European Journal of Trauma and Emergency Surgery (2019) 45:821–839
https://doi.org/10.1007/s00068-019-01097-2

REVIEW ARTICLE

Determination of mis-triage in trauma patients: a systematic review

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Received: 22 November 2018 / Accepted: 18 February 2019 / Published online: 23 February 2019

Abstract

Purpose Mis-triage including undertriage and overtriage is associated with morbidity and mortality. It is not clear what the extent of mis-triage rates among traumatic patients is. The aim of this study is to determine of mis-triage (undertriage and overtriage) in traumatic patients.

Methods This study was a systematic review about mis-triage rate among trauma patients. The following electronic databases were searched (Web of Knowledge, Scoups, PubMed, Cochrane library) from conception through February 1, 2018. Search terms included trauma, undertriage, and over-triage. Inclusion criteria were studies which report overtriage or undertriage rate in regard to triage of trauma patients; patients older than 18 years old, English-written papers. Irrelevant papers as well as conference abstract, letter, editorial, thesis and studies on special population were excluded. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Checklist was used to examine review process.

Results Twenty-one papers were included in this study. Sample size ranged from 244 to 550683 trauma patients. Fourteen studies originated from USA. Definition of mis-triage was summarized into four categories: ISS used to define undertriage error, formula for mis-triage (1—sensitivity), need for life-saving emergency intervention and patients triaged to a non-trauma center. Undertriage rate ranged from 1 to 71.9% and overtriage rate ranged from 19 to 79%.

Conclusions The standardization of mis-triage definitions is vital to estimate true rate of mis-triage among different studies and clarify the role of triage scales. The trauma triage scales need to be further developed to provide more valid and reliable results.

Keywords Triage · Undertriage · Over-triage · Emergency · Trauma

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Background

Severe trauma remains a major issue in public healthcare worldwide [1]. Approximately 5.8 million people die annually from traumatic injuries, comprising 10% of deaths worldwide [2]. Trauma triage is the process of categorizing trauma patients by injury severity and then allocating appropriate resources for care based on prioritization of their immediate surgical needs or by their likelihood to benefit from such resources [3]. Proper triaging of severe trauma patients affects their prognoses and outcomes [4–6]. Beneficial triage decisions direct trauma patients to the most appropriate hospitals, resulting in lower mortality rates. The National Study on Costs and Outcomes of Trauma (NSCOT) reported a 25% reduction of mortality in trauma patients when they are treated appropriately at accredited trauma centers [7].

Triage errors can occur when patients are given undertriage or overtriage decisions. Undertriage occurs when the severity of injury is underestimated and, therefore, the means necessary

to quickly evaluate and care for the patient are under-resourced, resulting in critically injured patients being transferred to non-trauma centers [3]. More than 30% of all patients with moderate to severe injuries are not treated at trauma centers and, therefore, undertriaged [8]. While the exact undertriage rate among trauma patients is unknown, some studies report it ranging from 2.7 to 15% [9, 10]. Overtriage is defined as inappropriately labelling patients with non-urgent presentations with high acuity designations, and it may have indirect but equally harmful effects on patients who receive unnecessary operations and are discharged within 48 h of admission [11–13]. Overtriage leads to the diversion of limited time and resources from the patients who need them most and the inappropriate allocation of these resources to patients with less severe conditions, resulting in overutilization of limited financial and human resources [13].

According to recommendations from the American College of Surgeons Committee of Trauma, an undertriage rate of no more than 5% and overtriage rates of up to 25–35% are the highest acceptable rates [14, 15]. Some studies reported overtriage rates ranging from 7.4 to 21.3% [9, 10]. Mistriage rates are directly connected to increased morbidity and mortality, with different mistriage rates being reported on in a variety of studies. Due to the lack of systematic review on adult trauma patients, it is necessary to further investigate mistriage rates among traumatic patients. Identifying overtriage and undertriage when it occurs enables emergency department officials to take steps towards improving emergency services by obtaining accurate data. Therefore, this study is aimed at determining the rate of mistriage (undertriage and overtriage) among adult trauma patients.

Methods

Study design

A systematic review has been performed to report mis-triage rate among trauma patients.

Data sources

The following electronic databases were searched (Web of Knowledge, Scoups, PubMed, Cochrane library) from conception through February 1, 2018. Search terms included trauma, undertriage, and over-triage. The search strategy formula was "(trauma) AND (triage) AND (under-triage OR undertriage OR undertriage* OR over-triage OR overtriage OR overtriage*)". Reference lists were checked to retrieve additional studies. Two reviewers (Z.N. and A.M.) selected studies separately and shared the final selected studies. All disagreements were solved by discussion and consensus.

Study selection

Inclusion criteria were studies which report overtriage or undertriage rate in regard to triage of trauma patients; older than 18 years old, English-written papers. Irrelevant papers were excluded as well as conference abstract, letter, editorial and thesis. Studies on special population such as pregnant women, elderly, pediatrics, and comorbidities were also excluded.

Data extraction

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Checklist was used to perform review process; author names, publication year, aim, design, inclusion and exclusion criteria, definition of mistriage (overtriage and undertriage) and conclusion.

Results

Search result

Four databases including web of knowledge, Scopus, PubMed, and Cochrane library were searched, and 101 were excluded and finally 21 papers were included. Figure 1 shows the details of the search strategy.

Study characteristics

Most studies [15] used retrospective design and six papers were designed prospectively [16–21]. Range of sample size in studies were from 244 to 550,683 trauma patients [21, 22]. Twenty-one papers were finally included from different countries including USA [15, 16, 20–29], UK [30], France [31], Norway [32–34], Canada [35], Denmark [19], and Netherlands [18] (Table 1).

