Validity of Helicopter Emergency Medical Services Dispatch Criteria for Traumatic Injuries

A systematic review

Akkie N. Ringburg, MD, Gijs de Ronde, MD, Stephen H. Thomas, MD, MPH,
Esther M. M. van Lieshout, PhD, Peter Patka, MD, PhD, Inger B. Schipper, MD, PhD

Department of Surgery–Traumatology (ANR, GdR, EMMvL, IBS), Erasmus MC, University Medical Center Rotterdam, The Netherlands; and theDepartment of Emergency Services (SHT), Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts.

Address correspondence and reprint requests to: Akkie N. Ringburg, MD, Erasmus MC, University Medical Center Rotterdam, Department of Surgery–Traumatology, P. O. Box 2040, 3000 CA Rotterdam, The Netherlands. e-mail: a.ringburg@erasmusmc.nl

Abstract

Objective This review provides an overview of the validity of Helicopter Emergency Medical Services (HEMS) dispatch criteria for severely injured patients.

Methods A systematic literature search was performed. English written and peer-reviewed publications on HEMS dispatch criteria were included.

Results Thirty-four publications were included. Five manuscripts discussed accuracy of HEMS dispatch criteria. Criteria based upon Mechanism of Injury (MOI) have a positive predictive value (PPV) of 27%. Criteria based upon the anatomy of injury combined with MOI as a group, result in an undertriage of 13% and a considerable overtriage. The criterion 'loss of consciousness' has a sensitivity of 93-98% and a specificity of 85-96%. Criteria based on age and/or comorbidity have a poor sensitivity and specificity.

Conclusion Only 5 studies described HEMS dispatch criteria validity. HEMS dispatch based on consciousness criteria seems promising. MOI criteria lack accuracy and will lead to significant overtriage. The first categories needing revision are MOI and age/comorbidity.

Introduction

In most western countries Helicopter Emergency Medical Services (HEMS) complement ground ambulances in providing prehospital care for severely injured patients. Although debate persists, this combination is believed to improve patient outcome [1]. HEMS dispatch should be efficient, as air transport represents a concentrated allocation of scarce healthcare resources. Inappropriate use of HEMS (overtriage, or dispatches for patients with insufficient injury severity to benefit from HEMS), leads to increased costs and unjustifiable safety risks[2]. On the other hand, when HEMS is *not* dispatched to patients that would benefit from specialized medical care (*i.e.* undertriage), patients are deprived from potentially lifesaving assistance. This undertriage results in missed chances to reduce morbidity and mortality in the prehospital setting. Developers of regional HEMS triage protocols must strike a delicate balance between dispatching HEMS too often (overtriage), which incurs unacceptable costs, or risking preventable mortality through insufficient use of HEMS (undertriage).

A 2005 Dutch study demonstrated that national use of HEMS was far from optimal, with air transport dispatch correlating poorly with patients' actual need of prehospital HEMS assistance[3]. The answer to the triage problem is not simply strict adherence to existing protocols; the study finds that consistent dispatch protocol adherence would lead to a sevenfold increase of HEMS dispatches, with subsequent risk of considerable overtriage.

The reasons for suboptimal use and compliance/adherence of dispatch criteria remain unclear. Perhaps the criteria are insufficiently communicated, or perhaps prehospital providers consider them as unreliable and choose not to use them. In either case, the first step in optimizing HEMS dispatch is to gain much more insight into the criteria driving the dispatch process. It is therefore mandatory to gain knowledge of the validity of individual criteria.

Unfortunately, such knowledge is not easily gained, since few data are available to inform decision-making about validity of HEMS dispatch parameters.

