of included articles and related reviews were screened for additional potential articles. In case of multiple publications regarding the same data set of patients, the article with the largest cohort was selected.

Outcomes

Sensitivity and specificity were used as primary outcome parameters. Sensitivity of a prehospital trauma triage protocol was defined as the proportion of severely injured patients identified as such using the prehospital trauma triage protocol. Specificity of the prehospital trauma triage protocol was defined as the number of patients without severe injuries identified as such using the prehospital trauma triage protocol. When sensitivity and specificity were not mentioned in the article, the percentages were calculated based on the definition of a severely injured patients and information provided by the article. The sensitivity and specificity for similar protocols and criteria were compared in a descriptive manner when possible. Actual triage quality in terms of transport to the correct destination facility—undertriage and overtriage of the system—was not investigated in the present review.

RESULTS

Search Results

A total of 721 unique studies were identified and screened based on title and abstract, after which 135 articles remained for full text review. One full text could not be retrieved.[22] After full-text review, 17 articles were eligible for inclusion and analysis. A survey of the references led to inclusion of four additional articles, resulting in a total of 21 articles (Fig. 1).[23–44]

Study Characteristics

The included studies were published between 1986 and 2016 (Table 2). Four studies investigated a newly developed prehospital triage protocol.[24,29,40,42] None of the studies described the indication or level of priority of the ambulance transportation. Protocol-based triage quality in terms of either sensitivity and specificity or undertriage and overtriage were the primary outcome in 17 articles.[23–36,39,40,42] Sensitivity of prehospital triage protocols ranged from 10% to 100%; specificity ranged from 9% to 100%. The percentage of severely injured patients ranged from 3% to 100% depending on study design and type of participating hospital.

Critical Appraisal

The methodological quality of the included studies was variable; most studies were of poor to intermediate quality (Table 3).

Seven of the studies used prehospital parameters scored by EMS providers on the scene.[23,24,31,32,34,36,39] Fifteen studies acquired the parameters in a different way. Lerner et al.[35] interviewed EMS providers at the hospital to obtain the parameters, for example. Whereas Ciesla et al.[28] used trauma alert fees as a proxy for meeting the prehospital triage criteria. Two studies used a combination of pre- and in-hospital data[25,26] and two used in-hospital data only[29,37] as prehospital parameters.

Only six studies included all trauma patients or adults only transported by EMS providers, whereas 15 studies included a specific group of trauma patients, potentially introducing selection bias.[23,28,31–34,36–38,41,43] For instance, Matsushima et al.[37] only included patients involved in a motor vehicle crash. Hamada et al.[31] retrospectively applied the triage protocol to a cohort of