Undertriage rate ranged from 1 to 71.9% [21, 30] and overtriage rate ranged from 19 to 79% [21, 31] (Table 2). Generally, definition of undertriage may be summarized into four categories: (1) ISS used to define undertriage error (ISS > 9, ISS > 15, ISS > 16) [15, 22, 27, 28, 34]; (2) formula for mis-triage (1—sensitivity) [19, 32–34]; (3) need for life-saving emergency intervention [16, 21, 29, 30] and (4) patients triaged to a non-trauma center [17, 18, 26, 35]. Mis-triage rate is not similar across studies and defined differently.

Definition of over triage was used in studies including: (1) overtriage formula (1—positive predictive value) [19, 32–34]; (2) patients who were transferred from another emergency department to a trauma center with an ISS < 10, did not require an operation, and were discharged to home

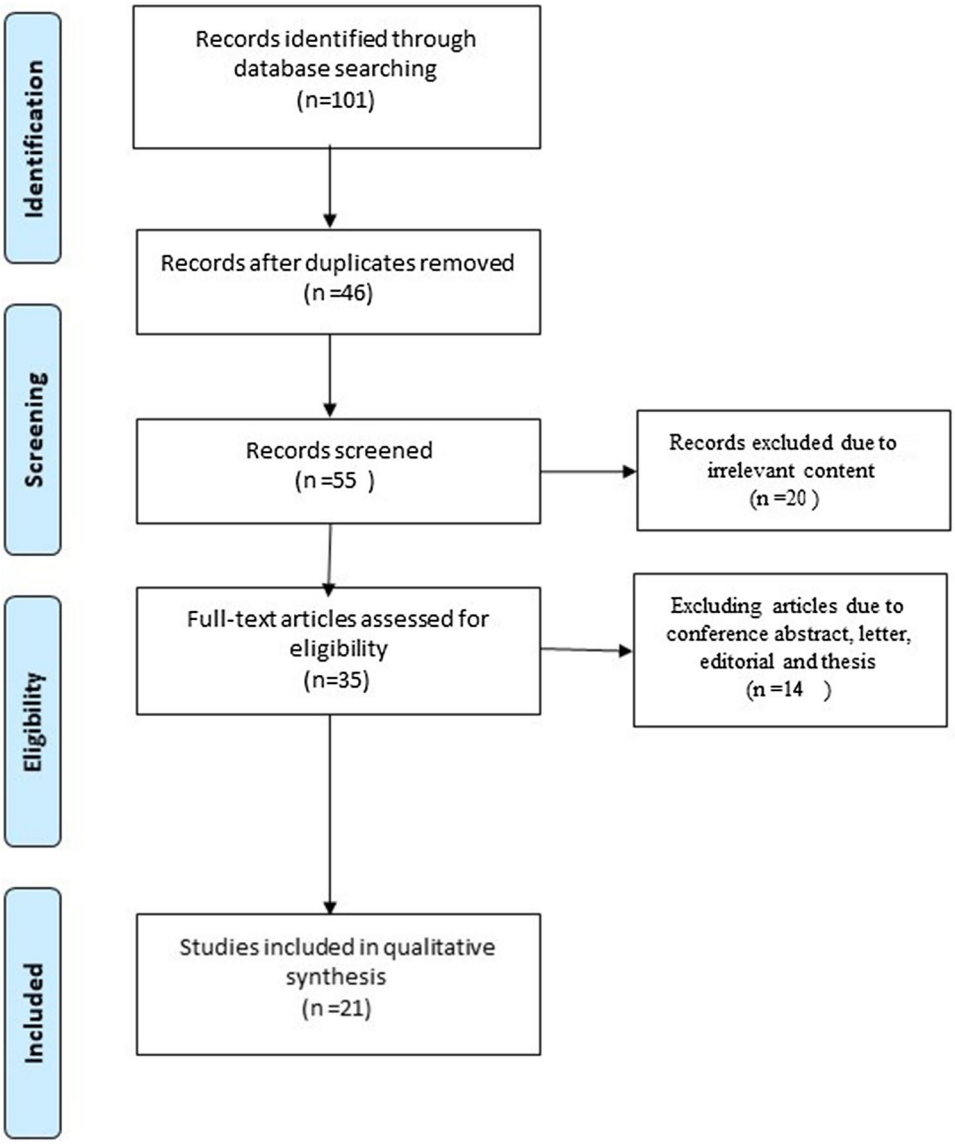

Fig. 1 PRISMA flowchart of inclusion and exclusion process

within 48 h of admission [20, 24, 25]; (3) did not require an urgent intervention either in the ED or operating room [16, 23, 30], minor injuries (ISS < 15–16) were triaged to the full trauma team treatment [15, 18] and (4) the use of Vittel criteria [31]. Three studies have been used different ISS criteria to define overtriage (ISS < 10, ISS < 15, ISS < 16) [15, 24, 34].

Discussion

The present study aims to determine the rate of mistriage (undertriage and overtriage) in trauma patients. To our knowledge, this study is the first systematic review assessing mistriage rates in trauma patients.

Mistriage significantly contributes to the care patients receive, with undertriage directly associated with higher morbidity and mortality rates and overtriage having the capacity to indirectly cause increased morbidity and mortality rates through the inappropriate use of resources in the ED. Since no review studies have been carried out on mistriage rates for trauma patients, the results of this study will make a crucial contribution to the research because such a wide range of mistriage rates (1–79%) have been documented for trauma patients in other studies [21].

Undertriage and overtriage rates have been documented as 1–71.9% and 19–79%, respectively. Such wide ranges can be attributed to a variety of factors. First, the precise definitions of mistriage vary across studies, resulting in inconsistent mistriage rates.