In general, the HEMS dispatch criteria are derived from the American College of Surgeons (ACS) trip destination guidelines [4] . There are also recommendations to supplement the ACS criteria with parameters based upon local circumstances. Importantly, although the two subjects are related, HEMS dispatch and trip destination constitute two separate issues. ACS guidelines were developed to identify severely injured trauma patients (*i.e.*, patients with a probability of survival [5]{Ps} <0.90), who need to be transported to a level I trauma centre. It is manifestly not the case that every patient who should go to a trauma centre, should go by HEMS. Rather, in many cases ground transport – even basic life support transport along the lines of “scoop and run” – is the best option.

The purpose of this review was to provide an overview of HEMS dispatch criteria for patients with traumatic injuries described in the literature. All criteria described, the level of evidence, and the criterion validity were listed. Based upon this, the validity of HEMS dispatch criteria used was discussed.

Methods

A computerised literature search was performed. The electronic databases searched were: National Library of Medicine's MEDLINE, Cochrane Library, Scopus, UpToDate, Web of Science, PiCarta and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Databases were examined, from the earliest data available through April 2007, for publications on HEMS dispatch criteria to scene flights for trauma patients. The search terms used were: (Air ambulances *OR* Aeromedical *OR* Air Medical *OR* Emergency Medical Service* *OR* Helicopter) and (Criteri* *OR* Guideline* *OR* Protocol *OR* Standard*) and

(Dispatch *OR* Deployment *OR* Triage *OR* Utilization). Herein, the asterisk indicates a wildcard.

Only manuscripts written in English and published in peer-reviewed, indexed journals were considered eligible. While this approach may have excluded some worthy studies, the use of indexed journals constituted a well-defined, objective threshold for study inclusion that was tied to scientific quality. The title and abstracts were first reviewed by two reviewers (AR and GdR). Eligible for inclusion in this review were all publications addressing criteria for HEMS dispatch to a trauma scene. There were no restrictions with respect to study design or the method of analysis. All references in the eligible papers, as well as references in background literature, were also reviewed to ensure no papers were missed with the chosen search strategy.

The included criteria were divided into the following internationally accepted major subgroups: (1) Mechanism of injury (MOI), (2) Patient characteristics – Anatomic, (3) Patient characteristics – Physiologic, and (4) Other.

Since the ACS trauma centre triage guidelines [4] and the criteria for HEMS dispatch constitute separate issues, a distinction between these two is drawn in this review. Only when the ACS guidelines were explicitly named and used as HEMS dispatch criteria, they were accounted as such.

A dispatch criterion is said to be valid, if it identifies what it is meant to identify (*i.e.* if it accurately identifies patients most likely to benefit from HEMS). Data on the validity of HEMS dispatch criteria were either extracted from the studies found, or calculated from the data presented. Validity is determined by a dispatch criterion's sensitivity, specificity, and positive and negative predictive values (PPV and NPV), as outlined in Table 1. The discriminatory values of individual dispatch criteria are usefully expressed by PPV and NPV.

The degree of overtriage and undertriage are helpful in determining the relevance of triage criteria within the trauma system.

To assess the quality of evidence underlying these validity measures, relevant studies were rated for their level of evidence as described previously [6-8]. A systematic review of randomized controlled trials (RCTs) with or without meta-analysis was considered level I, a single RCT was level II, cohort studies level III, case-control studies level IV, case series level V, case reports level VI and opinion papers as level VII.

Results

Thirty-four publications met the inclusion criteria (Figure 1). No non-English articles in indexed journals were identified. From these 34 papers a total of 49 HEMS dispatch criteria were identified and categorized into one of the main criterion subdivisions (Table 2). Twenty-two dispatch criteria primarily concerned the MOI. Eleven anatomic and 9 physiologic criteria were identified. The remaining 7 criteria, which dealt with logistics, co-morbidity, or age, fell into the “Other” category.

Five of the 34 manuscripts retrieved addressed accuracy of HEMS dispatch criteria (Table 3). Three of these studies were level III (cohort) evidence [9-11], one was level IV (case control) [12] and one was level V (case series) [13].

