



Injury severity in polytrauma patients is underestimated using the injury severity score: a single-center correlation study in air rescue

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Abstract

Purpose Prehospital estimation of injury severity is essential for prehospital therapy, deciding on the destination hospital and the associated emergency room care. The aim of this study was to compare prehospital estimates of the abbreviated injury scale (AIS) and the Injury Severity Score (ISS) by emergency physicians with the values of AIS and ISS of injury severity determined at the conclusion of diagnostics.

Methods In this prospective study, the ISS was determined prehospital by emergency physicians. The validated AIS and ISS were analyzed based on final diagnoses. A Bland–Altman plot was used in analyzing the agreement between two different assays as well as sensitivity and specificity were determined. Confidence intervals were calculated for a Wilson score. Significance level was set at $p \leq 0.05$.

Results The prehospital ISS was estimated at 26.0 ± 13.0 and was 34.7 ± 16.3 ($p < 0.001$) after in-hospital validation. In addition, most of the AIS subgroups were significantly higher in the final calculation than preclinically estimated ($p < 0.05$). When analyzing subgroups of trauma patients (ISS < 16 vs. ISS \geq 16), we were able to demonstrate a sensitivity of > 90% to identify a multiple-trauma patient. Diagnosing a higher injury severity group (ISS \geq 25), sensitivity dropped to 61.1%. The Bland–Altman plot demonstrates that injury severity is underestimated in higher injury levels.

Conclusion Multiple-trauma patients can be identified using the ISS. Anatomic scores might be used for transport decisions; however, an accurate estimation of the injury severity should also be based on other criteria such as patient status, mechanism of injury, and other triage criteria.

Keywords AIS · ISS · Multiple trauma · Air rescue

Introduction

Prehospital estimation of injury severity is essential for prehospital therapy, deciding on the destination hospital and the associated level of trauma care [1].

In stressful situations and under great pressure, it can be difficult to make a correct estimate of injury severity. In this context, preclinical trauma triage is a critical step in allocating the right patient in the right time to the right hospital [2, 3].

Undertriage is defined as the underestimation of injury severity and, conversely, overtriage is the excessive estimation of injuries. Overtriage rates of 50% and undertriage rates of 5–10% are acceptable, according to the contemporary literature [1, 4, 5]. Providing clinical capacity in terms of staff and equipment to treat multiply injured patients results in considerable costs for hospitals. An overtriaged patient activates unnecessary resources, whereas an undertriaged patient may receive the necessary diagnostics and treatment too late and is, therefore, exposed to unnecessary risk. Frequent overtriage leads to increased costs for hospitals and the health system as both emergency personnel and clinical resources are assessed wrongly and must be

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provided. On the other hand, frequent undertriage leads to a lack of emergency means and clinical facilities and thus to undertreatment of injured patients. Thus, a correct estimate of injury severity is essential [6].

Regardless of the emergency physician's experience, it is useful to employ a uniform score to estimate injury severity. In this regard, the Injury Severity Score (ISS) is a routinely and globally used score in routine clinical trauma care [7]. In 1974, Baker et al. of Johns Hopkins University devised the injury severity score to be able to compare trauma patients with regard to their injury severity rather than as a triage score. The ISS was the first score of this kind and enabled trauma centers and treatment methods to be compared for the first time. This pioneering score compares both anatomical information and the severity of the corresponding injury. Over time, it became apparent that the ISS is not only a tool for comparison but also demonstrates a correlation with morbidity and mortality [8, 9]. The ISS is based on the Abbreviated Injury Scale [AIS] and is the world's most frequently employed trauma score [10]. The following six of the nine AIS regions are included in the ISS: head and neck; face; chest; abdomen; pelvis; extremities and external (soft tissue).

The simplicity of the ISS makes it a rapid scoring system and enables physicians to approximate a score fast after radiologic diagnostics.

However, it is unclear whether the AIS and ISS can be estimated without knowledge of the diagnostics and, therefore, prehospital. This could add critical information to other preclinical triage aspects such as physiological status and mechanism of injury [11]. Moreover, it could simplify the choice of destination hospital and reduce secondary transports and delayed treatment.

The aim of this study was to show how far the prehospital estimate of emergency physicians deployed on rescue helicopters agrees with the clinical determination of the AIS and ISS of injury severity. Of particular interest is the sensitivity (correct positive assessment) and specificity (correct negative assessment) of the expected compared with the validated injury severity as well as to the related correlations.

