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ORIGINAL ARTICLE

Which pre-hospital triage parameters indicate a need for immediate evaluation and treatment of severely injured patients in the resuscitation area?

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Abstract

Purpose To find ways to reduce the rate of over-triage without drastically increasing the rate of under-triage, we applied a current guideline and identified relevant pre-hospital triage predictors that indicate the need for immediate evaluation and treatment of severely injured patients in the resuscitation area.

Methods Data for adult trauma patients admitted to our level-1 trauma centre in a one year period were collected. Outpatients were excluded. Correct triage for trauma team activation was identified for patients with an ISS or NISS ≥ 16 or the need for ICU treatment due to trauma sequelae. In this retrospective analysis, patients were assigned to trauma team activation according to the S3 guideline of the German Trauma Society. This assignment was compared to the actual need for activation as defined above. 13 potential predictors were retained. The relevance of the predictors was assessed and 14 models of interest were considered. The performance of these potential triage models to predict the need for trauma team activation was evaluated with leave-one-out cross-validated Brier and logarithmic scores.

Results A total of 1934 inpatients ≥ 16 years were admitted to our trauma department (mean age 48 ± 22 years, 38% female). Sixty-nine per cent ($n = 1341$) were allocated to the emergency department and 31% ($n = 593$) were treated in the resuscitation room. The median ISS was 4 (IQR 7) points and the median NISS 4 (IQR 6) points. The mortality rate was 3.5% ($n = 67$) corresponding to a standardized mortality ratio of 0.73. Under-triage occurred in 1.3% (26/1934) and over-triage in 18% (349/1934). A model with eight predictors was finally selected with under-triage rate of 3.3% (63/1934) and over-triage rate of 10.8% (204/1934).

Conclusion The trauma team activation criteria could be reduced to eight predictors without losing its predictive performance. Non-relevant parameters such as EMS provider judgement, endotracheal intubation, suspected paralysis, the presence of burned body surface of > 20% and suspected fractures of two proximal long bones could be excluded for full trauma team activation. The fact that the emergency physicians did a better job in reducing under-triage compared to our final triage model suggests that other variables not present in the S3 guideline may be relevant for prediction.

Keywords Triage · Severely injured · Under-triage · Over-triage

Introduction

Assessment of injury on the scene is difficult and can be troublesome. Communication with, and allocation of a patient to, the right hospital is an essential task for the emergency team. Criteria have been established by specialist medical societies to assess injuries and to assign patients appropriately. Different criteria for field triage have been established to improve patient outcomes in the European region [1–4]. These criteria are based on the trauma mechanism and the patient´s anatomical or physiological disorders.

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Most severely injured patients are admitted to a level-1 trauma centre.

Because of increasing cost pressures, the current resuscitation-activating guidelines have been discussed in the context of over- and under-triage. Patients with a minor injury admitted to the resuscitation area are considered to be "over-triaged", and those whose injury is underestimated and who are sent to the emergency department instead of the resuscitation area are considered to be "under-triaged" because of the potential harm for the patient. We will define the under- and over-triage rates as being the percentage of wrongly assigned cases among all considered patients. The rate of over-triage is assumed to be 30–50%, which is high but understandable given the aim to reduce avoidable adverse events in the daily activities of the trauma team. The ideal rate for patient safety would be 0% under-triage, together with 0% over-triage in terms of resources and costs [5].

In the context of the discussion of the costs of over-triage, many studies have reported on the use of the current guidelines [2–4]. These guidelines contain several indicating parameters to activate the trauma team in the resuscitation area (henceforth called the "trauma team"). We are interested in whether there is a simpler way to optimise triage for severely injured patients and to reduce the rate of over-triage without increasing the rate of under-triage too greatly. We evaluated the parameters given by the S3 guideline [4] and tried to identify which of these provide the most relevant pre-hospital triage information that indicates the need for immediate evaluation and treatment of severely injured patients in the resuscitation area. We conducted a retrospective study within our institution to investigate these questions.