Rhodes et al [10] evaluated 143 trauma patients transported by HEMS. In their study, HEMS dispatch was considered correct and justified (*i.e.* true positive, TP) if a patient was severely injured as defined by Ps<0.90. The vital sign with the best discriminatory performance was loss of consciousness (LOC), with a sensitivity of 93% and a specificity of 85%. Other physiologic parameters were considered as a group. A sensitivity of 98% and a specificity of

43% were achieved when HEMS dispatch was triggered by abnormalities in one or more of the following: LOC, respiratory rate (RR), pulse (HR) and blood pressure (BP). A conclusion of this study was that the criterion ‘entrapment’ might not be an effective dispatch indicator, given its poor sensitivity and specificity of 43% and 45%, respectively. The authors also suggested that, although their numbers were insufficient for definitive analysis, the presence of an associated fatality appeared to serve as a valid triage tool.

In a cohort study, Coats et al [9] studied 574 accident-site HEMS dispatch decisions. In their study, HEMS dispatch was retrospectively adjudicated to be indicated when the air medical unit was appropriately used to bypass the closest facility in order to transport patients to a hospital further away. The authors demonstrated that triage by criteria based on MOI alone had a PPV of 27%. An extremely low overall overtriage of 1.2% was reported, but the figure was calculated in terms of adherence to their triage protocols (rather than any *a posteriori* judgment about appropriateness). In other words, the authors used their protocol, consisting of 6 categories, as the benchmark to define appropriateness of dispatch. Such an analysis is a necessary, but not sufficient, approach to addressing overtriage. While HEMS triage should obviously be in line with the extant protocols, meaningful evaluation for overtriage must include an assessment of true “need” as judged externally to triage guidelines. In their protocol, for instance, an ISS of 9 or higher could be adjudicated a “justified dispatch.” Critical examination of their data revealed that overtriage actually approached 50%, since at least 269 cases had insufficient injury severity to warrant HEMS assistance. If an ISS of >15 (a common benchmark for “high-acuity” trauma) is used as the demarcation line for HEMS justification, the overtriage rate from the UK group would be substantially greater.

Schoettker et al [11] studied 71 consecutive patients ejected from a four-wheel vehicle. They concluded that ejection was a valid dispatch criterion. When an ISS of at least 16 was used to retrospectively define a justified HEMS dispatch, the ejection criterion had a PPV of 59%.
In a case-control study Moront et al [12] evaluated 3861 pediatric patients who were transported by either ground EMS or HEMS to a level I trauma centre. In their study, HEMS dispatch based upon the Glasgow Coma Scale (GCS) was retrospectively adjudicated as appropriate only if patients had probability of survival (Ps) of less than 0.95. They concluded that the GCS has a high sensitivity and specificity (98% and 96%, respectively) for appropriate HEMS dispatch, and considered it a good HEMS triage tool. Combining HR with GCS increased sensitivity to 99%, but incurred a cost in specificity (which dropped to 90%) that could translate into overtriage.
Wuerz et al [13] evaluated 333 cases of patients transported by HEMS. In their study, HEMS dispatch (based on the ACS Trauma Triage Scheme) was considered indicated if one or more of the following criteria were met: Injury Severity Score (ISS) > 15, transport time > 20 minutes, prolonged entrapment, remote incident site, or need for advanced life support (ALS) personnel at the scene. In this case series it was concluded that the scheme was highly sensitive (97%), but had a very low specificity of 8%. When criteria based upon MOI and anatomic markers were evaluated as a group, there was high sensitivity (87%) and low specificity (20%); predictive values were also poor (PPV of 32%, NPV 23%). In this study the physiologic criteria as a group showed a moderate sensitivity (56%) and a high specificity (86%). Use of abnormal vital signs alone had a high PPV (76%), but resulted in significant undertriage (44%).