In two studies, the ISS scale is used to calculate undertriage rates. Despite using the same criteria, the undertriage rate was recorded to be 24% by one study and 34% by the other. Other studies suggest that moderate ISS [15–24]

Table 1 Methodological characteristics of eligible studies

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Lossius et al. [17]	To evaluate the efficiency of activation of the trauma team in a Norwegian trauma referral center	A prospective analysis was performed on a trauma patient Registered in hospital and trauma referral center	**Inclusion criteria** ISS > 15 Patient need of intensive care for more than 2 days after the injury Patient died in hospital after the injury **Exclusion criteria** Patients older than 65 years Isolated proximal femoral fracture from a fall	**Undertriage** Severely injured patients were admitted when the trauma team had not been activated **Overtriage** Patients with minor injuries admitted after activation of the trauma team	The undertriage rate and a positive predictive value indicate a need for improvement of our activation system
Jin et al. [18]	Determine the effect on overtriage rates by the Academic Medical Center (AMC) downgrading protocol (AMCDP)	A prospectively analysis was performed for the undertriaged patients treated by the downgraded trauma team (DTT)	**Inclusion criteria** Patients older than > 15 years **Exclusion criteria** Incomplete data collection Patients not transported by ambulance	**Undertriage** All patients with severely injured (SI) treated by the DTT **Overtriage** Patients treated by a full trauma team (FTT) while not classified as an SI patient	Implementation of the Academic Medical Center Downgrading Protocol (AMCDP) reduced overtriage from 70 to 26.8%
Kann et al. [19]	Determine the precision (sensitivity, specificity, undertriage, overtriage and positive predictive value) of our triage protocol to identify severely injured, defined as an injury severity score (ISS > 15)	A prospective analysis was performed to evaluate between trauma team activation criteria and ISS patients triaged to a level I trauma center	**Inclusion criteria** All patients with ISS > 15 **Exclusion criteria** Patients transferred from other hospitals	**Undertriage** 1—sensitivity **Overtriage** 1—specificity	The positive predictive value of our triage protocol was low, only 22%
Lehmann et al. [23]	Determine the accuracy of the current system and to identify the most Reliable variables for trauma triage	A retrospective analysis between current triage system and simplified triage system were performed in a level II trauma center	**Inclusion criteria** All trauma admission Patient older than > 16 years **Exclusion criteria** Burn injury Patients transferred from our emergency department to another facility	**Undertriage**: no trauma team activation for a patient required ≥ 1 urgent interventions **Overtriage** Trauma team activation for a patient did not require urgent intervention	Using a simplified triage system can safely reduce the rate of overtriage

Table 1 (continued)

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Uleberg et al. [32]	Determine the performance of our trauma team's activation protocol	A retrospective analysis was performed on injured patients with trauma team activation (TTA) admitted to St. Olav's Hospital	**Inclusion criteria** Patients with TTA Admission to the intensive care unit (ICU), surgical and neurosurgical intermediate care units with a trauma diagnosis Trauma-related death in the emergency department **Exclusion criteria** Not mentioned	**Undertriage** 1—sensitivity The complimentary event and interpreted clinically as the probability of no TTA conditional on serious injury **Overtriage** 1—positive predictive value (PPV) The PPV is the probability of serious injury conditional on TTA	A TTA protocol based on physiological, anatomical and interfacility transfer criteria seems to yield a higher precision than, in particular, that based on mechanism of injury criteria
Ciesla et al. [24]	Determine the incidence of secondary overtriage in a region without a formal trauma system	A retrospective analysis was performed on institutional trauma registry data Level I trauma center and regional referral center	**Inclusion criteria** All patients with acute trauma Patients transported to the hospital with a trauma mechanism **Exclusion criteria** Not mentioned	**Undertriage** Not mentioned **Overtriage** Transferred patients with an ISS < 10, who did not require an operation, and who were discharged to home within 48 h of arrival at our hospital	Excessive overtriage calls for the development of a regional inclusive trauma system with established primary and secondary triage guidelines to improve access to care and trauma system efficiency
Lehmann et al. [21]	Determine the performance of our institution's current triage system compared with a simplified system	A prospective analysis between current triage system and a simplified triage protocol (hypotension, mental status, altered respirations, and penetrating truncal wound) were performed in academic level II trauma center located	**Inclusion criteria** Patients older than 15 years All trauma admissions **Exclusion criteria** Not mentioned	**Undertriage/Over triage** Calculated based on the need for an urgent procedure in the ED or emergent transfer to the OR for a lifesaving procedure	Using a simplified triage system can safely reduce the rate of overtriage
Rehn et al. [33]	Determine age, gender, category of pre-hospital care provider, vital signs, type of injury and triage criteria influenced triage precision	A retrospective analysis was performed from the trauma registry data for all patients with TTA (Trauma Team Activation) or severe injury	**Inclusion criteria** ISS > 15 Proximal penetrating injury patient Patient admitted ICU > 2 days Transferred intubated patient to another hospital within 2 days Dead from trauma within 30 days **Exclusion criteria** Patient interhospital transfers to Ulleval University Hospital (UUH) and admitted by non-healthcare personnel	**Undertriage** The fraction of severely injured admitted without TTA (1—sensitivity) and probability of not being met by a trauma team despite being severely injured **Overtriage** The fraction of TTA where patients are not severely injured (1—positive predictive value) and probability of a patient being severely injured when the trauma team is activated	Triage precision had not improved after TTA guideline introduction. Massive undertriage among paramedics is a great concern

Table 1 (continued)