Patients and methods

All trauma patients admitted to our institution in the year 2010 were identified and evaluated in this study. Activation of the trauma team responsible for the resuscitation room was coordinated following the underlying criteria based on the S3 guideline [4] (Table 1). Excluded were ambulatory-treated patients, patients younger than 16 years and patients allocated secondarily from other hospitals. 1934 patients were retained. Correct triage for trauma team activation was estimated by one collaborator and in general identified if the patients had an ISS or NISS ≥ 16 or the need for treatment in the intensive care unit (ICU) due to direct trauma sequelae. Over- and under-triage was individually crosschecked by the senior author for every patient in terms of mismatches, especially in cases of need for ICU treatment with an ISS or NISS < 16 and if once ISS or NISS were < 16. Over-triage was recorded if the criteria were not fulfilled and the patient was treated in the resuscitation room, in the opposite situation we are in the presence of under-triage. Age, sex, vital signs (blood pressure, pulse rate, breathing rate and oxygen saturation), Glasgow Coma Scale (GCS) score, rescue resource [self, emergency medical service (EMS) or helicopter EMS (HEMS)], trauma mechanism and anatomical disorders were documented. Admittance to an ICU, mortality and several trauma and prognostic scores [ISS, new ISS (NISS), revised trauma score (RTS), revised injury severity classification (RISC) and trauma ISS (TRISS)] were recorded retrospectively [6–9].

A detailed analysis of the data showed that most of the variables used to describe the trauma mechanisms were mutually exclusive (see Table 1 in the supplementary material). To reduce the risk of over-fitting, we summarised those in one categorical predictor depending on the type of accident: fall and/or explosion, traffic accident, entrapment, unclear and other. Note that the levels "other" and "unclear" are different; if the type of accident is 'unclear' the trauma mechanism is totally unknown. The level 'other' on the other hand refers to a known trauma mechanism which is not present in the list. We will refer to this categorical predictor as accident factor (AF).

Statistical analysis

First, the inclusion probabilities are calculated with modern Bayesian variable selection techniques [11] for the 13 retained predictors (see Table 3). These probabilities restrict us to order the potential predictors according to their relevance in the final triage model. A more detailed description on how these probabilities are computed can be found in the supplementary material.

Using the latter probabilities, 14 possible triage models can be defined as follows: The first model is the one including all the predictors. Then, for the other models, the predictors are dropped successively in an order depending on their inclusion probabilities until we attain a model with no predictor. Brier and logarithmic scores of the candidate triage models were calculated using leave-one-out cross-validation (LOO CV) [12] to evaluate how well they predict the resuscitation room necessity [13, 14]. The smaller the scores are, the better the prediction performance of the model.With this approach, we were able to find the number of predictors that should be used to assure the best possible prediction performance. Afterwards, the selected predictors have been used in a simplified 'at least one out of x' version of the model: a patient is triaged to the resuscitation room once one of the x predictors is different from its reference, where x is the number of selected predictors. This proceeding is equivalent to a prediction model with x predictors, is easy to understand and to apply. In a final step, the predictive accuracy of the 14 possible 'at least one out of x' models

Table 1 Current guidelines for trauma team activation

	S3 [4]	ACS COT 2006 [10]	ACS COT 2014 [3]
Physiological			
A	Respiratory impairment or requirement for intubation	–	Unable to be adequately ventilated, intubated or given assisted ventilation
B	–	Respiratory rate < 10 or > 29/min	Respiratory rate < 10 or > 29/min
C	SBP < 90 mmHg	SBP < 90 mmHg	SBP < 90 mmHg
D	GCS < 9	GCS < 14	GCS ≥ 13
	–	–	Deterioration of a previously stable patient
	–	–	Transfer requiring blood transfusion
Anatomical	Open head wounds	Open or depressed skull fractures	Open or depressed skull fractures
	Unstable chest	Unstable chest	Unstable chest
	Gunshot wounds and penetrating injuries to the neck and torso region	All penetrating injuries to the neck, torso and extremities proximal to the elbow and knee	All penetrating injuries to the neck, torso and extremities proximal to the elbow and knee
	Pelvic fractures	Pelvic fractures	Pelvic fractures
	Fracture of > 2 proximal bones	Fracture of > 2 proximal bones	Fracture of > 2 proximal bones
	Amputation injury proximal to hand/foot	Amputation injury proximal to wrist/ankle	Amputation injury proximal to wrist/ankle
	Spinal cord injury	Paralysis	Paralysis
	Burns > 20% and degree ≥ 2b	–	Burns > 10% and degree ≥ 2b and/or inhalation injury (L)
	EMS provider judgement	EMS provider judgement	EMS provider judgement
	–	Mangled extremity	Mangled extremity
Mechanism of injury	Fall from > 3 m height	Fall from > 3 m height	Fall from > 3 m height (L)
	–	–	Fall from any height if anticoagulated (L)
	RTA: Delta v > 30 km/h	Vehicle telemetry data consistent with a high risk of injury	Vehicle telemetry data consistent with a high risk of injury (L)
	RTA: Collision involving a pedestrian or two-wheeler	Collision involving a pedestrian or two-wheeler or v > 32 km/h	Collision involving a pedestrian or two-wheeler or v > 32 km/h (L)
	RTA: Frontal collision with intrusion by more than 50–75 cm	Collision with intrusion of > 30 cm (occupant site) or > 46 cm (any site)	Collision with intrusion of > 30 cm (occupant site) or > 46 cm (any site) (L)
	RTA: Death of a driver or passenger	Death of a driver or passenger	Death of a driver or passenger (L)
	RTA: Ejection of a driver or passenger	Ejection of a driver or passenger	Ejection of a driver or passenger (L)
	–	–	Striking fixed objects with momentum (L)
	–	–	Blast or explosion (L)
	–	–	High energy electrical injury (L)
	–	–	Suspicion of hypothermia, drowning, hanging (L)
	–	–	Suspected non-accidental trauma (L)
	–	–	Blunt abdominal injury with firm or distended abdomen or with seatbelt sign (L)