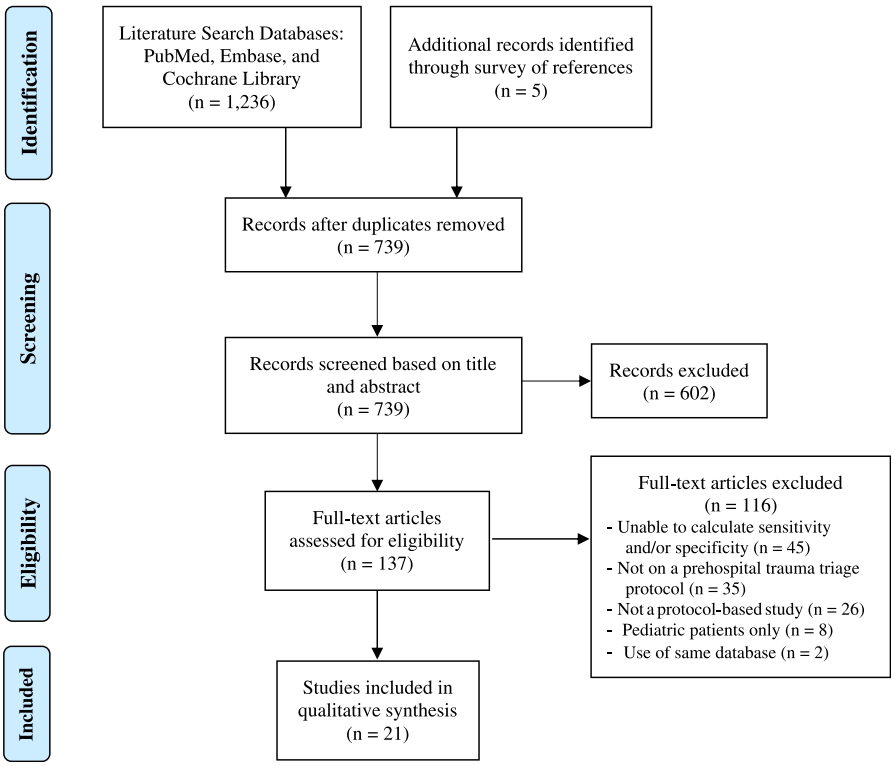

Figure 1. Flowchart of the selection process.

patients admitted to a trauma center and a cohort of severely injured patients only.

Nine of the studies calculated sensitivity and specificity based on only patients transported to a high-level trauma center.[23,27,29,31,35,36,38,40,42] Three studies developed a new triage protocol using this study design.[29,40,42]

Missing data were a significant problem in most of the studies, with fractions up to 50%.[24,26,29,30,32–37,39,40,42] Seven studies did not mention the amount of missing data.[27,28,31,33,37,41,42] Three studies used multiple imputation to handle missing data,[26,33,39] no alternative methods were used by the other articles. None of the studies reported a structural reason for missing data.

Protocol Triage Quality

Protocol-based studies investigate the quality of triage based on the accuracy of a specific prehospital triage protocol in identifying patients with severe injuries, regardless of destination facility. Sensitivity and specificity were calculated by retrospectively applying the triage protocol on a data set of prehospital parameters (Table 4).

There are two types of protocol-based studies to be distinguished. The first type investigates the quality of the *original* protocol that was actually used for prehospital triage in the investigated cohort of patients. The second type investigates a *virtual* protocol that is often based on a newly developed set of prehospital parameters. Some studies test a range of protocols on the same data set.[24,27,30,32–36,42,44]

The Trauma Score (TS) assesses respiratory rate and effort, capillary refill, and Glasgow Coma Scale (GCS). Evaluation of the TS resulted in variable, but relatively low sensitivity (43% to 88%), with a more than adequate specificity (88–99%).[32,34,38] Adding mechanism of injury and anatomic criteria improved sensitivity and specificity.[34,36] The mechanism criterion "penetrating trauma" resulted in the highest predictive value for severely injured patients.[34]

The Revised Trauma Score for Triage is a revision of the TS and consists of systolic blood pressure, respiratory rate, and GCS. This protocol had a lower sensitivity compared with the TS.[27,30,41]

The ACS COT established the Field Triage Decision Scheme (FTDS) in 1986 and continues to publish modified protocols at regular intervals.[45] It consists of four aspects: mechanism of injury, physiologic criteria, anatomic criteria, and special considerations. The special considerations criterion includes, among others, older than 55 years, comorbidity, and EMS provider judgment. Alterations in the FTDS from 1999 to 2006 resulted in an increase of specificity and a small decrease in sensitivity.[35] Upon analyzing specific aspects of the 2006 FTDS, various criteria predicted the need for high-level trauma care. Physiologic criteria were predictive when the Injury Severity Score (ISS) was greater than 15, whereas anatomic criteria were better at predicting the need for an urgent operative intervention.[25,26] A new model that added six new mechanism of injury criteria to the 2006 FTDS increased sensitivity from 84% to 92%.[40] In the 2011 FTDS, age older than 64 years was a strong predictor of the need for high-level trauma care among motor vehicle crash victims.[37]

Gray et al.[30] and Hedges et al.[32] assessed the Circulation, Respiration, Abdomen, Motor, Speech scale, but reported an over 15% difference in both sensitivity and specificity.

The Prehospital Index (PHI) is a combination of systolic blood pressure, pulse, respiratory rate, and level of consciousness.