Materials and methods

The study was approved by the Ethical Committee of Hannover Medical School (ID 3438-2016) and followed the declaration of Helsinki in its latest version. Trauma patients aged > 17 years with full available data and who were transported by rescue helicopter to Hannover Medical School, a level 1 trauma center, were included prospectively. The rescue helicopter, Christoph 4, is stationed at Hannover Medical School.

The ISS was estimated in the prehospital setting by the attending emergency physicians using a score sheet (group expected). After the recruitment phase, the validated injury severity was analyzed based on clinical and radiological findings and the final diagnoses in a blinded fashion (group hospital). We excluded patients who were initially treated at another hospital or with an incomplete data set.

Other evaluated variables included demographics, prehospital time, interventions such as intubations, and chest tubes as well as the amount of crystalloids and colloids present.

Prehospital and hospital data

Abbreviated injury scale and injury severity score

The ISS is an anatomical score to assess the degree of injury of polytraumatized patients. Six body regions are included in the assessment. All injuries are scored according to severity (1 = mild injury to 6 = fatal injury). Injuries are assessed with the AIS 2005. Overall, the ISS consists of the squared scores of the three most severely affected AIS regions. By definition, a maximum score of 75 is possible [8, 9]. The prehospital (expected) AIS and ISS were estimated prehospital by the helicopter physician during preclinical management of the patient and entered into a template.

The hospital (validated) ISS was determined retrospectively by two independent researchers after combining all the diagnoses, without knowing the expected and estimated AIS/ISS.

Prehospital management

Our department hosts a helicopter emergency medical service, which covers an area with a diameter of 100 km around Hannover, Germany. The rescue helicopter is staffed with specially trained staff consisting of one physician, one paramedic, and a pilot from the German federal police.

All physicians appointed to prehospital trauma care are at least third-year registrars and have completed training on the trauma intensive care unit (ICU) where grading according to AIS and ISS is taught and used on a daily basis. In addition, they have acquired the certificate of specialist training for emergency medicine from the Medical Council of Lower Saxony, are at least Advanced Trauma Life Support (ATLS) providers, and have completed our own rescue helicopter simulation training "Christoph life" [19].

Emergency helicopter deployment is coordinated through the regional control center of Hannover municipal fire service. Treatment of polytraumatized patients was according to ATLS® criteria. A six-channel ECG is recorded and analyzed routinely. Pulse oximetry, capnometry, blood pressure measurement, blood glucose measurement, volume

administration, and application of a cervical spine support are performed as standard and, if necessary, intubation, catecholamine administration, and insertion of chest tubes are performed, also according to ATLS criteria. These measures and the results of examination, the initial Glasgow Coma Scale (GCS), National Advisory Committee for Aeronautics (NACA) score, and the number of peripheral venous accesses were documented in the emergency physician's notes.

All helicopter physicians estimated the scores on the AIS on the basis of their examination findings and clinical experience, and calculated the ISS. Following prehospital examination and management of the injured patient and the decision to transport the patient to Hannover Medical School, the emergency physician contacts the trauma surgeon on duty by phone to refer the patient, informing the surgeon of the injury pattern.

Clinical management

After admission and initial diagnostics, including routine X-rays of the chest, pelvis, cervical spine, and extremities suspicious of injury, a computed tomography scan of the head, spine, chest, abdomen, and pelvis followed. Depending on the status of the patient and injury pattern, we followed the principles of early total care or damage control surgery in conjunction with other specialties such as neuro-, vascular, and visceral surgeons. In addition, depending on the injury pattern, the patient was either transferred directly to the operating theatre or admitted to our trauma ICU.

Statistical analysis

To estimate sensitivity and specificity of AIS in the expected group compared to the hospital group, all AIS scores were dichotomized to 0–1 and 2–6. Sensitivity and specificity were calculated based on all patients included in this study and for subgroups of patients with (a) $ISS \geq 16$ and (b) $ISS \geq 25$. Furthermore, sensitivity and specificity for differentiation among stages of injury were calculated. Therefore, patients were dichotomized to $ISS < 16$ vs. $ISS \geq 16$ and $ISS < 25$ vs. $ISS \geq 25$ accordingly. Accompanying to the estimates of sensitivity and specificity, Wilson score confidence intervals were computed. Differences in AIS and ISS between the expected and the hospital group were tested with the asymptotic Wilcoxon signed-rank test. In addition, a Bland–Altman plot was used to analyze the agreement between two different assays [12].