Discussion

International HEMS dispatch criteria are largely based on the ACS trip destination guidelines[4]. These ACS-based HEMS dispatch criteria are nearly always supplemented with local criteria. The ACS criteria are meant to identify patients warranting trauma center care, rather than those cases in which HEMS should be deployed. Despite the fact that ACS parameters should not be assumed to apply to HEMS dispatch, the trauma triage literature fails to separately address accuracy of HEMS dispatch criteria.

The failure of the literature to address HEMS dispatch in a methodogically sound fashion is multifactorial. In part, the void in the published data reflects the complexity of research into the validity of HEMS dispatch criteria. A concise population-based trauma registry would be needed to achieve sound results[14]. However, establishment of such a registry is very labour-intensive and requires resources unavailable in most countries at present.

In addition to the low number of studies evaluating HEMS dispatch criteria, the quality of the available evidence is an additional problem. The level of evidence of the few studies investigating HEMS dispatch criteria performance is no better than level lII (cohort study). As randomisation is widely viewed as unethical for HEMS scene response studies, investigators and clinicians may have to accept the fact that research addressing HEMS dispatch will never include RCTs.

The limitation in quantity and quality of available evidence should not preclude some overview of conclusions suggested by extant studies. In the few studies that actually describe it, the validity of the HEMS dispatch criteria varies widely (Table 3). In order to draw more meaningful conclusions regarding the validity of HEMS dispatch criteria or per criterion category, a comparison was made with the available data on ACS trip destination guidelines (Table 4).

Criteria based on Mechanism of Injury

The results of this review reveal that the group of HEMS dispatch criteria based upon MOI have a very low PPV (27%). Furthermore, the sole use of the entrapment criterion would indisputably result in significant overtriage and undertriage. The criterion “ejection” (PPV 59%) might be considered a (more) valuable triage tool.

The available literature concerning the ACS MOI guidelines, as considered either individually or as a category, finds a sensitivity between 0-73% and a specificity that ranges 72-97% [15-18] (Table 4). These numbers translate into very little overtriage, but high undertriage. As opposed to the results found regarding appropriate HEMS dispatch, ACS literature regarding the ejection criterion [19, 20] describes low PPV (22-25%), with moderate sensitivity (59%) and high specificity (95%). The low PPV reduces the utility of a positive ejection criterion.

Criteria based on Anatomy of Injury

Only Wuerz et al [13] described HEMS dispatch criteria based upon anatomic variables (though combined with MOI). These criteria would result in a nearly acceptable undertriage level (13%), but are associated with unacceptable overtriage.

Literature on ACS trip destination guidelines based on the anatomic parameters suggests a low sensitivity (45%) with a PPV between 22% and 38%[18, 19] (Table 4). The ACS trip destination guidelines based upon anatomic variables such as ‘flail chest’ and ‘two long bone fractures’ [19] would lead to an unacceptable rate of undertriage (55%).

Criteria based on Physiologic parameters

Rhodes et al [10] found that, as a group, the HEMS dispatch criteria based on physiologic parameters exhibit high sensitivity but poor specificity (98% and 43%, respectively). This is in contrast to the findings of Wuerz et al [13], who reported these criteria to have moderate sensitivity (56%) and a high specificity (86%). The only plausible explanations for the divergent findings seem to be possible selection bias or the difference in era during which the studies took place (1986 vs. 1996). The criterion LOC seems excellent as a discriminator for appropriate HEMS dispatch, as it will result in minimal overtriage and undertriage [10, 12]. It should be noted that the results of the study by Moront et al [12] have to be interpreted separately, since their study involved pediatric patients. The dispatch criteria for pediatric patients are suspected to differ from the adult population. The pediatric trauma system is still evolving and it has not really been decided which patients really have to go to pediatric centers[21].

Literature addressing the physiologic parameters in the ACS guidelines [15, 18] reports results comparable to the HEMS dispatch criteria results described by Wuerz et al [13]. Overall, application of these criteria would appear to result in little overtriage and moderate undertriage. ACS trip destination guidelines literature based on LOC also indicate this parameter to be a good criterion for trip destination [19, 22-24] (Table 4).