TABLE 2. Baseline Characteristics of All Included Articles

First Author (Year)	Patients (n)	Population (Year of Inclusion)	Type Trauma Center (Location)	Definition of a Severely Injured Patient	Severely Injured Patients (%)
Baxt (1990)[23]	1,004	Admitted trauma patients >14 years old (unknown)	1 Level I trauma center (USA, California)	Nonorthopedic surgery, fluid resuscitation, invasive CNS monitoring, or death	21.0
Bond (1997)[24]	3,147	Trauma patients >13 years old (1995)	2 trauma and 2 community centers (Canada, Alberta)	ISS >15	2.6
Brown (2011)[25]	1,086,764	Transferred, admitted, or deceased trauma patients >17 years old (2002–2006)	Levels I, II, III, IV, or undesignated centers (USA)	ISS >15, ICU admission within 24 h, or urgent surgery	42.0
Brown (2015)[26]	1,555,944	Transferred, admitted, or deceased trauma patients >15 years (2010–2012)	Not reported (USA)	ISS >15, ICU admission within 24 h, urgent surgery, or death in ED	Not reported
Champion (1989)[27]	2,166	Admitted trauma patients (1982–1985)	Trauma center, not further specified (USA, Washington)	ISS >15	30.3
Ciesla (2015)[28]	116,990	Admitted adult trauma patients (2012)	Trauma and nontrauma centers, not further specified (Florida, USA)	ICISS <0.85	10.0
Dihn (2014)[29]	3,027	Trauma patients >14 years old (2007–2011)	1 major trauma center	ISS >15, ICU admission, or in-hospital death	21.6
Gray (1997)[30]	213	Trauma patients admitted to the resuscitation room (1993–1995)	Not reported	ISS >15, ICU admission, or death	46.0
Hamada (2014)[31]					
Cohort 1	825	Admitted trauma patients (2010–2012)	2 trauma centers, not further specified (France)	ISS >15	Not reported
Cohort 2	190	Severely injured patients, not further specified (2010–2012)	5 trauma centers, not further specified and peripheral hospitals (France)	ISS >15	Not reported
Hedges (1987)[32]	130	All trauma patients (1982)	Trauma centers and nontrauma centers, not further specified (USA, Washington)	No vital signs, death in ED, nonorthopedic surgery, or ICU admittance	31.0
Ichwan (2015)[33]	101,577	Transferred, admitted, or deceased trauma patients >15 years old (2006–2011)	Trauma centers and nontrauma centers, not further specified (Ohio, USA)	ISS >15	23.5
Knopp (1988)[34]	1,473	Admitted trauma patients >1 and <65 years old (1986)	1 Level I and 2 Level III trauma centers (USA, California)	ISS >15	6.6
Lerner (2011)[35]	11,891	All trauma patients >17 years old (unknown)	1 Level I trauma center (USA, Wisconsin, New York, Michigan)	ISS >15	9.3
				Nonorthopedic surgery <24 h, ICU admission, or death	11.5
Long (1986)[36]	898	Admitted trauma patients (1983–1985)	1 Level I trauma center (USA, Oregon)	ISS >15	26.8