ACS COT American College of Surgeons, committee on trauma, *Delta v* difference of speed (deceleration), *A* airway (according to ATLS), *B* breathing, *C* circulation, *D* disability, *E* exposure, *SBP* systolic blood pressure, *RTA* road traffic accident, *L* light trauma team activation criteria

has been assessed by calculating their under- and over-triage rates. More detailed information on the methodology can be found in the supplementary material.

All data were recorded using IBM SPSS Statistics for Windows (Version 23.0; IBM Corp., Armonk, NY, USA) and the statistical analysis was done with R [15].

Results

In the analysed 1 year period, 1934 inpatients admitted to our trauma department fulfilled the inclusion criteria. Their mean age was 48.2 ± 21.5 years; 1192 (61.6%) were males and 742 (38.4%) were females. The median ISS was 4 (IQR 7) points and the median NISS 4 (IQR 6) points. A trauma team was activated for 593 patients (31%). The median ISS of those allocated to the resuscitation area was 9 (IQR 14) points and the median NISS 10 (IQR 20) points. The other 1341 patients (69%) were allocated to the emergency department and their median ISS was 4 (IQR 3) points and the median NISS 4 (IQR 3) points. A high percentage of patients ($n = 1066$, 55.1%) has been taken to hospital by the EMS, 717 patients (37.1%) were self-allocated and 151 patients (7.8%) were admitted through the HEMS. Sixty-seven patients died, giving a mortality rate of 3.5%. From these patients, six patients died being treated in the emergency department. According to a RISC of 95.23% this equates to a standardized mortality ratio (SMR) of 0.73. The baseline data is shown in Table 2. Twenty-six of the patients (1.3% of the 1934 patients) were classified as being under-triaged and 349 (18% of all the patients) as being over-triaged. In the detailed analysis of the 26 patients who received under-triage, 17 (65.4%) experienced an underestimated traumatic brain injury that was considered an indication for trauma team activation following minor trauma (low fall), had an initial GCS of 13–15 and suffered from either a chronic alcohol consumption or a diminished coagulation due to permanent medication. Twelve of the 26 under-triaged patients (46.2%) were over 65 years old.

The triage predictors were ordered according to their inclusion probabilities (Table 3). As shown in Fig. 1, the model with the 11 most relevant predictors according to their inclusion probabilities performs best for predictions regarding the logarithmic score [calculated using leave-one-out cross validation (LOO CV)]. The minimal (LOO CV) Brier score is acquired with 11 predictors as well. However, the performance of these prediction models does not decrease significantly by reducing the number of predictors to eight (see supplementary material for details). The final eight predictors retained are: thorax instability, the accident factor, open TBI, penetrating injury, SBP < 90 mmHg, pelvic