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Cherry et al. [25]	Determine outcomes of injured patients who were undertriaged and compared them with those meeting full trauma team activation (TTA) criteria	A retrospectively analysis was performed for trauma patients with a blunt mechanism Level 1 trauma team activation (TTA)	**Inclusion criteria** Blunt trauma patients **Exclusion criteria** Penetrating trauma Interfacility transfers Burn injury Age < 18 years	**Undertriage** Result of underestimating the severity of injury and, therefore, under-resourcing the means necessary to emergently evaluate and care for the patient **Overtriage** Patients who were transferred from another emergency department to a trauma center with an ISS < 10, did not require an operation, and were discharged to home within 48 h of admission	The UTG had a lower ISS and improved outcomes compared to the CTG with no differences in OR delays. Despite inherent challenges in TTA protocols, patients who were undertriaged at our institution appear to have satisfactory outcomes
Haas et al. [35]	Determine outcomes among undertriaged patients and the true mortality cost of undertriage	A retrospective analysis was performed for all severely injured patients surviving to reach an emergency department	**Inclusion criteria** Adult aged 18 years or older and ISS > 15 **Exclusion criteria** Burn injury, foreign bodies, poisonings, toxic effects, suffocation, drowning, and complications of medical/surgical patient Patients discharged home from the ED, and did not have severe injuries Patient dead on arrival and death in the ED	**Undertriage** Patients triaged to a non-trauma center who died in the non-trauma center ED before successful transfer or admission to the non-trauma center (ED-death cohort) **Overtriage** Not mentioned	Undertriage after major trauma is associated with substantial mortality

Table 1 (continued)

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Dehli et al. [34]	Determine the predictive properties of our TTA protocol and its individual criteria in an effort to improve the protocol's precision	A retrospective analysis was performed. All patients admitted with the trauma team at the University Hospital of North Norway (UNN)	**Inclusion criteria** Patient with ISS > 15 Undergoing an emergency procedure (for stabilization of compromised airways, respiration or circulation) Transfers from other hospitals up to 48 h after the time of injury **Exclusion criteria** Burn injury Asphyxia patient	**Undertriage** The fraction of patients admitted without TTA despite severe injuries (ISS > 15) or receiving an emergency procedure **Undertriage formula** 1—sensitivity **Overtriage** The fraction of TTA where the patients are not severely injured (ISS ≤ 15) or did not undergo an emergency procedure **Overtriage formula** 1—positive predictive value (PPV)	The over- and undertriage of our protocol are both too high
Scerbo et al. [20]	Determine the Random Forest computer model (RFM) as a tool to triage minimally injured trauma patients away from Level I centers using pre-hospital variable	A prospective analysis was performed for Adult trauma patients with "medium activation" presenting via helicopter to a Level I Trauma Center	**Inclusion criteria** Adult trauma patients with medium activation **Exclusion criteria** Transferred patients Burn injury Patients under 18 years Patients with the highest activation	**Undertriage** Not mentioned **Over triage** Patients were discharged from the ED of admitted to a lower level unit, or did not utilize the resources unique to a Level I trauma center	Computer modeling potentially could be used to guide triage decisions, allowing both more accurate triage and more efficient use of the trauma system
Staudenmayer et al. [22]	Determine triage patterns for the injured population to determine those factors associated with undertriage	A retrospective analysis was performed for all hospital visits and discharges with the using of the Office of Statewide Health Planning and Development Database (OSHPD)	**Inclusion criteria** Patients ≥ 18 years of age Hospital admission with trauma coding **Exclusion criteria** Hospital admission with trauma coding Burn injury Elective admission Admission was not to a general acute care hospital (e.g. psychiatric health facility) Patients dead-on-arrival Died in the ED Uncompleted patient records in database	**Undertriage**: any patient with an ISS > 15 who was never taken to a Level I/II trauma center **Over triage** Not mentioned	Undertriage varied substantially by region and was associated with multiple factors including access to care and patient factors

Table 1 (continued)

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Xiang et al. [26]	Determine the characteristics and diagnoses of the undertriaged patients	A retrospective analysis was performed to examine the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases and the State Inpatient Databases	**Inclusion criteria** ISS ≥ 16 **Exclusion criteria** Patients had injuries from late effects Superficial injuries Injuries due to foreign bodies	**Undertriage** Undertriaged patients were those with a major trauma who were (1) treated and released from an non-trauma center (NTC) or a level III trauma center (TC) ED (2) admitted into an NTC or a level III TC, or (3) died in the ED of a NTC or a level III TC **Overtriage** Not mentioned	More than one-third of US ED major trauma patients were undertriaged, and more than 40% of undertriaged diagnoses were TBIs
Cotte et al. [31]	Determine the characteristics of severe, stable trauma patients without vital distress to describe over-triage related to the use of the Vittel criteria	A retrospective analysis of the data was performed in level I trauma referral center	**Inclusion criteria** Trauma patients with at least one positive Vittel criterion Transported directly from the scene of injury to the trauma center **Exclusion criteria** Inter-hospital transfers from lower level facilities Patients under 18 years of age	**Undertriage** Not mentioned **Overtriage** The use of Vittel criteria	Vittel criterion use in trauma patients induces an acceptable over-triage rate
Shawhan et al. [16]	Determine the safety, efficacy, and surgeon satisfaction with the newly introduced triage system	A prospective database analysis was performed for all patients triaged using the newly implemented system (simplified 2-tiered system)	**Inclusion criteria** Trauma patients older than 16 years of age Presented to our trauma center during the specified time period **Exclusion criteria** Not mentioned	**Undertriage** Any patient requiring an urgent intervention that was not triaged as a Level 1 trauma activation **Overtriage** Any Level 1 trauma (full activation), which did not necessitate an urgent intervention either in the ED or operating room (OR)	The new simplified triage system significantly reduced the rate of overtriage, while safely maintaining a low undertriage rate
Davis et al. [15]	Determine the effectiveness of the Matrix method by comparing patients appropriately triaged with those undertriaged	A retrospective analysis was performed in Trauma registry data, at a Level I trauma center	**Inclusion criteria** Patients with ISS ≥ 16 were classified by activation level (full, limited, consultation), and triage category by matrix **Exclusion criteria** Not mentioned	**Undertriage** ISS ≥ 16 without full activation **Over triage** ISS < 16 with full activation	Despite having an ISS ≥ 16, patients with limited activations were dissimilar to patients with full activation. Evaluation of the process of care, regardless of level of activation, should be used to evaluate trauma center performance