Continued next page

TABLE 2. *(Continued)*

First Author (Year)	Patients (n)	Population (Year of Inclusion)	Type Trauma Center (Location)	Definition of a Severely Injured Patient	Severely Injured Patients (%)
Matsushima (2016)[37]	3,998	Trauma patients involved in a motor vehicle crash with vehicle intrusion (2002–2012)	Not reported	Intubation at ED, nonorthopedic surgery, ICU admission, or in-hospital mortality	14.5
Morris (1986)[38]	1,099	Admitted trauma patients >18 years old (1983–1984)	Trauma center, not further specified (USA, California)	ISS >20	17.5
Newgard (2016)[39]	17,633	All trauma patients (2011)	5 Level I trauma centers, 2 Level II trauma centers, 5 Level II trauma centers, 5 Level IV trauma centers, and 11 nontrauma centers (US, Oregon and Washington)	ISS >15	3.1
				Critical resource use within 24 h	1.7
				ISS >15, or critical resource use within 24 h	4.1
Ocak (2009)[40]	1,396	Admitted trauma patients >17 years old (2004–2005)	Trauma center, not further specified (the Netherlands)	ISS >15	12.7
Strums (2006)[41]	451	Patients with an ISS >15 (2001–2003)	3 Level I and 7 nontrauma centers (the Netherlands)	ISS >15	100
Tamim (2002)[42]	1,291	Trauma patients >15 years old (1993–1996)	2 Level I trauma centers (Quebec, Canada)	Death <8 days, nonorthopedic surgery <4 days, or ICU admission <7 days	45.0
Zimmer-Gembeck (1995)[43]	26,025	Admitted trauma patients (1990–1992)	2 Level I trauma centers and 15 nontrauma centers (USA, Oregon)	Nonorthopedic surgery, fluid resuscitation, invasive CNS monitoring, or death	10.0

CNS, central nervous system; ICU, intensive care unit; ICISS, International Classification Injury Severity Score; ED, emergency department.

Three studies assessed PHI > 3 and found a sensitivity ranging from 35% to 73%.[24,32,42] Tamim et al.[42] created a new model based on the PHI, combined with age, body region injured, mechanism of injury, and comorbidity. The model was made using logistic regression analysis to produce an algorithm, which resulted in improved triage rates.[42] However, according to the authors, the correct cutoff point has yet to be determined. The combination of PHI and mechanism of injury criteria identified severely injured patients more accurately than PHI score or mechanism of injury alone, with sensitivity and specificity of 78% and 89%, respectively.[24]

Among statewide or national protocols, the Vittel Triage Criteria of France (consisting of mechanism of injury, physiologic criteria, anatomic criteria, applied resuscitation measures, and medical history) excelled, with a sensitivity of 98% to 99% and a specificity of 54% to 64%.[31] Two cohorts were used: one with patients admitted to a high-level trauma center and one with severely injured patients (without specifying definition).

Ichwan et al.[33] compared Ohio's 2009 geriatric prehospital triage criteria with corresponding adult criteria in a cohort of patients who died, were transferred, or were admitted for 48 hours or longer. Both protocols included physiologic and anatomic criteria with lower thresholds for high-level trauma care in the geriatric population (patients aged 70 years or older). Considering the geriatric patients only, the geriatric triage criteria resulted in a higher sensitivity compared with the adult criteria (61% vs. 93%), but this came at the cost of a decrease in specificity (49% vs. 61%).

Assessment of severely injured patients, not identified as such by the Oregon triage criteria (consisting of the mechanism of injury, physiologic, and anatomic criteria) showed that many were elderly (≥65 years of age).[43]

Dihn et al.[29] developed a new prehospital triage protocol consisting of age of 65 years or older, abnormal vital signs, GCS less than 14, penetrating injury, multiregion injuries, and falls. The resulting sensitivity and specificity were 90% and 58%, respectively. This cohort was predominantly elderly with low rates of penetrating injuries.

DISCUSSION

In this systematic review, all currently available studies on prehospital trauma triage protocols were analyzed and showed a wide variety in sensitivity and specificity. A critical appraisal of included studies demonstrated that the majority was of poor