Table 3 Triage predictors with inclusion probabilities

Variable	Inclusion probability
(1) EMS provider judgement	0.5909
(2) Endotracheal intubation	0.8570
(3) Fracture of > 2 proximal bones	0.8602
(4) Burns > 20% and degree ≥ 2b	0.9327
(5) Paralysis	0.9772
(6) GCS < 9	0.9806
(7) Amputation injury proximal to hand/foot	0.9939
(8) Pelvic fracture	0.9977
(9) SBP < 90 mmHg	0.9985
(10) Penetrating injury	> 0.9999
(11) Open TBI	> 0.9999
(12) Accident factor	> 0.9999
(13) Unstable chest	> 0.9999

Potential predictors ordered using their inclusion probabilities

EMS emergency medical service, *GCS* glasgow coma scale, *SBP* systolic blood pressure, *TBI* traumatic brain injury

Table 2 Baseline data for all patients

Variable	ED ($n = 1341$)	RR ($n = 593$)	All ($n = 1934$)	Missing (n)
Age (years)	49.2 ± 22.0	45.7 ± 20.3	48.2 ± 21.5	0
ISS (points)	4 (IQR 3)	9 (IQR 14)	4 (IQR 7)	0
NISS (points)	4 (IQR 3)	10 (IQR 20)	4 (IQR 6)	0
TRISS (%)	98.8 ± 1.4	96.6 ± 7.7	98.2 ± 4.3	104
RISC (%)	97.5 ± 2.7	90.2 ± 20.4	95.2 ± 12.0	0
Sex female (%)	41.8	30.7	38.4	0
Admittance				
Self (%)	52.3	2.5	37.1	0
EMS (%)	47.5	72.3	55.1	0
HEMS (%)	0.2	25.2	7.8	0
ICU (%)	1.6	40.1	13.4	0
Mortality (%)	0.4 ($n = 6$)	10.3 ($n = 61$)	3.5 ($n = 67$)	0
SMR	0.2	1.1	0.7	0

ED admitted to emergency department, *RR* admitted to resuscitation room, *NISS* new ISS, ISS and NISS given as median and interquartile range, *TRISS* trauma ISS, *RISC* revised injury severity classification, *EMS* emergency medical service, *HEMS* helicopter EMS, *SMR* standardized mortality ratio

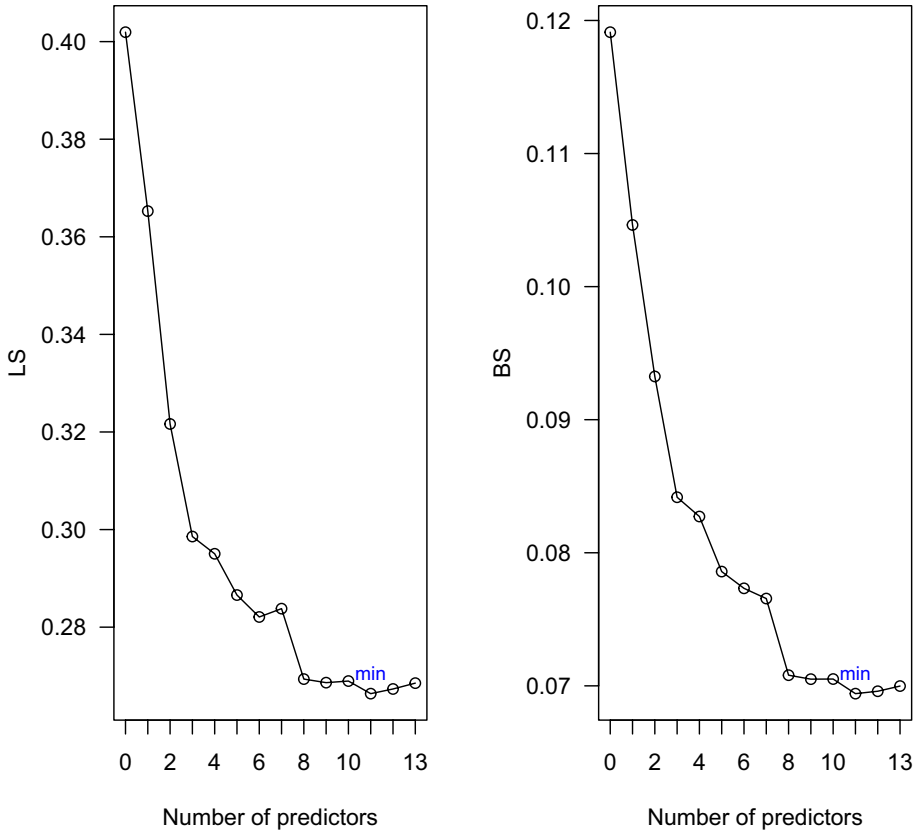

Fig. 1 Brier and logarithmic scores for the different triage models

fracture, amputation, GCS < 9. Figure 2 shows the so-called prediction nomogram [12], a graphical presentation of the prediction model where, depending on the patients' characteristics they are attributed a certain amount of points. Using the total number of points, the necessity of trauma team activation can be read off easily (using the last two axes). We refer to the supplementary material for more information on the statistical analysis.