Significance level was set to $\alpha = 5\%$ (two-sided). Descriptive statistics are reported as mean \pm standard deviation and for skewed distributed data median (IQR) as well. Statistical analysis was performed using R (version 3.1.3) [13] and SPSS (version 19 SPSS Inc., Chicago, IL, USA).

Results

Demographic data

Forty-eight patients were included in the study. There were 34 men and 14 women. The average age of the injured patients was 41.5 ± 21.0 years.

Prehospital data

The duration of prehospital management was 38.2 ± 12.4 min. Thirty patients had a prehospital induction of anesthesia. A cervical spine support was applied to 46 patients. Insertion of one or more chest drain was necessary in nine cases. The mean volume administration was 1300 ± 808.1 ml and eight patients were given a catecholamine dose as part of prehospital care. An average of 1.8 ± 0.5 venous access lines was placed. The mean body temperature at the accident site was $36.1 \text{ }^\circ\text{C} \pm 0.7 \text{ }^\circ\text{C}$ and in the hospital was $35.9 \pm 1.1 \text{ }^\circ\text{C}$ ($p = 0.394$).

Comparison of expected and validated AIS/ISS

The prehospital (expected) ISS was estimated to be 26.0 ± 13.0 . In-hospital validation found the ISS to be 34.7 ± 16.3 , leading to a significant difference of $p < 0.001$. In addition, AIS_{Face} , AIS_{Chest} , AIS_{Abdomen} , and the AIS_{Spine} were significantly higher in the final calculation than preclinically estimated ($p < 0.05$, Table 1).

Sensitivity and specificity of the expected and validated AIS and ISS

Overall, AIS_{Head} was predicted most accurately preclinically and we found the correlation to be even better in more severely injured patients. In addition, thoracic injuries were detected with a sensitivity of $> 85\%$. As demonstrated in Tables 2, 3, 4, and 5, specificity increases for most of the evaluated AIS when analyzing more severely injured patients.

When analyzing subgroups of multiple-trauma patients, we were able to demonstrate a sensitivity of $> 90\%$ to identify a multiple-trauma patient ($ISS < 16$ vs. $ISS \geq 16$). Evaluating a higher injury severity group ($ISS < 25$ vs. $ISS \geq 25$), the sensitivity to rate a patient with an $ISS \geq 25$ dropped to 61.1% but specificity was 100% (Table 5).

Table 1 Comparison of the expected and validated AIS and ISS (mean \pm standard deviation and median [IQR])

	Expected		Hospital (validated)		<i>p</i> value
AIS head	2.54 \pm 1.52	3.00 (3.00)	2.65 \pm 1.76	3.00 (3.00)	0.413
AIS face and neck	0.85 \pm 1.32	0.00 (2.00)	1.38 \pm 1.63	0.50 (3.00)	0.018
AIS chest	1.96 \pm 1.47	3.00 (3.00)	2.35 \pm 1.72	3.00 (4.00)	0.036
AIS abdomen	0.46 \pm 1.01	0.00 (0.00)	0.88 \pm 1.50	0.00 (2.00)	0.039
AIS spine	0.58 \pm 1.07	0.00 (1.00)	1.52 \pm 1.75	0.50 (3.00)	<0.001
AIS pelvis	0.52 \pm 1.11	0.00 (0.00)	0.71 \pm 1.32	0.00 (1.00)	0.250
AIS upper extremities	0.75 \pm 1.30	0.00 (1.00)	1.04 \pm 1.49	0.00 (2.00)	0.053
AIS lower extremities	1.33 \pm 1.55	0.50 (3.00)	1.56 \pm 1.58	1.00 (3.00)	0.062
AIS soft tissue	0.75 \pm 1.35	0.00 (1.00)	1.04 \pm 1.44	0.00 (2.00)	0.050
ISS	26.06 \pm 13.04	22.00 (19.00)	34.46 \pm 16.08	34.00 (24.00)	<0.001

Table 2 Sensitivity and specificity in comparison of expected to definitive values. All AIS dichotomized to 0–1 and 2–6, Wilson's confidence intervals