TABLE 3. Critical Appraisal

First Author (Year)	Study Setting*	Domain*	Collection of Data*	Timing of Triage*	Missing Data*
Baxt (1990)[23]	−	−	+	−	+
Bond (1997)[24]	+	+	+	+	+/−
Brown (2011)[25]	+	−	−	−	+
Brown (2015)[26]	−	−	−	−	−
Champion (1989)[27]	−	−	−	−	−
Ciesla (2015)[28]	+	−	−	−	−
Dihn (2014)[29]	−	+	−	−	+/−
Gray (1997)[30]	−	−	−	−	+
Hamada (2014)[31]					
Cohort 1	−	−	+	+	−
Cohort 2	+	−	+	+	+
Hedges (1987)[32]	+	+	+	+	+
Ichwan (2015)[33]	+	−	−	+	−
Knopp (1988)[34]	+	−	+	−	+
Lerner (2011)[35]	−	+	−	−	+
Long (1986)[36]	−	−	+	+	+
Matsushima (2016)[37]	−	−	−	+	−
Morris (1986)[38]	−	−	−	+	+
Newgard (2016)[39]	+	+	+	−	−
Ocak (2009)[40]	−	−	+	+	+
Strums (2006)[41]	+	−	−	−	−
Tamim (2002)[42]	−	+	−	+	−
Zimmer-Gembeck (1995)[43]	+	−	−	−	+

*Items and scoring system are described in Table 1.

quality. Most protocols included an assessment of vital signs, suspicion of specific anatomic injuries, and often mechanism of injury. The use of nearly all protocols resulted in suboptimal or inadequate accuracy. Given the poor methodological quality and inadequate triage rates of the available protocols, it is difficult to determine which protocol is best.

In 1976, the ACS COT established the first prehospital trauma triage protocol—which included the concept of bypassing the nearest hospital for a high-level trauma center— and initiated the process of accreditation of trauma centers. Both have proven pivotal in the development prehospital trauma triage systems.[13,45] In this review, we specifically evaluated protocol-based triage quality, or the quality of triage based on the accuracy of a prehospital trauma triage protocol in identifying patients with severe injuries, regardless of destination facility. The protocol-based triage quality was assessed using sensitivity and specificity. A high sensitivity of a protocol identifies severely injured patients as such using the protocol, so these patients are recognized and taken to a high-level trauma center, lowering undertriage. On the other hand, a high specificity ensures that less severely injured patients are identified by the protocol and are taken to a lower-level trauma center, to lower overtriage. Since undertriage results in an increased mortality and morbidity rate, efforts should be made to lower undertriage, thus increasing the sensitivity of a triage protocol.

For an accurate and complete view of prehospital triage quality, assessment of an entire trauma system is necessary. This includes prehospital parameters measured on the scene by EMS providers, all types of trauma patients, and all levels of trauma centers. An adequate protocol should be the foundation of a competent trauma system.

As shown by our critical appraisal, most studies were of poor methodological quality. The majority of prehospital trauma triage protocols were judged on unreliable prehospital parameters, used specific subgroups of patients, or were established using only one type of trauma center. Data collection of prehospital variables should take place on the scene and at the same moment throughout the study, since the parameters can change over time. The destination facility itself does not influence triage parameters when looking at protocol-based triage quality. However, using only patients transported to a high-level trauma center potentially excludes an important population of patients: the patients undertriaged to a lower-level trauma center, who have severe injuries that may be more difficult to identify. The protocol-based triage quality can only truly be judged based on prehospital parameters determined on the scene by EMS providers and using all trauma patients transported to the different levels of trauma centers in a region. For example, Bond et al.[11] included adult trauma patients transported to all levels of trauma centers in a specific region. The on-scene prehospital parameters consisted of all the variables needed to test the prehospital trauma triage protocol, which were the PHI and mechanism of injury in this case. This study design guarantees a realistic analysis of triage rates using a certain protocol. The sensitivity rates of the protocol in this study were low, however, ranging from 40% to 78%. Analysis of the Vittel Triage Criteria demonstrated excellent sensitivity (98–99%).[21] However, the inclusion of patients was highly selective, which inevitably affected the sensitivity and specificity. Two cohorts were analyzed: one with patients admitted to a high-level trauma center and one with exclusively severely injured patients (without specifying definition or how this was determined). Both cohorts are not representative of a general trauma population. A significant proportion of patients is missed in both cohorts, one in which identifying patients with severe injuries would likely be even more challenging. In the first cohort, the patients taken to a lower-level trauma center were missed, including the severely injured, undertriaged, patients. In the second cohort it is unknown if truly all severely injured patients were included. Additionally, the patients without severe injuries, including the potentially overtriaged ones, were missed.