Other criteria

Wuerz et al [13] also concluded that HEMS dispatch criteria based on the ACS triage scheme would result in an acceptable aircraft undertriage (3%), but at a cost of enormous overtriage (92%).

Evaluations of the ACS scheme as a whole (*i.e.* including all categories) show comparable results the results found by Wuerz et al for HEMS dispatch [18, 25, 26] (Table 4). In a point of critical relevance to determining acceptability of HEMS dispatch criteria, the ACS trip destination guidelines conclude that an overtriage rate of 50% must be expected to keep undertriage rates acceptable (no more than 10%) [4].

Differences found between the accuracy of ACS trip destination guidelines and criteria for appropriate HEMS dispatch can be explained by differences in definition and usage. ACS guidelines are intended for use as part of an overall triage plan, rather than as singly applied criteria. Furthermore, it is worth emphasis that meeting an ACS guideline criterion does not necessarily mean that HEMS dispatch is indicated.

Future Research

As noted by others [1, 27], comparing different studies is complicated due to (large) differences in study characteristics and outcomes measures used. In order to facilitate cross-comparison of studies, we recommend developing a consensus definition of which patients actually benefit from HEMS.

The following outcome measures should be included in delineating patients most likely to benefit from HEMS: Ps < 0.9 as calculated with Trauma Injury Severity Score (TRISS) or TRISS-like model, direct admission to a critical care unit, immediate non-orthopedic emergency surgery, and death within 24 hours. Additionally, a consensus methodology to allow for retroactive adjudication of HEMS appropriateness should include logistics considerations (*e.g.* time and distance factors).

Further work in the arena of HEMS triage and appropriateness determinations should include assessment of system-specific characteristics such as the HEMS crew's level of medical training (*e.g.* physician, paramedic) and scope of practice. Equally important is the need to draw a distinction between primary and secondary dispatches. Secondary dispatches are more often based on judgment of healthcare professionals, thus improving the quality of information available at the time of dispatch decision-making. Additional attention should focus on the concept of "autolaunch" (*i.e.* HEMS dispatch at the time of rescue/EMS call rather than after evaluation by a healthcare provider), the use of which obviously complicates the process of triage.

The greatest challenge in HEMS dispatch criteria research is to achieve complete population-based (trauma) registration. Only then can the state of the evidence progress past the point of studies describing only the outcome measure of overtriage – an outcome measure that is useful but, given limitations of the current literature, tends to be useful only within a given region. A reliable (trauma) registration system seems likely to significantly reduce overtriage, since the “true negative” patients (the ones most easily missed by current study methods) would be included in such an approach.

In an era of healthcare costs savings correct triage plays an important role, since triage and cost-benefit are inexorably linked. Overtriage results in an increase of costs and reduces the cost-benefit ratio. Overtriage is also associated with unjustifiable safety risk for crew and patients. On the other hand, undertriage can result in adverse outcome for patients, since it can influence survival and functional outcome. To measure the effects of triage on cost-effectiveness is a daunting task, because determining what costs are fair to accredit to HEMS is complicated. The "costs" of HEMS should ideally be considered the difference in costs between air transport and the alternative modalities. Furthermore, cost-benefit calculations should incorporate the occasional instances in which air transport is the only way to get patients to timely care that substantially improves outcome (e.g. Level I trauma centres, percutaneous coronary intervention, hospitals with stroke neurointerventional capabilities).

Conclusion

This systematic review of literature shows that there are few studies describing the validity of criteria defining appropriate HEMS dispatch, and that, the results from these studies lack general applicability. At least one HEMS dispatch criterion, loss of consciousness, seems promising, but further assessment of its use is required using more rigorous methodology. Mechanism of injury criteria lack accuracy, and will inevitably lead to significant overtriage. The first HEMS dispatch categories needing revision are mechanism of injury and age/comorbidity. Efforts should be made to achieve results that are comparable and universally applicable. This study shows that it is important that local and regional authorities prospectively evaluate their triage criteria, thereby striving to modify their guidelines based upon a continuous assessment.