AIS	Sensitivity	95% confidence interval [%]	Specificity	95% confidence interval
Head	32/35 = 91.4%	[77.62; 97.04]	10/13 = 76.9%	[49.74; 91.82]
Face and neck	11/20 = 55.0%	[34.21; 74.18]	27/28 = 96.4%	[82.29; 99.37]
Chest	28/32 = 87.5%	[71.93; 95.03]	13/16 = 81.2%	[56.99; 93.41]
Abdomen	4/12 = 33.3%	[13.81; 60.94]	34/36 = 94.4%	[81.86; 98.46]
Spine	8/21 = 38.1%	[20.75; 59.12]	27/27 = 100%	[87.54; 100.00]
Pelvis	5/10 = 50.0%	[23.66; 76.34]	36/38 = 94.7%	[82.71; 98.54]
Upper extremities	10/14 = 71.4%	[45.35; 88.28]	33/34 = 97.1%	[85.08; 99.48]
Lower extremities	18/22 = 81.8%	[61.48; 92.69]	26/26 = 100%	[87.13; 100.00]
Soft tissues	7/16 = 43.8%	[23.10; 66.82]	29/32 = 90.6%	[75.78; 96.76]

Table 3 Sensitivity and specificity in comparison to clinical values

AIS	Sensitivity	95% confidence interval	Specificity	95% confidence interval
Head + neck	30/31 = 96.8%	[83.81; 99.43]	9/11 = 81.8%	[52.30; 94.86]
Face + neck	10/18 = 55.6%	[33.72; 75.44]	23/24 = 95.8%	[79.76; 99.26]
Chest	28/32 = 87.5%	[71.93; 95.03]	8/10 = 80.0%	[49.02; 94.33]
Abdomen	4/12 = 33.3%	[13.81; 60.94]	29/30 = 96.7%	[83.33; 99.41]
Spine	6/19 = 31.6%	[15.36; 53.99]	23/23 = 100%	[85.69; 100]
Pelvis	5/10 = 50%	[23.66; 76.34]	30/32 = 93.8%	[79.85; 98.27]
Upper extremity	10/14 = 71.4%	[45.35; 88.28]	27/28 = 96.4%	[82.29; 99.37]
Lower extremity	17/21 = 81.0%	[60.00; 92.33]	21/21 = 100%	[84.54; 100]
Soft tissue	7/15 = 46.7%	[24.81; 69.88]	24/27 = 88.9%	[71.94; 96.15]

Dichotomized by injury severity ISS \geq 16

Bland–Altman and scatter plot of the expected and validated ISS

The Bland–Altman plot analysis of the expected and validated ISS is shown in Fig. 1. We were able to demonstrate that the injury severity was mainly underestimated in the study population. The corresponding scatter plot is given in Fig. 2.

Discussion

Preclinical trauma triage relies on various aspects such as mechanism of injury, physiological status of the patient, and finally on the expected injury severity.

The aim of this study was to show the extent to which injury severity in polytraumatized patients can be estimated by an emergency physician deployed on a rescue helicopter

Table 4 Sensitivity and specificity in comparison to clinical values

	Sensitivity	95% confidence interval	Specificity	95% confidence interval
Head	26/26 = 100%	[87.13; 100]	8/10 = 80.0%	[49.02; 94.33]
Face + neck	9/16 = 56.2%	[33.18; 76.90]	19/20 = 95.0%	[76.39; 99.11]
Chest	25/29 = 86.2%	[69.44; 94.50]	6/7 = 85.7%	[48.69; 97.43]
Abdomen	4/10 = 40.0%	[16.82; 68.73]	26/26 = 100%	[87.13; 100]
Spine	6/18 = 33.3%	[16.28; 56.25]	18/18 = 100%	[82.41; 100]
Pelvis	4/9 = 44.4%	[18.88; 73.33]	25/27 = 92.6%	[76.63; 97.94]
Upper extremity	10/13 = 76.9%	[49.74; 91.82]	22/23 = 95.7%	[79.01; 99.23]
Lower extremity	15/19 = 78.9%	[56.67; 91.94]	17/17 = 100%	[81.57; 100]
Soft tissue	7/15 = 46.7%	[24.81; 69.88]	19/21 = 90.5%	[71.09; 97.35]

Dichotomized by injury severity ISS ≥ 25

Table 5 Sensitivity and specificity of diagnosing ISS values ≥ 16 and ≥ 25

ISS	Sensitivity	95% CI	Specificity	95% CI
Diagnosing ≥ 16	38/42 = 90.5%	[77.93; 96.23]	3/6 = 50.0%	[18.76; 81.24]
Diagnosing ≥ 25	22/36 = 61.1%	[44.86; 75.22]	12/12 = 100%	[75.75; 100.0]