Table 1 (continued)

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Horst et al. [27]	Determine the percentage of patients that meet the Trauma criteria but who receive care at non-trauma centers	A descriptive retrospective analysis was performed to examine two databases PTSF and PHC4	**Inclusion criteria** Death secondary to trauma ICU/step-down unit admissions Length of stay (LoS) > 48 h or LoS between 36 and 48 h with ISS > 9 Admitted transfers in/out of the hospital **Exclusion criteria** Not mentioned	**Undertriage** The proportion of PHC4 database cases that were not represented in the PTSF database (for both cases with ISS > 9 and ISS > 15) **Undertriage** (PHC4-PTSF)/PHC4	A third of severely injured trauma patients are managed at hospitals outside of the trauma system
Tignanelli et al. [28]	Determine the compliance rate of American College of Surgeons Committee on Trauma (ACS-COT) verified level 1 and 2 trauma centers with the ACS-6 triage criteria	A retrospective database analysis was performed to examine the Michigan Trauma Quality Improvement Program (MTQIP) database	**Inclusion criteria** Age ≥ 16 years At least one valid trauma International Classification of Diseases (ICD-9-CM) code Primary mechanism of injury classified as either blunt or penetrating ISS ≥ 5 Emergency Department (ED) and hospital discharge disposition must be known **Exclusion criteria** Late effects, superficial injuries, foreign bodies Directly admitted No signs of life at initial evaluation	**Undertriage** The patients had major trauma (ISS > 15) and did not receive a full TTA (trauma team activation: severe) **Over triage** Not mentioned	Compliance with ACS-COT minimum criteria for full TTA remains sub-optimal and undertriage is associated with increased mortality. This study suggests that practice pattern modification to more strictly adhere to the minimum ACS-COT criteria for full TTA will save lives

Table 1 (continued)

References	Aim	Design	Inclusion/exclusion criteria	Mis-triage definition	Conclusion
Vassallo et al. [30]	Determine mortality in those undertriaged by existing major incident triage tools	A retrospective database analysis was performed to examine the UK Trauma Audit Research Network (TARN) (UK) in regard to patients categorized by the Modified Physiological Triage Tool (MPTT), National Ambulance Resilience Unit (NARU) Sieve and existing Major Incident Medical Management and Support Triage Sieve	**Inclusion criteria** Adult patients (≥ 18 years) sustaining moderate to major injuries Trauma patients, who are admitted to hospital for at least 3 days, have a critical care unit admission or die in hospital Only direct admissions from scene of injury with complete physiological data **Exclusion criteria** Patient admissions from inter-hospital trauma transfers Respiratory rate > 45 bpm Heart rate > 170 bpm Systolic blood pressure > 206 mmHg	**Undertriage** Needing life-saving intervention **Overtriage** Needing life-saving intervention	The Modified Physiological Triage Tool (MPTT) misses fewer severely injured patients, with a significant reduction in mortality
Yonge et al. [29]	Determine our institutional level 3 undertriage rate and identify injury patterns that result in undertriage and Modify our current level 2 activation criteria to reduce the rate of level 3 undertriage, without substantially increasing over-triage	A retrospective analysis was performed at the Oregon Health and Sciences University (OHSU)	**Inclusion criteria** Patients ≥ 14 years of age Transported directly to our institution **Exclusion criteria** Data absent	**Undertriaged** Patients have current level 1 or 2 criteria, or requiring a predefined critical intervention **Over triage** Not mentioned	Addition of pre-hospital tachypnea with suspicion of blunt thoracic injury to the current triage criteria stands to reduce the overall undertriage rate without significantly increasing over-triage

Table 2 Epidemiological characteristics of eligible studies

References	Country	Settings	Data collection	Sample size	Study population	Results
Lossius et al. [17]	Norway	Level I: Ulleval University Hospital is an emergency hospital for East and Southern Norway, and is responsible for ambulance services, the 113 emergency calls service and air ambulance and patient transportation	They were collected trauma patients during a 12-month period at 1996 in Ulleval University Hospital	3391 injured patients was divided into three groups The correct triage group; undertriage group; overtriage group	Correct triage: 240 patients Undertriage: 43 patients Overtriage: 267 patients **ISS > 14** Correct triage: 110 (46) Undertriage: 27 (63)	**Undertriage**:15% **Overtriage**: 9%
Jin et al. [18]	Netherlands	Level I: The Academic Medical Center (AMC) is responsible for its part of the 1200 trauma victims that are distributed over the Northwest-Netherlands Trauma Center	They were collected trauma patients that admitted to the Academic Medical Center (AMC), (Level-1 trauma center), from July to December 2002	254 Trauma patients were divided into two groups Downgraded trauma and full trauma	Downgraded trauma team: 95 Full trauma team: 125 **ISS (Median)**: 5 (1—66) Male: 67.3% Mortality: 15 (6.8%)	**Overtriage**: 27%
Kann et al. [19]	Denmark	Level I: Arhus University Hospital is a large university hospital located in Aarhus in Denmark and is a referral trauma center for a population of 1.2 million	They were collected patients triaged to the Aarhus University Hospital) level I trauma center) from February to August 2003	848 Severely injured patients	The trauma team was activated:242 Injured patients without TTA: 606	**Undertriage**: 8% **Overtriage**: 24%
Lehmann et al. [23]	USA	Level II: Madigan Army Medical Center is a level II state-designated trauma center located in Pierce County, Washington. Major services include general medical and surgical care, adult and pediatric primary care clinics, 24-h Emergency department, specialty clinics, clinical services, wellness and prevention services, veterinary care, and environmental health services	They were collected trauma patients met trauma registry From 2002 to 2005	1782 patients were included in the trauma registry and categorized into two groups based on whether they required an urgent emergency room or operative intervention	Emergent intervention: 188 patients No emergent intervention: 1163 patients male: 70%	**Undertriage** Current triage system: 1% Simplified triage system: 3% **Overtriage** Current triage system: 51% Simplified triage system: 29%