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Table 1. Definitions of validity measures with regard to HEMS dispatch criteria

Validity measure	Definition
Sensitivity = TP / (TP + FN) * 100 % (parameter of the test)	The proportion of patients eligible for receiving HEMS assistance that is correctly identified by the dispatch criterion
Specificity = TN / (TN + FP) * 100 % (parameter of the test)	The proportion of patients not eligible for receiving HEMS assistance that is correctly identified by the criterion
PPV = TP / (TP + FP) * 100 % (utility of the test)	The proportion of patients identified by the criterion that is eligible for receiving HEMS assistance
NPV = TN / (TN + FN) * 100 % (utility of the test)	The proportion of patients not identified by the criterion that is not eligible for receiving HEMS assistance
Overtriage = 1 – Specificity	False-positive rate
Undertriage = 1 – Sensitivity	False-negative rate

TP, True Positive; FN, False Negative; TN, True Negative; FP, False Positive; PPV, Positive Predictive Value; NPV, Negative Predictive Value.

Table 2. HEMS Dispatch criteria identified by a systematic review of literature

Mechanism of Injury	**References**
High-speed (>40 mph; >65 km/h) moving vehicle accident	3, 9, 13
Multiple casualty incidents	3, 11, 28-32
Motor vehicle collision with significant vehicle deformity	13, 30, 32, 33
Frontal collision on hardened roads outside urban area	3
Significant compartment intrusion on patient side, or on opposite side	13, 34, 35
Significant displacement of front or rear axle	13, 34, 35
Lengthy extrication and significant injury / entrapment	3, 10, 11, 13, 28-30, 33-36
Overwhelming with debris, including head and/or chest	3
Vehicle turnover	13, 30, 34, 35
Fatality on high speed roads	30
Death same compartment	3, 10, 13, 31, 34, 35, 37
Patient ejected from vehicle	3, 9, 11, 13, 31, 32, 34-37
Thrown from motorcycle > 20 mph	3, 30, 32, 34, 35
Pedestrian struck ≥ 20mph	3, 9, 13, 30-32, 34-37
Explosion	3
Electricity or lightning accident	3, 31, 38
Fire in confined space, or inhalational injury	3, 31, 38, 39
Logging/farm/industrial accidents	30, 38
Exposure to hazardous materials	3
Fall from height	3, 9, 11, 13, 31, 32, 34, 35
Diving accident	3, 11
(Near) Drowning	3, 30, 31
Patient characteristics – Anatomy	
Penetrating injury to head, neck, chest, abdomen, or groin	3, 9, 13, 30-32, 34, 37 35
Blunt injury with significant involvement of head, neck, chest, abdomen, or pelvis	3, 9, 31, 32, 37, 40
Skull fracture / severe facial and eye injuries	31, 32, 40
Flail chest or pneumothorax	13, 31
Two or more proximal long bone fractures, or open long bone fractures	3, 9, 13, 31, 32
Potential injury to spinal cord, or column	3, 11, 31, 32, 34, 35, 37, 40, 41
Major proximal amputation or deglovement injury	11, 31, 32, 34, 35
Amputation or near amputation when emergent evaluation for reimplantation	31, 32, 34, 35, 37
Fracture or dislocation with vascular compromise	31, 32
Burns of significant BSA or relevant body regions	3, 13, 30-32, 34, 35, 37-39, 41, 42
Multiple system injury	31, 40, 41
Patient characteristics – Physiologic parameters	
Low or high respiratory rate, risk of airway obstruction or other signs of respiratory distress	3, 9, 10, 13, 32, 34, 35, 37, 38, 40
Low systolic blood pressure, tachycardia, or pulse character	3, 9, 10, 12, 13, 31, 32, 34, 35, 37, 40, 43, 44
(Post-traumatic) cardiac arrest	40
Low (CRAMS) score	34, 35
Low Glasgow coma scale	3, 9, 10, 12, 13, 31, 32, 34, 35, 37, 43, 44
Low (Revised) Trauma score	3, 31, 33-35
Age < 5yr or > 55yr	11, 13, 31, 34, 35, 37
Known cardiac or respiratory disease/ cardiovascular instability	13, 33, 37, 38, 41
Known pregnancy	31, 32, 37
Others	
Medical control approval	2, 41, 45-47
Paramedic judgment/intuition	31-33, 48-51
Anticipated need for ATLS procedures	31, 50, 52
(Expectation of) prolonged transport time/prehospital time	2, 10, 11, 13, 31, 33, 37, 41, 48-50, 52-54
Inaccessible road/area	2, 10, 13, 28-31, 33, 37, 51, 52
Heavy traffic conditions	28, 29, 37, 48, 49, 52
Under staffing of ground units in a region/ local resources overwhelmed	13, 31, 32, 37, 42, 48, 49, 52