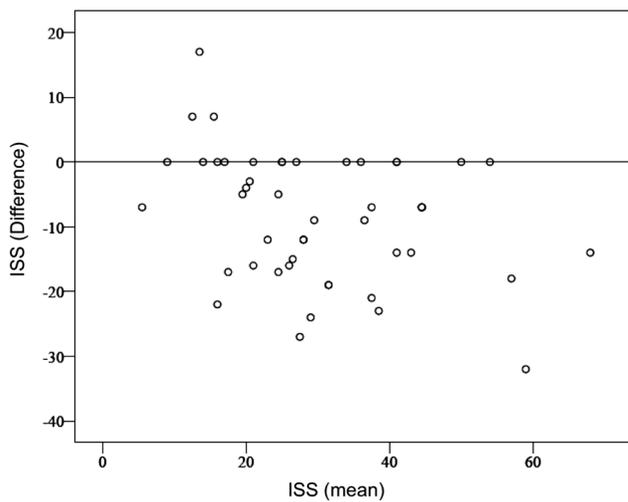


Fig. 1 Bland–Altman plot demonstrating that the overall injury severity is mainly underestimated

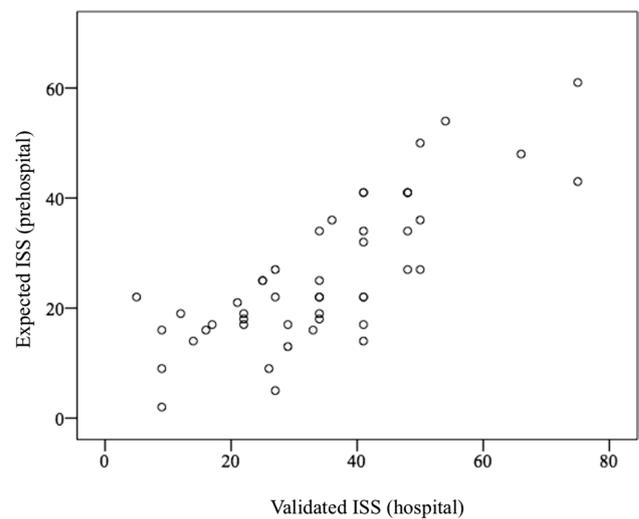


Fig. 2 Scatter plot of the study population; underestimation of overall injury severity

using the AIS and the ISS. Particular interest was paid to the sensitivity (correct positive assessment) and specificity (correct negative assessment) of the expected score.

In general, multiple-trauma patients (ISS ≥ 16) can be identified using this grading system with an appropriate sensitivity of 90.5%. However, we found that injury severity itself is widely underestimated using the anatomical AIS and ISS.

Adequate assessment of injured patients at the accident site is difficult even for experienced emergency physicians and paramedics on account of the limited diagnostics and stress situation, and yet, it is highly important for many different areas of medical care [14]. Therefore, a simple but

accurate preclinical assessment in terms of predicting injury severity is of great importance.

Physiological disturbances already can point to severe injuries such as pneumothorax, abdominal, or pelvic trauma. Therefore, the combination of several issues including anatomical and physiological aspects has to be evaluated in preclinical trauma cases. Triage protocols aim to combine these factors; however, protocols have also been evaluated with incoherent results.

Just recently, Voskens et al. evaluated the accuracy of prehospital triage in selecting severely injured trauma patients. The authors conducted a prospective multicenter study and were able to analyze 4950 patients. In summary,

they found an undertriage in 20% of the patients who were not transported to a level-1 trauma center. Since there is a better outcome of severely injured patients in level-1 trauma centers, they came to the conclusion that an improvement of the existing triage protocols is necessary [15].

Van Rhein et al. performed a comprehensive review of the available studies investigating triage protocols in selecting multiple-trauma patients. They were able to demonstrate that significant predictors for severe injury were vital signs, suspicion of certain anatomic injuries, mechanism of injury, and age. Nonetheless, the authors state that there is poor quality of the studies available and there is great need for creating and improving prehospital trauma triage protocols [1]. Additional factors not recognized so far could help to improve the existing protocols.

For various reasons, we decided to use the ISS based on the AIS. An advantage of this anatomical score is the scientifically demonstrated good prediction of mortality and its widespread use [10]. As a result, trauma emergency physicians and intensive care physicians are familiar with this comparatively simple trauma score. Up to date, there is very limited information about the reliability to estimate AIS scores and determine the ISS prehospital [16].