It is important to classify severely injured patients correctly to accurately determine sensitivity and specificity of a trauma triage protocol. Surrogate markers are used to classify severely injured patients. In the included articles, an ISS > 15 was the most commonly used surrogate for a severely injured patient. However, there is much debate on this subject in recent studies.[46–50] Legitimate classification is difficult and depends on the country, regional circumstances, and trauma center level. Although the definitions are different, a common factor is that the severity is determined at the hospital, mostly days after admission and not on the scene. Predicting these outcomes is difficult on the scene, but essential to accurately determine if a patient should be taken to a high-level trauma center. Changing the definition may produce better sensitivity and specificity, but will not affect the quality of trauma care.

TABLE 4. Rates of Sensitivity and Specificity per Prehospital Trauma Triage Protocol

First Author (Year)	Assessment of Protocol	Triage Protocol	Severely Injured Patients (%)	Sensitivity	Specificity
Baxt (1990)[23]	Retrospective	TTR	21.0	91.0	91.0
Bond (1997)[24]	Prospective	PHI >3		40.0	98.0
		Mechanism of injury	2.6	73.0	91.0
		PHI >3 and mechanism of injury		78.0	89.0
Brown (2011)[25]	Retrospective	Physiologic criteria of 2006 FTDS	42.0	32.0	91.0
		Anatomic criteria of 2006 FTDS		26.0	85.0
		Physiologic or anatomic criteria of 2006 FTDS		49.0	78.0
		Physiologic and anatomic criteria of 2006 FTDS		45.0	73.0
Brown (2015)[26]	Retrospective	Adult (16–65 y)			
		SBP <110 mm Hg		23.0	90.0
		SBP <90 mm Hg		10.0	98.0
		Physiologic and anatomic criteria of 2011 FTDS using SBP <110 mm Hg		67.0	62.0
		Physiologic and anatomic criteria of 2011 FTDS using SBP <90 mm Hg		62.0	67.0
		Geriatric (>65 y)	Not reported		
		SBP <110 mm Hg		13.0	93.0
		SBP <90 mm Hg		5.0	91.0
		Physiologic and anatomic criteria of 2011 FTDS using SBP <110 mm Hg		44.0	71.0
		Physiologic and anatomic criteria of 2011 FTDS using SBP <90 mm Hg		40.0	75.0
Champion (1989)[27]	Retrospective	TS <13 or GCS <11		48.0	92.0
		T-RTS <12	30.3	59.0	82.0
		T-RTS <11		49.0	92.0
		T-RTS <10		39.0	96.0
Ciesla (2015)[28]	Retrospective	Field triage of Florida	10.0	57.0	89.0
Dihn (2014)[29]	Retrospective	New model >4	21.6	90.0	58.0
Gray (1997)[30]	Retrospective	CRAMS <9	46.0	69.0	75.0
		T-RTS <12		60.0	90.0
Hamada (2014)[31]	Retrospective	Cohort 1—Vittel Triage Criteria	Not reported	99.0	64.0
		Cohort 2—Vittel Triage Criteria		98.0	54.0
Hedges (1987)[32]	Retrospective	Kane's		85.0	65.0
		CRAMS <9		85.0	54.0
		CRAMS <7		39.0	89.0
		TS <13, GCS <11, or mechanism of injury = 1		78.0	63.0
		TS <13 or GCS <11		54.0	93.0
		TS <13	31.0	46.0	97.0
		Respiratory, systolic pressure, GCS score = 1		73.0	79.0
		PHI >3		73.0	75.0
		Respiratory/pulse/motor response score <11		61.0	88.0
		Respiratory/systolic blood pressure/motor response score <11		59.0	92.0
		Paramedic severity impression = 3		51.0	96.0
		Mechanism of injury = 1		49.0	69.0
Ichwan (2015)[33]	Retrospective	Adult triage criteria <70 y	23.5	87.0	44.0
		Adult triage criteria >69 y		61.0	61.0
		Geriatric triage criteria <70 y		94.0	35.0
		Geriatric triage criteria >69 y		93.0	49.0
Knopp (1988)[34]	Prospective	TS <13		70.1	98.5