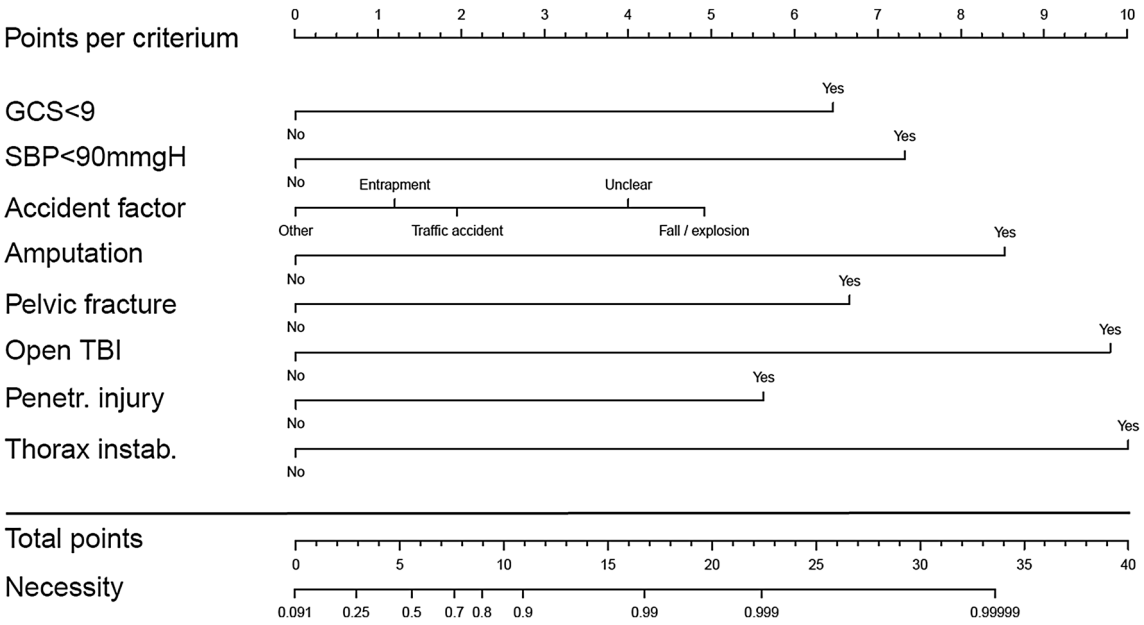

Fig. 2 Nomogram of the prediction model with eight predictors

The model with eight predictors is equivalent to an 'at least one out of eight' approach. With the latter procedure we would activate the trauma team once at least one of the seven binary predictors is set to true or the accident factor is different from its reference value ('other'). This approach leads to an over-triage rate of 10.8% and an under-triage rate of 3.3%. We also investigated how the under- and over-triage rate would evolve depending on how many predictors where considered in the 'at least one out of x' approach. Figure 3 shows the rates for different x'es (number of predictors selected). This figure reveals that even if we consider the 13 possible predictors and check their occurrence (for example occurrence of thorax instability, yes or no) to decide on the trauma team activation, we are not able to attain an under-triage rate smaller than 3.1%.

Discussion

The aims of this study were to evaluate the S3 guideline for triage of severely injured patients and to identify the main predictors for the need for immediate evaluation and treatment of severely injured patients in the resuscitation area.

By investigating which parameters could be discarded without decreasing the performance of the prediction model, we reduced the number of triage predictors from 13 to 8. These variables can easily be ascertained in a preclinical allocation call. For simplicity, we decided not to employ the prediction model directly but use a simplified version: once one of the seven selected binary predictors is set to true or the accident factor is different from 'other', the trauma team is activated.

Recent studies have shown that the accepted trauma field triage parameters and guidelines are evolving continuously and are difficult to summarize [16, 17]. The mechanism-related criteria have poor specificity [18–24]. Each scoring system has its own strengths and weaknesses, and these should be considered when applying any of these systems [25].