Table 2 (continued)

References	Country	Settings	Data collection	Sample size	Study population	Results
Uleberg et al. [32]	Norway	Level I: St. Olav's University Hospital is a 1064-bed, Level I hospital, which serves as a trauma center for central Norway, with a population of approximately 643,000. The regional EMS dispatch center is located at St. Olav's Hospital, and co-ordinates land and air ambulances in the region	They were collected seriously injured patients admitted to St. Olav's Hospital from 2004 to 2005	809 trauma patients were divided into two groups: with trauma team activation (TTA) and not-trauma team activation (NTTA)	TTA: 768 (95%) NTTA: 41 (5%) **ISS > 15**: 185 (23%) Mortality in all patients: 33 (4%)	**Undertriage**:13% **Over triage** TTA: 78% Based of mechanism of injury: 93%
Ciesla et al. [24]	USA	Level I: Washington Hospital Center also serves as a safety net hospital for the District of Columbia and a multistate tertiary referral center for the National Capitol Region	They were collected from all trauma patients entered into the registry admitted in Washington Hospital Center (Level I trauma center) from 2003 to 2006	9064 Trauma patients were divided two groups: scene and transferred	Scene group: 6,875 (76%) Transferred group: 2,189 (24%) **ISS (mean)**: 8.6 ± 10.4 Male: 77%	**Overtriage**: 39%
Lehmann et al. [21]	USA	Level II: Madigan Army Medical Center is a level II state-designated Trauma center located in Pierce County, Washington	They were collected from trauma patients met from 2007 to 2008 in Madigan Army Medical Center (level II state-designated trauma center)	244 Trauma patients based on Pre-hospital Trauma Triage Guidelines	Blunt injury: 95% Male: 81%	**Undertriage**: 1% **Overtriage**: 79%
Rehn et al. [33]	Norway	Level I: Ulleval University Hospital (UUH) is the largest trauma hospital in Norway and the trauma referral center for half of the Norwegian population. UUH is the major trauma hospital for 550 000 and referral trauma hospital for 2.5 million people	They were collected from trauma registry in Ulleval University Hospital from 2001 to 2007	4659 Patients were divided into two groups: activations trauma team (TTA) and not-activated trauma team (NTTA)	TTA: 95% NTTA: 5% Male: 74.83% **ISS > 15**: 1641 (35%) Mortality (30 days): 358 (8%)	**Undertriage**: 10% **Overtriage**: 55%

Table 2 (continued)

References	Country	Settings	Data collection	Sample size	Study population	Results
Cherry et al. [25]	USA	Level I: The Penn State Hershey Medical Center is a Regional Resource (Level 1) Trauma Center for adult and pediatric patients in central Pennsylvania and northern Maryland	Patients who met Level 1 trauma team activation (TTA) was collected in The Penn State Hershey Medical Center From 2002 to 2008	1424 Blunt trauma patients All patient was divided two groups Undertriage group (UTG) Correctly triaged group (CTG)	Correctly triaged group: 1106 (77.66%) Undertriaged group: 318 (22.3%) **Male** CTG: 70.4% UTG: 67.1% **Mortality** CTG: 4.5% UTG: 0.6%	**Undertriage: 22.3%**
Haas et al. [35]	Canada	Level I–III: The Emergency Room (ER) visit data are part of the Ambulatory Visit Database, obtained from the National Ambulatory Care Reporting System (NACRS) developed by the Canadian Institute for Health Information (CIHI) and the Ministry of Health and Long-Term Care of Ontario (MOHLTC)	They recorded patients in health databases, the National Ambulatory Care Reporting System (NACRS), from 2002 to 2007	11,398 Severely injured patients based on how transfer to trauma center divided into two groups: transported directly from the scene to a trauma center and transferred from a non-trauma center to a trauma center	**ISS (16–24)** In direct group: 46% In undertriage group: 39% **ISS (25–47)** In direct group: 48% In undertriage group: 49% **Mortality** In undertriage group: 51% In all patients: 22%	**Undertriage**: 34.3% Undertriage-based MOI In head trauma: 56% In chest trauma: 46%
Dehli et al. [34]	Norway	Level I: University Hospital of North Norway is a hospital and health trust. It serves the regional Emergency Medical Communication Center and operates a number of ambulance stations in Nordland and Troms	They recorded patients in University Hospital of North Norway (UNN) from 2006 to 2007	441 injury severity patient with ISS > 15 and need for emergency procedure	**ISS [IQR]**: 9 (1–19) Mortality (30-day): 29 (6.6%) **Undertriage** ISS[IQR]:16 (16–24) 30-Day mortality: 4 (7%) Two-thirds of those undertriaged had head injuries	Based on ISS > 15 **Undertriage: 32%** **Overtriage: 71%** Based on need for emergency procedure **Undertriage: 21%** **Overtriage: 71%**
Scerbo et al. [20]	USA	Level I trauma center	They collected adult trauma patients presenting via helicopter to a Level I Trauma Center from 2007 to 2009	1653 trauma patients were divided two groups: admitted and discharged	999 admitted 1194 discharged Male: 70%	**Undertriage**: 8.3% **Overtriage**: 66% Based on RFM (Random Forest computer model): 42%