When comparing our results to the published literature using triage protocols, we found that discrimination between patients $ISS < 16$ and more severely injured patients ($ISS \geq 16$) using the ISS is as accurate as in other studies. Laarhoven and colleagues evaluated the Dutch field triage protocol in selecting severely injured patients. The protocol consists of parameters such as physiological condition, mechanism of injury, and injury type. The investigators found a sensitivity of 89.1% and a specificity of 60.5%—compared to a sensitivity of 90.5% and specificity of 50.0% in our cohort. The authors showed an undertriage in 16.5% of the patients with only a positive mechanism criterion [2]. Therefore, further optimisation of triage protocols is required, since these patients have not been identified as severely injured. Data of our study might help in this development, demonstrating that prediction of injury severity is also possible using the trauma score ISS. In this regard, the combination of established triage protocols and the ISS might end up in an improved triage which might be an issue in upcoming studies.

If the composition of the expected ISS and validated ISS is considered, a congruent injury pattern is apparent compared with recent studies [17, 18]. The ISS recorded by the helicopter physician and the validated ISS are determined especially by injuries to the “Head and neck,” “Chest,” and “Extremities” regions, while the abdominal injuries, which are underestimated by the emergency physician also play a significant role in the validated ISS. Our study shows that an approximate preclinical estimation of the ISS in polytraumatized patients by a trauma emergency

physician on a rescue helicopter is possible, but it seems that overall injury severity is generally underestimated. However, estimates are reasonable especially in injuries of the head, chest, and extremities. It was shown that injuries are identified correctly for three of the AIS regions.

The small number of cases can be regarded as a limitation of this study. Moreover, due to the deployment pattern of the rescue helicopter, an anticipation bias is likely in the emergency physicians with a resulting incorrect estimate of the patients' status. The rescue helicopter is staffed exclusively by trauma surgeons and this may be a source of confounding factors as anaesthesiologists or other emergency physicians, for example, could assess injuries differently. However, this theory has not been confirmed scientifically. A further limitation of this study is the difficulty in dealing with the AIS, especially in the face and soft-tissue regions. Patients with severe injuries of more than three body regions are under-assessed as only three regions are included in the ISS.

Another important and interesting aspect would be the estimation of injury severity by the receiving trauma team in the emergency department without possible prehospital confounding factors such as pressure of time or therapeutic decisions. Differing estimates of injury severity by the senior receiving physician might possibly be made in the hospital environment, which would have revealed potential distractors in the prehospital setting.

Nonetheless, we feel safe in drawing further conclusions from the study at hand. Meanwhile, quantification of the overall injury severity between multiply injured patients seems to be limited; the ISS seems to be suitable for identifying multiply injured patients equal to or exceeding an ISS of 16, which is an important value of preclinical decision-making, and for identifying the proper receiving hospital.

In conclusion, our study adds information on in-field triage in severely injured patients. Ultimate goal is to get the right patient to the right hospital and the ISS is only one of the items in this respect. We, therefore, recommend to apply triage strategies including mechanism of injury and physiological status and combine these algorithms with data out of our study keeping in mind that sensitivity to identify patients exceeding an $ISS > 25$ drops, however, presenting a specificity of 100% [19].

In this respect, the combination of anatomical scores and physiological impairments might help to identify the multiple-trauma patients more precisely as it was also shown in the revision of the polytrauma definition, namely the Berlin definition [20].

However, to do so, additional data and potentially multicenter studies involving various air rescue bases as well as trauma centers should be performed also investigating the different subspecialties of emergency physicians and paramedics.

In addition, data out of trauma registries with focus on the preclinical status and the estimated injury severity might help to build up a more precise preclinical triage system.

Conclusion

Multiple-trauma patients with an ISS ≥ 16 can be identified using the ISS from a trauma cohort. Discrimination between severe, mild, or moderate polytrauma patients seems to be limited. We showed that the injury severity of multiple-trauma patients can be estimated by an emergency physician for some regions of the AIS.

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Compliance with ethical standards

Conflict of interest Christian Schröter, Florian Urbanek, Cornelia Frömke, Marcel Winkelmann, Philipp Mommsen, Christian Krettek, and Christian Zeckey declare that they have no conflict of interest.

Research involving human participants and/or animals The study was approved by the Ethical Committee of Hannover Medical School (ID 3438-2016) and followed the declaration of Helsinki in its latest version.

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