Our findings on pre-hospital predictors are consistent with those reported in the literature for adult patients. As shown in recent studies, pre-hospital information for presumed polytrauma or severely injured patients (EMS provider judgement) involving the presence of a burned body surface of $>20\%$ should be treated with caution [8, 18, 26]. But regarding burned body surface in paediatric patients it was told to be relevant to identify the need for admission to resuscitation room [19]. We cannot further discuss this parameter hence paediatric patients are excluded in this study. Due to the difficulties in EMS provider judgement in the field triage there seem to be a lot of intubated patients on the scene in this study, which do not fulfil the criteria

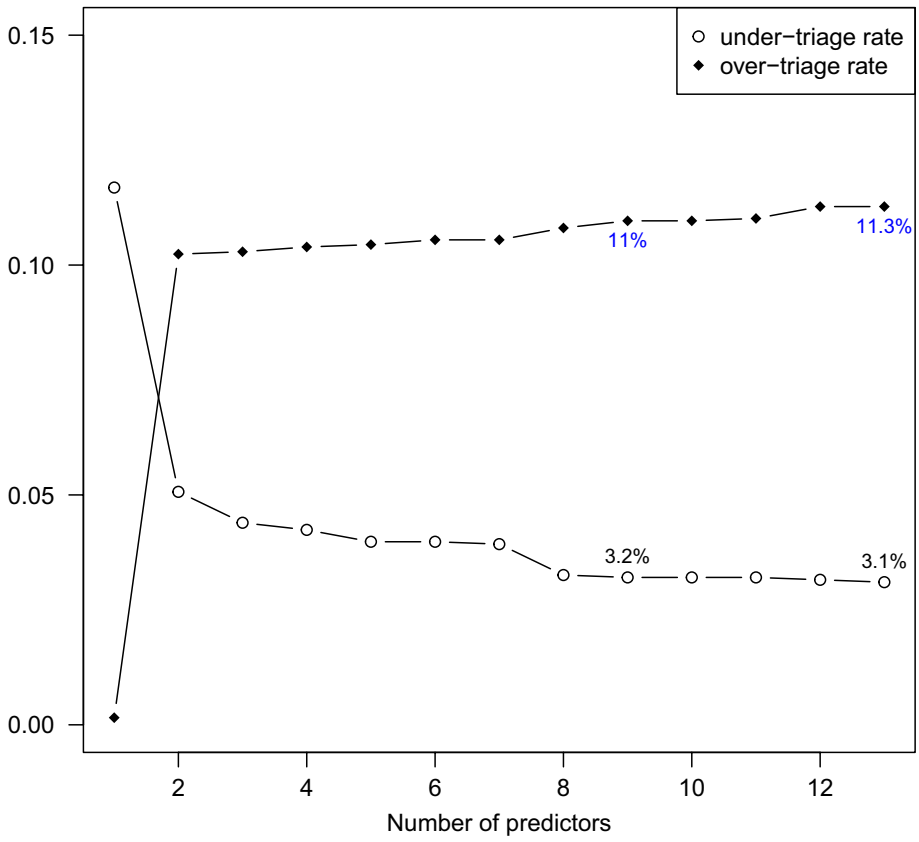

Fig. 3 Under- and over-triage rates as a function of the number of predictors in an 'at least one out of x' model setting

of severely injured patients with the need of resuscitation room treatment. Despite this, in practice, probably every intubated patient after trauma will be admitted to the resuscitation room, whereas Harbrecht et al. [27] pointed out that regarding to age, penetrating injury, traumatic brain injury and systolic blood pressure, a limited trauma team activation can be possible in intubated patients. This is discussed controversy [28, 29]. Several studies have reported that the condition of older patients is often misjudged, which leads to under-triage and increased mortality [18, 30–35]. Our results could not confirm these findings, but the closer view to the detailed analysis of the under-triaged patients assumes this, therefore, further research is indicated.

An 'at least one out of eight'-prediction model leads to an over-triage rate of 10.8% and under-triage rate of 3.3%. Our model performs slightly worse than the triage by the emergency physicians. This is probably due to the fact that the choice of the physicians is based on other parameters than the ones in the S3 guideline of the German Trauma Society. Unfortunately, our dataset is not suitable to answer the questions of possible other triage predictors.