Table 3. Accuracy of criteria for appropriate HEMS dispatch, sorted by level of evidence

Author	Criterion	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Level of Evidence
Rhodes et al.,1986 [10]	Entrapment	43	45			III
	Physiologic	98	43			
	LOC	93	85			
	RR	52	77			
	P	43	75			
	BP	33	77			
Coats et al., 1993 [9]	MOI group			27		III
Schoetker et al.,2001 [11]	Ejection			59		III
Moront et al., 1996 [12]	GCS	98	96			IV
	P + GCS	99	90			
Wuerz et al.,1996 [13]	MOI + Anatomy	87	20	32	23	V
	Physiologic	56	86	76	30	
	Age + Comorbidity	56	45	23	10	
	Triage Scheme	97	8	47	22	

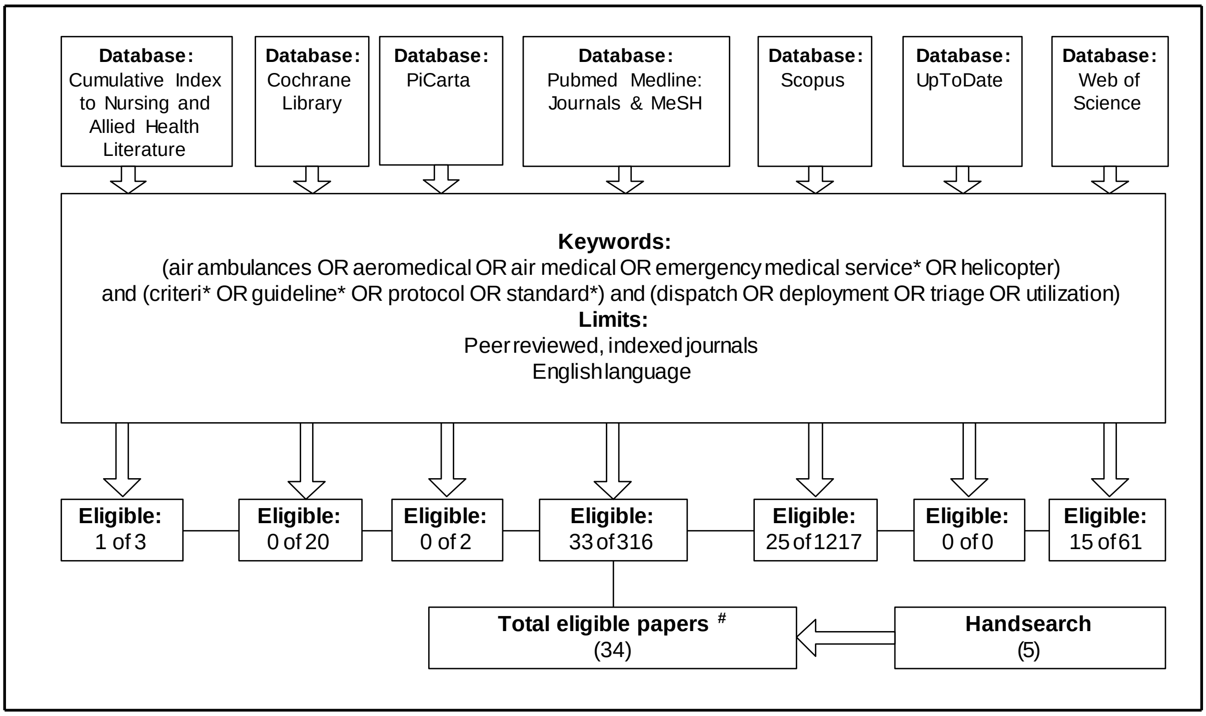
BP, blood pressure; GCS, Glasgow Coma Scale; LOC, loss of consciousness; MOI, mechanism of injury; ns, not specified; NPV, negative predictive value; P, pulse; PPV, positive predictive value; RR, respiratory rate; III, cohort study; IV, case control study; V, case series.