Table 2 (continued)

References	Country	Settings	Data collection	Sample size	Study population	Results
Staudenmayer et al. [22]	USA	Level I-III: California's Office of Statewide Health Planning and Development (OSHPD) is the leader in collecting data and disseminating information about California's health-care infrastructure	Office of Statewide Health Planning and Development Database (OSHPD) was utilized from 2005 to 2009	550,683 severely injured patients were divided based on field triage into three level: primary field triage, re-triage, undertriage	Primary field triage: 35,299 patients Re-triage: 3342 patients Undertriage: 20,988 patients **ISS (15–24)** Primary field triage: 27063 (76.67%) Re-triage: 2795 (83.63%) Undertriage: 683 (89.02%) **ISS (> 25)** Primary field triage: 8236 (23.33%) Re-triage: 547 (16.37%) Undertriage: 2305 (10.98%) **Mortality (60 days)** Primary field triage: 4492 (13.12%) Re-triage: 413 (12.85%) Undertriage: 3222 (16.41%) **Mortality (1 year)** Primary field triage: 4603 (16.42%) Re-triage: 451 (17.61%) Undertriage: 4034 (24.7%)	**Undertriage: 35%**
Xiang et al. [26]	USA	Level I–III: The Health-care Cost and Utilization Project (HCUP) is the Nation's most comprehensive source of hospital care data, including information on in-patient stays, ambulatory surgery and services visits, and emergency department encounters	Nationwide Emergency Department Sample (NEDS) in 2010 was utilized. It consists of two databases 1-The Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases 2-The State Inpatient Databases	49,397 major trauma patients with ISS ≥ 16 were divided into two levels Level I or II trauma centers (TCs) Level III non-trauma centers (NTCs)	Level I or level II (TCs): 23,992 Level III or non-trauma centers (NCT): 18,457 TBI patients: > 40% of undertriaged diagnoses	**Undertriage: 34.0%**

Table 2 (continued)

References	Country	Settings	Data collection	Sample size	Study population	Results
Cotte et al. [31]	France	Level I trauma center	Patients were collected from 2010 to 2012 in Sainte-Anne Military Hospital, Toulon (level I trauma)	252 Trauma patients with using Vittel criteria were split in two groups depending on the presence or absence of a vital distress	Patients with vital distress: 132 (52.4%) Patients without vital distress: 120 (47.6%) **ISS: median (IQR)** Without vital distress: 9 (4–19) significant visceral injury: 4 (1–9) **Mortality**: Without vital distress: 1 (0%) Significant visceral injury: 0 (0%)	**Overtriage: 19%**
Shawhan et al. [16]	USA	Level II: Madigan Army Medical Center is a level II state-designated trauma center located in Pierce County, Washington	Madigan Army Medical Center Institutional Review Board (Level II trauma center) was utilized for all trauma from 2010 to 2013	704 trauma patients were divided based on formal trauma team activation into two levels: Level 1 (full trauma team activation) and Level 2 (modified trauma team activation)	Level 1: 89 Level 2: 146 **ISS (mean + SD)** Level 1: 13.7 ± 12.2 Level 2: 5.7 ± 6.9 **Mortality** In undertriage patient: 0%	Old triage system **Undertriage: 1.2%** **Overtriage: 79%** New triage system **Undertriage: 1.6%** **Overtriage: 44%**
Davis et al. [15]	USA	Level I: Community Regional Medical Center is a regional hospital in Fresno, California	Community Regional Medical Center (Level I trauma center) was utilized from 2013 to 2015	7031 patients was divided based on trauma team activation into three level: full activation (severe), limited activation (moderate) and consultation (mild)	Full activation: 1874 (27%) Limited activation: 1061 (15%) Consultation: 4096 (58%) **ISS ≥ 16**: 2282 (32%) **ISS < 16**: 4749 (68%) **Mortality** Full activation: 332 (32%) Limited activation: 27 (7%) Consultation: 30 (3%) All patients: 8% Undertriage: 4% Overtriage: 13%	**Undertriage** based on all patient: 24% **Undertriage** based on ISS ≥ 16 Limited activation: 17% Consultation: 38% **Overtriage**: 45%

Table 2 (continued)

References	Country	Settings	Data collection	Sample size	Study population	Results
Horst et al. [27]	USA	Level I-III: PTSF is a statewide trauma registry with all documented trauma cases treated at accredited trauma centers (TCs). PHC4 is an administrative dataset that contains all inpatient admissions (n = 185 facilities) within the state of Pennsylvania and essentially encompasses all trauma patients treated at TCs and non-trauma centers (NTC)	Two databases were utilized from 2003 to 2015 in USA PTSF database (The Pennsylvania Trauma Systems Foundation) and PHC4 database (Pennsylvania Health Care Cost Containment Council)	225,263 trauma patients with ISS > 9	PTSF: 173,022 patients PHC4: 255,263 patients Male: 60.9% **ISS 10–15**:41.8% **ISS 16–25**:42.18% **ISS ≥ 26**:16% **Mortality**: 3.71%	**Undertriage** based on ISS ISS > 9: 31.1% ISS > 15: 33.4%
Tignanelli et al. [28]	USA	Levels I–II: MTQIP was created in 2008 as a pilot program involving six trauma centers in Michigan. The MTQIP registry currently receives over 19,000 case submissions a year from 35 adult Level I and II trauma centers in Michigan and Minnesota	The Michigan Trauma Quality Improvement Program (MTQIP) Database was utilized for collection of patients admitted at participating trauma centers from 2014 to 2016	51,792 patients with ≥ 16 years and ISS ≥ 5	Full TTA (presence of at least one ACS-6 criteria): 2,424 patients **ISS** 16–24: 33% 25–35: 29% **Mortality**: 30%	**Undertriage**: based on mortality: 43%
Vassallo et al. [30]	UK	Trauma I–III: The TARN has maintained a national database of trauma patients since 1988 and is the largest trauma database in Europe	Trauma Audit Research Network (TARN) database was utilized from 2006 to 2014	218 985 adult patients with moderate to major injuries patients were categorized by the Modified Physiological Triage Tool (MPTT), National Ambulance Resilience Unit (NARU) Sieve and existing Major Incident Medical Management and Support Triage Sieve	**ISS**: 9 [9–16] Mortality: 7266 (5.7%)	**Undertriage**: based on The Modified Physiological Triage Tool (MPTT): 42.4% **Undertriage**: based on the UK Military Sieve: 71.9%