Our study has also other limitations. One key limitation is the retrospective design within a single centre. Further studies are needed to confirm our data, refine the underlying triage parameters (e.g. heart rate, systolic blood pressure, shock index, duration of unconsciousness, GCS on the scene and at admission, paralysis at the spinal cord level, etc.) and assess the role of other preclinical predictors such as anticoagulative medication, chronic alcohol consumption or age as potential factors that can predict the need for trauma team activation.

Conclusions

Different interpretations of the triage guidelines for the resuscitation area can lead to under- or over-triage, risk of increased use of resources, or risk to the patient. In the present study, the criteria could be reduced to 8 predictors without compromising the predictive performance of the model. Non-relevant predictors such as the pre-hospital estimated injury severity, endotracheal intubation, suspected fractures of 2 proximal long bones, the presence of a burned body surface of > 20% and suspected paralysis could be excluded for full trauma team activation. The fact that the emergency physicians did a better job in reducing under-triage compared to our final triage model suggests that other variables not present in the S3-guideline may be relevant for prediction. Our findings indicate that the triage criteria for the need of immediate evaluation and treatment in the resuscitation area should be reformulated.

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Compliance with ethical standards

Ethical approval Approval by the local ethics committee was obtained for the analysis (KEK-ZH-Nr. 2013-0037). The study was conducted according to our institutional guidelines for good clinical practice and was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. Due to this ethical approval no consent to participate in the study was needed, because only anonymised data were used.

Conflict of interest Jensen KO, Heyard R, Schmitt D, Mica L, Ossendorf C, Simmen HP, Wanner GA, Werner CML, Held L and Sprengel K declare that they have no conflict of interest.

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References

1. Sasser SM, Hunt RC, Faul M, Sugerman D, Pearson WS, Dulski T, Wald MM, Jurkovich GJ, Newgard CD, Lerner EB, et al. Guidelines for field triage of injured patients: recommendations of the National Expert Panel on field triage, 2011. MMWR Recomm Rep. 2012;61(RR-1):1–20.
2. Bouillon B, Flohe S, Lendemans S, Ruchholtz S, Siebert H. Weissbuch schwerverletzten-versorgung. empfehlungen zur struktur, organisation und ausstattung sowie förderung von qualität und sicherheit in der schwerverletzten-versorgung in der bundesrepublik deutschland. Orthopädie Unfallchirurgie Mitteilungen Nachrichten. 2012;1(3, Supplement 1):1–35.
3. American College of Surgeon CoT. 2014 Resources for optimal care of the injured patient 2014. American College of Surgeons, Chicago.
4. Siebert H, Stürmer KM, Neugebauer E. S3-Leitlinie Polytrauma/Schwerverletzten-Behandlung. Orthopädie Unfallchirurgie Mitteilungen Nachrichten. 2011;1(1, Supplement 1):1–188.
5. Carron PN, Taffe P, Ribordy V, Schoettker P, Fishman D, Yersin B. Accuracy of prehospital triage of trauma patients by emergency physicians: a retrospective study in western Switzerland. Eur J Emerg Med. 2011;18(2):86–93.
6. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the Trauma Score. J Trauma. 1989;29(5):623–9.
7. Lefering R. Development and validation of the revised injury severity classification score for severely injured patients. Eur J Trauma Emerg Surg. 2009;35(5):437–47.
8. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14(3):187–96.
9. Champion HR, Sacco WJ, Hunt TK. Trauma severity scoring to predict mortality. World J Surg. 1983;7(1):4–11.
10. American College of Surgeon. Resources for optimal care of the injured patient 2006. 1st ed. Chicago: American College of Surgeon, Committee on Trauma; p. 181.
11. Held L, Sabanes Bove D, Gravestock I. Approximate bayesian model selection with the deviance statistic. Stat Sci. 2015;30(2):242–57.
12. Steyerberg E. Clinical prediction models: a practical approach to development, validation and updating. New York: Springer; 2008.
13. Gneiting T, Raftery AE. Strictly proper scoring rules, prediction, and estimation. J Am Stat Assoc. 2007;102(477):359–78.
14. Brier GW. Verification of forecasts expressed in terms of probability. Mon Weather Rev. 1950;78(1):1.