Table 4. Accuracy of ACS guidelines for appropriate trip destination for trauma patients

Author	**Criterion**	**Sensitivity (%)**	Specificity (%)	PPV (%)	NPV (%)	**Level of Evidence**
Knopp et al., 1988 [20]	Penetrating injury			60		III
	Extrication			40		
	Ejection			22		
	Fatality			21		
	Space intrusion			19		
	Auto vs Pedestrian			18		
	Age <1 or> 65 years			12		
	Trauma Score < 13			76		
Knudson et al., 1988 [17]	MOI	0-24	72-97			
Norcross et al., 1995 [18]	MOI	54		16		III
	Anatomy	45		22		
	Physiologic	65		42		
	Physiologic/Anatomy	83		27		
	Overall	95		8		
Meredith et al., 1995 [23]	GCSM < 6	59	98			III
	Trauma Score	46	99			
Cooper et al., 1995 [16]	MOI			7		III
Henry et al., 1996 [19]	Flail chest	52	98	38	99	III
	2 Long bone FX	50	98	38	99	
	Ejection	59	95	25	99	
	Penetrating injury	64	91	18	99	
	Intrusion opp. side	71	86	13	99	
	Rollover	73	82	11	99	
	GCS	39	98	39	98	
	RR	57	96	30	99	
	Age	85	70	8	99	
Bond et al., 1997 [15]	MOI	73	91	18	99	III
	PHI	41	98	40	98	
	MOI / PHI	78	89	17	99	
Ross et al., 1998 [24]	GCS	62	89			III
	GCSM < 6	61	89			
Engum et al., 2000 [25]	Simplified ACS*	100	29			III
Garner et al., 2001 [22]	GCSM < 6	73	96			III
	RR > 29 (br/min)	15	95			
	10 > RR > 29 (br/min)	25	95			
	P > 160 (b/min)	33	92			
	BP < 80 (mmHg)	30	99			
	Capillary Refill > 2s	36	93			
Báez et al., 2003 [55]	Physiologic/Anatomy	poor	poor			III
Scheetz et al., 2003 [26]	Overall	82-92	31-55			V

BP, blood pressure; b/min, beats per minute; br/min, breaths per minute; FX, fracture; GCS, Glasgow Coma Scale; GCSM, Glasgow Coma Scale Motor Response; Intrusion opp. side, intrusion on the opposite site of the vehicle; MOI, mechanism of injury; NPV, negative predictive value; ns, not specified P, pulse; PHI, Prehospital Index; PPV, positive predictive value; RR, respiratory rate; s, seconds.

Figure 1. Results of the systematic database search



*, Wildcard; #, Duplicates were omitted.