Continued next page

TABLE 4. *(Continued)*

First Author (Year)	Assessment of Protocol	Triage Protocol	Severely Injured Patients (%)	Sensitivity	Specificity
		TS <16	6.6	87.6	86.9
		TS <15 + 11 MOI/ANA criteria		92.8	76.2
		TS <13 + 9 MOI/ANA criteria		89.7	87.1
Lerner (2011)[35]	Retrospective	1999 FTDS ISS >15	9.3	64.0	62.3
		1999 FTDS trauma center need	11.5	77.3	64.7
		2006 FTDS ISS >15	9.3	56.2	74.7
		2006 FTDS trauma center need	11.5	71.6	77.5
Long (1986)[36]	Prospective	TS <15 + space violation		82.4	90.4
		TS <15 + delayed extrication		78.8	96.2
		TS <15 + patient ejected		83.9	87.7
		TS <15 + patient fall		81.1	89.2
		TS <15 + death of other occupant		80.0	91.7
		TS <15 + child struck by car		100	83.3
		TS <15 + pedestrian struck by car	26.8	92.9	92.9
		TS <13 + space violation		77.6	93.6
		TS <13 + delayed extrication		67.3	98.1
		TS <13 + patient ejected		74.1	92.6
		TS <13 + patient fall		64.9	97.3
		TS <13 + death of other occupant		70.8	95.8
		TS <13 + child struck by car		94.4	100
		TS <13 + pedestrian struck by car		71.4	96.4
Matsushima (2016)[37]	Retrospective	Motor vehicle intrusion all patients		—	14.5
		Motor vehicle intrusion <19 y	14.5	—	10.8
		Motor vehicle intrusion 19–64 y		—	135
		Motor vehicle intrusion >64 y		—	31.8
Morris (1986)[38]	Retrospective	TS <13	17.5	43.3	96.8
		TS <15		63.3	88.4
Newgard (2016)[39]	Prospective	2006 FTDS ISS >15	3.1	66.2	87.8
Ocak (2009)[40]	Retrospective	PHY, ANA, and MOI criteria of 2006 FTDS	12.7	84.1	77.5
		New model		92.1	79.5
Strums (2006)[41]	Retrospective	T-RTS <11	100	34.1	—
		T-RTS <12		47.0	—
Tamim (2002)[42]	Retrospective	PHI >0		55.0	71.0
		PHI >1		47.0	77.0
		PHI >2		46.0	78.0
		PHI >3		35.0	91.0
		PHI >4		28.0	94.0
		PHI >5		20.0	96.0
		PHI >6		17.0	97.0
		PHI >7		15.0	98.0
		New Triage Protocol >2		99.0	9.0
		New Triage Protocol >3		95.0	24.0
		New Triage Protocol >4	45.0	85.0	42.0
		New Triage Protocol >5		64.0	67.0
		New Triage Protocol >6		51.0	80.0
		New Triage Protocol >7		43.0	88.0
		New Triage Protocol >8		36.0	92.0
		New Triage Protocol >9		29.0	96.0
		New Triage Protocol >10		21.0	97,0
		New Triage Protocol >11		15.0	98.0
Zimmer-Gembeck (1995)[43]	Retrospective	Triage criteria by Oregon	10.0	78.5	71.8 (ISS, 1–9)

TTR, Trauma Triage Rule; PHI, prehospital index; SBP, systolic blood pressure; MOI, mechanism of injury; PHY, physiologic criteria; ANA, anatomic criteria; T-RTS, Revised Trauma Score for Triage; CRAMS, Circulation, Respiration, Abdomen, Motor, Speech criteria; HTI-ISS, Hospital Trauma Index Injury Severity Score.