15. R Development Core Team. R: a language and environment for statistical Computing. Vienna: R Foundation for Statistical Computing; 2016.
16. Mackersie RC. History of trauma field triage development and the American College of Surgeons Criteria. Prehospital Emerg Care. 2006;10(3):287–94.
17. Moore K. Trauma triage: right person, right place, right time. J Emerg Nurs. 2012;38(2):193–4. **(Quiz 201)**.
18. Kohn MA, Hammel JM, Bretz SW, Stangby A. Trauma team activation criteria as predictors of patient disposition from the emergency department. Acad Emerg Med. 2004;11(1):1–9.
19. Engum SA, Mitchell MK, Scherer LR, Gomez G, Jacobson L, Solotkin K, Grosfeld JL. Prehospital triage in the injured pediatric patient. J Pediatr Surg. 2000;35(1):82–7.
20. Bond RJ, Kortbeek JB, Preshaw RM. Field trauma triage: combining mechanism of injury with the prehospital index for an improved trauma triage tool. J Trauma. 1997;43(2):283–7.
21. Santaniello JM, Esposito TJ, Luchette FA, Atkian DK, Davis KA, Gamelli RL. Mechanism of injury does not predict acuity or level of service need: field triage criteria revisited. Surgery. 2003;134(4):698–703. **(Discussion 4)**.
22. Matsushima K, Chouliaras K, Koenig W, Preston C, Gorospe D, Demetriades D. Should we still use motor vehicle intrusion as a sole triage criterion for the use of trauma center resources? Injury. 2016;47(1):235–8.
23. Dowd MD, McAneney C, Lacher M, Ruddy RM. Maximizing the sensitivity and specificity of pediatric trauma team activation criteria. Acad Emerg Med. 2000;7(10):1119–25.
24. Mutschler M, Nienaber U, Munzberg M, Fabian T, Paffrath T, Wolfl C, Bouillon B, Maegele M. Assessment of hypovolaemic shock at scene: is the PHTLS classification of hypovolaemic shock really valid? Emerg Med J. 2014;31(1):35–40.
25. Senkowski CK, McKenney MG. Trauma scoring systems: a review. J Am Coll Surg. 1999;189(5):491–503.
26. Knopp R, Yanagi A, Kallsen G, Geide A, Doehring L. Mechanism of injury and anatomic injury as criteria for prehospital trauma triage. Ann Emerg Med. 1988;17(9):895–902.
27. Harbrecht BG, Franklin GA, Smith JW, Benns MV, Miller KR, Nash NA, Bozeman MC, Coleman R, O'Brien D, Richardson JD. Intubated trauma patients do not require full trauma team activation when effectively triaged. J Am Coll Surg. 2016;222(4):603–11.
28. Tinkoff GH, O'Connor RE. Validation of new trauma triage rules for trauma attending response to the emergency department. J Trauma. 2002;52(6):1153–8. **(Discussion 8–9)**.
29. Cudnik MT, Werman HA, White LJ, Opalek JM. Prehospital factors associated with mortality in injured air medical patients. Prehosp Emerg Care. 2012;16(1):121–7.
30. Curtis K, Olivier J, Mitchell R, Cook A, Rankin T, Rana A, Watson WL, Nau T. Evaluation of a tiered trauma call system in a level 1 trauma centre. Injury. 2011;42(1):57–62.
31. Davis JS, Allan BJ, Sobowale O, Ivascu F, Orion K, Schulman CI. Evaluation of a new elderly trauma triage algorithm. Southern Med J. 2012;105(9):447–51.
32. Demetriades D, Sava J, Alo K, Newton E, Velmahos GC, Murray JA, Belzberg H, Asensio JA, Berne TV. Old age as a criterion for trauma team activation. J Trauma. 2001;51(4):754–6. **(Discussion 6–7)**.
33. Kuhne CA, Ruchholtz S, Kaiser GM, Nast-Kolb D. Mortality in severely injured elderly trauma patients–when does age become a risk factor? World J Surg. 2005;29(11):1476–82.
34. Grossman MD, Miller D, Scaff DW, Arcona S. When is an elder old? Effect of preexisting conditions on mortality in geriatric trauma. J Trauma. 2002;52(2):242–6.
35. Justiniano CF, Evans DC, Cook CH, Eiferman DS, Gerlach AT, Beery PR, 2nd, Lindsey DE, Saum GE, Murphy CV, Miller SF, et al. Comorbidity-polypharmacy score: a novel adjunct in post-emergency department trauma triage. J Surg Res. 2012;172:348.