Table 2 (continued)

References	Country	Settings	Data collection	Sample size	Study population	Results
Yonge et al. [29]	USA	Trauma I: The Oregon Health and Sciences University (OHSU) Medical Center is a level 1 trauma center Utilizing a three-tiered trauma triage system. Level 1: physiologic criteria. Level 2: anatomic criteria. Level 3: mechanism of injury	Oregon Health and Sciences University (**OHSU**) database was utilized from 2004 to 2014	12,332 Trauma patients with ≥ 14 years of age were categorized into three levels	Level 1 activation: 1445 (11%) Level 2 activation: 3007 (25%) Level 3 activation: 7880 (64%) **Mortality** Level 1: 301 (20%) Level 2: 92 (3%) Level 3: 49 (0.6%) **ISS (median)** Level 1: 18 Level 2:9 Level3: 5	**Undertriage** based on level 3 activations: **5.9%** **Undertriage** based on the level 1 or 2 activation criteria:4.9% **Undertriage** based on the need for a lifesaving intervention: 0.1%

scores, compared with notably high or low ISS scores, have greater mistriage rates, specifically exhibiting undertriage. Staudenmayer et al. reported undertriage rates of 89.02% and 10.98% for ISS scores of 15–24 and scores greater than or equal to 25, respectively [22]. Youge's study reported undertriage rates of 4.9% and 5.9% for ISS scores of 9–15 and scores of 5, respectively [29]. These results indicate that patients with more severe conditions, as well as outpatients, are detected more easily. In contrast, patients with moderate acuity face the highest mistriage rates. This presents a serious challenge in the care of patients with trauma because these cases constitute the majority of trauma patients, and they have a high chance of survival with prompt and accurate detection.

Other studies identify referral to non-traumatic centers as the criterion for mistriage, reporting rates of undertriage ranging from 15 to 34.3% [17, 35]. The greatest difference in rates was observed in the separate studies of Lehmann and Vassallo, in which life-saving emergency intervention was used and mistriage rates fluctuated between 1% and 42.4% [21, 30].

This was also true for overtriage rate. Using the "1—positive predictive value" formula for the definition of overtriage, mistriage rates have been reported as ranging from 24 to 78% [19, 32]. Further, use of the referral-to-trauma-center criterion is reported at 23.3–66% [20]. It is clear that the use of different criteria will yield contradictory results, as well as making it difficult to compare across studies. This issue indicates the need for a standard formula to calculate a more precise mistriage rate. Most studies [18] have reported more on undertriage rates than overtriage rates [13] in trauma patients. Studies report overtriage rates reaching 79%, indicating that overtriage deserves more attention in further studies. Overtriage can lead to the inappropriate consumption of resources while restricting the provision of care and treatment for seriously injured patients. The Field Triage Guideline has been introduced to level 1 trauma centers to prevent overtriage and limit inappropriate referrals of patients. Application of this guideline can contribute to reducing incidents of mistriage, especially overtriage. In general, the effectiveness of triage assessment depends on the balance between correct detection of people in need of life-saving measures and minimizing patients being mistakenly identified with high needs [30, 36].

This review shows that no standard definition for assessing the triage of trauma patients currently exists. Some authors have used ISS to define critically ill trauma patients as having a score of 15 or greater, and in a number of studies, life-saving interventions have been used for these patients [37, 38]. While ISS provides a scale for the severity of patients' injuries, it is only a retrospective measurement that is less effective in identifying the

severity of the patient's condition and the potential need for life-saving measures several days after admission [39].

It is likely that the inclusion of non-physiological criteria into the triage process (e.g. anatomical injury assessment), along with evaluating the level of consciousness and identifying risk factors, such as age, can improve triage validity [21, 40]. Therefore, triage criteria must be developed comprehensively on the triage scale. While general triage scales have been developed, triage scales for trauma patients remain limited, and it is uncertain whether or not general triage systems are suitable for patients with trauma. Future studies should, therefore, focus on this critical subgroup of patients to determine the effectiveness of general triage scales on trauma patients, and any triage system developed for trauma patients should be capable of being generalized.

Conclusion

Significant mis-triage in traumatic patients indicates that patients' triage process needs to be revised seriously. The highest rate of mis-triage occurs among moderately ill traumatic patients, who constitute the majority of patients with trauma. In traumatic outpatients and critically ill patients with trauma, the triage error is minimized. On the other hand, moderate ill traumatic patients are more likely to become seriously ill. Therefore, it is necessary to develop triage scales for patients with trauma. It is also likely that the standardization of mis-triage definitions can reduce misinterpretation of triage error among different studies and clarify the role of triage scales. The trauma triage scales need to be further developed to provide more valid and reliable results and ultimately lead to reduced mis-triage rate.

Funding This project was supported by funding from Shahid Beheshti University of Medical Sciences.

Compliance with ethical standards

Conflict or interest No conflict of interest has been declared by the authors.

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