Sensitivity was lower among geriatric patients compared to younger patients, which is a well-known problem.[7,26,33,39,43] Identifying a severely injured younger patient is more straightforward, compared to geriatric patients, due to a difference in mechanism of injury. Even minor geriatric injuries carry a higher mortality rate compared with the young.[51,52] High mortality of geriatric trauma patients is attributed to the prevalence of preexisting diseases and masked physiologic derangement, possibly due to medication.[53,54] Because geriatric injuries are increasing in frequency and these patients are hard to identify, age should be included as a criterion to increase the sensitivity of a trauma triage protocol. The classification of geriatric patients remains ambiguous; cut-off points between 55 years and 70 years as lower limit for age are used.[55]

Triage quality may vary greatly between countries, aside from other prehospital trauma triage protocols used, differences in geographical distance, compliance to the triage protocol, and education of EMS providers constitute to this. The protocol-based triage quality is not affected by these factors, however a difference in population might be. In a trauma population with a lot of penetrating traumas, the severely injured patients are more easily recognized, compared with a population consisting predominantly of elderly trauma patients for example. In this review differences between countries could not be analyzed, because of the different protocols and definitions for severely injured patients used in each article.

In this review, a newly developed critical appraisal was used, based on the critical appraisal tools from the Centre for Evidence Based Medicine of the University of Oxford.[21] In this critical appraisal, all items necessary to judge the methodological quality of a study evaluating a prehospital trauma triage protocol were included to eliminate biases and accurately assess a protocol.

The major limitation of this review was the heterogeneity of the included studies, which made it difficult to accurately compare the studies. First, none of the studies described the indication or level of priority of the ambulance transportation, leading to a possible difference in the population. Also, the studies use different protocols, definitions, and selection criteria, making the ability to directly compare these studies limited. Therefore, it is impossible to recommend the best protocol. Another limitation is the possibility of publication bias; unpublished work on for example poor performance of a protocol might be missing. Even though the grey literature (i.e. conference abstracts, editorials, and dissertations) was excluded in this review, a thorough search led to only one conference abstract on prehospital trauma triage protocols, minimizing the possibility of publication bias.

Further research should focus on creating and improving prehospital trauma triage protocols. First, all trauma patients and levels of trauma centers of a specific region should be included in the study, to minimize selection bias. Second, prehospital parameters should be scored by EMS providers on the scene, since these are the potential predictors of severe injury of a protocol. Vital signs, anatomic injuries, mechanism of injury, and age were all predictors for severe injury, but to different degrees. Multiple studies found penetrating trauma as a strong predictor of severe injury;[23,29,34] however, these types of relatively obvious injuries are not expected to improve triage significantly, as they will be recognized as such without the use of a protocol. The sensitivity and specificity of a protocol needs to be improved using less obvious, but still strong predictors of severe injury. Other specific strong predictors in a number of the included studies were: pelvic fractures, GCS score less than 14, and multiregions injuries.[25,29,40] Furthermore, protocols are less sensitive when applied to geriatric patients, compared to younger patients, so age has a strong potential to improve the sensitivity of a protocol. As seen in the study by Tamim et al.[42] creating an algorithm using logistic regression to calculate need for high-level trauma center care improved sensitivity and specificity. In an algorithm, GCS and age could potentially be included as continuous variables, in addition to dichotomous variables, such as multiregion injuries. Future protocols should therefore be more dynamic, preferably with weighted continuous and dichotomous parameters, taking these differences into account. An electronic device could help calculate the chance of severe injury when using weighted prediction parameters. This could improve the accuracy of the protocol as well as increase EMS provider compliance to the protocol.[39] Ultimately, the goal of prehospital trauma triage is to get the right patient to the right hospital in the right time. This will decrease mortality and avert lifelong disabilities.

CONCLUSION

This systematic review shows that nearly all of the studied prehospital trauma triage protocols were unable to adequately identify severely injured patients. In addition, the overall methodological quality was poor. Based on these findings, it is impossible to recommend a superior protocol among those investigated. To improve prehospital trauma triage protocols, future studies should be of high methodological quality to properly investigate their accuracy. Only then can a proper evidence-based decision be made on which protocol is best.

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DISCLOSURE

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