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ORIGINAL ARTICLE

Blood glucose concentrations in prehospital trauma patients with traumatic shock

A retrospective analysis

Janett Kreutziger, Wolfgang Lederer, Stefan Schmid, Hanno Ulmer, Volker Wenzel, Maarten W. Nijsten, Daniel Werner and Thomas Schlechtriemen

BACKGROUND Deranged glucose metabolism after moderate to severe trauma with either high or low concentrations of blood glucose is associated with poorer outcome. Data on prehospital blood glucose concentrations and trauma are scarce.

OBJECTIVES The primary aim was to describe the relationship between traumatic shock and prehospital blood glucose concentrations. The secondary aim was to determine the additional predictive value of prehospital blood glucose concentration for traumatic shock when compared with vital parameters alone.

DESIGN Retrospective analysis of the predefined, observational database of a nationwide Helicopter Emergency Medical Service (34 bases).

SETTING Emergency trauma patients treated by Helicopter Emergency Medical Service between 2005 and 2013 were investigated.

PATIENTS All adult trauma patients (≥18 years) with recorded blood glucose concentrations were enrolled.

OUTCOMES Primary outcome: upper and lower thresholds of blood glucose concentration more commonly associated with traumatic shock. Secondary outcome: additional predictive value of prehospital blood glucose concentrations when compared with vital parameters alone.

RESULTS Of 51 936 trauma patients, 20 177 were included. In total, 220 (1.1%) patients died on scene. Hypoglycaemia (blood glucose concentration 2.8 mmol l^{-1} or less) was observed in 132 (0.7%) patients, hyperglycaemia (blood glucose concentration exceeding 15 mmol l^{-1}) was observed in 265 patients (1.3%). Blood glucose concentrations more than 10 mmol l^{-1} ($n = 1308$ (6.5%)) and 2.8 mmol l^{-1} or less were more common in patients with traumatic shock ($P < 0.0001$). The Youden index for traumatic shock ((sensitivity + specificity) − 1) was highest when blood glucose concentration was 3.35 mmol l^{-1} ($P < 0.001$) for patients with low blood glucose concentrations and 7.75 mmol l^{-1} ($P < 0.001$) for those with high blood glucose concentrations. In logistic regression analysis of patients with spontaneous circulation on scene, prehospital blood glucose concentrations (together with common vital parameters: Glasgow Coma Scale, heart rate, blood pressure, breathing frequency) significantly improved the prediction of traumatic shock in comparison with prediction by common vital parameters alone ($P < 0.0001$).

CONCLUSION In adult trauma patients, low and high blood glucose concentrations were more common in patients with traumatic shock. Prehospital blood glucose concentration measurements in addition to common vital parameters may help identify patients at risk of traumatic shock.

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Introduction

Glucose derangements such as hypoglycaemia and hyperglycaemia have been proven to be predictive for outcome in severely ill and critically impaired patients.[1–4] Trauma when associated with blood glucose derangements has a poor outcome.[5–12] In a recent investigation, blood glucose on admission was found to be predictive for haemorrhagic shock in polytraumatised patients.[13] Currently, data are scarce on blood glucose concentrations in prehospital trauma patients with traumatic shock. Blood glucose concentration measurement on-site could provide a useful, simple, rapid and inexpensive screening tool for patients at increased risk of traumatic shock.

The aim of this study was to analyse prehospital blood glucose concentrations in trauma patients and determine whether blood glucose concentrations correspond with severity of trauma and traumatic shock.

Methods

We retrospectively analysed data from prehospital missions conducted by the Helicopter Emergency Medical Service (HEMS) of Allgemeiner Deutscher Automobil Club (ADAC) in Germany. A nationwide, multicentre study including all 34 ADAC helicopter bases was conducted and involved all trauma patients treated by ADAC-HEMS between 1 January 2005 and 31 December 2013. The standardised definition of trauma used in all contributing centres was physical trauma caused by a sudden event. The study was approved by the Ethics Committee of the Medical Association of the Saarland (Ärztekammer des Saarlands, No. 69/14, 24 April 2014, chairman Professor Dr. med. Gerd Rettig-Stürmer) and by the Institutional Review Board. Inclusion criteria were adult trauma patients (≥18 years), in whom blood glucose concentration was measured on-site. Exclusion criteria were interhospital transfers and incomplete or incongruent data records regarding demographics, initial vital signs or important accident data such as injury pattern, trauma course and trauma causes.

The following parameters were recorded routinely according to the predefined emergency physician dataset (Minimaler Notarzt-Datensatz, MIND2[14]) within the prospective, observational database of ADAC (Luftrettungs, Informations und Kommunikations System, LIKS®): demographic data, first vital parameters [heart rate (HR), breathing frequency, SBP] upon arrival of the professional rescuers, Glasgow Coma Scale (GCS), trauma mechanism, clinical evaluation of injury severity of the following body regions: head/brain, neck, face, chest, abdomen, thoracic and lumbar spine, pelvis, upper and lower extremities (1 = no injury, 2 = minor injury, 3 = moderate injury, 4 = severe injury, not life threatening, 5 = severe injury, life threatening, 6 = critical injury, life threatening, 7 = deadly injury), whole injury pattern (1 = single injury, 2 = multiple injuries, 3 = polytrauma defined as life-threatening multiple trauma), the National Advisory Committee for Aeronautics (NACA) index (0 = no injury, 1 = minor injury, no intervention by a physician necessary; 2 = minor to moderate injury, ambulatory evaluation, 3 = moderate to severe injury, not life threatening, in-patient care necessary, 4 = severe severe injury, potentially life threatening, emergency physician care necessary, 5 = acute life-threatening injury, 6 = apnoea and circulatory arrest/resuscitation, 7 = deceased; of note: we included only patients who were alive upon arrival of the HEMS emergency physician). In addition, the given volume, type of drug administered and rescue intervals were recorded.

Blood glucose concentration (in mmol l^{-1}) was measured with point-of-care devices at the scene. In most cases, glucose was measured from blood drawn immediately after venous access. Glucose concentrations were categorised into three groups: 2.8 mmol l^{-1} or less, 2.81 to 10.0 mmol l^{-1}, and more than 10.0 mmol l^{-1}. The thresholds of 2.8 mmol l^{-1} and 10.0 mmol l^{-1} are commonly used in emergency medicine and intensive care.[15,16]

Traumatic shock was defined as SBP 90 mmHg or less or administration of catecholamines.

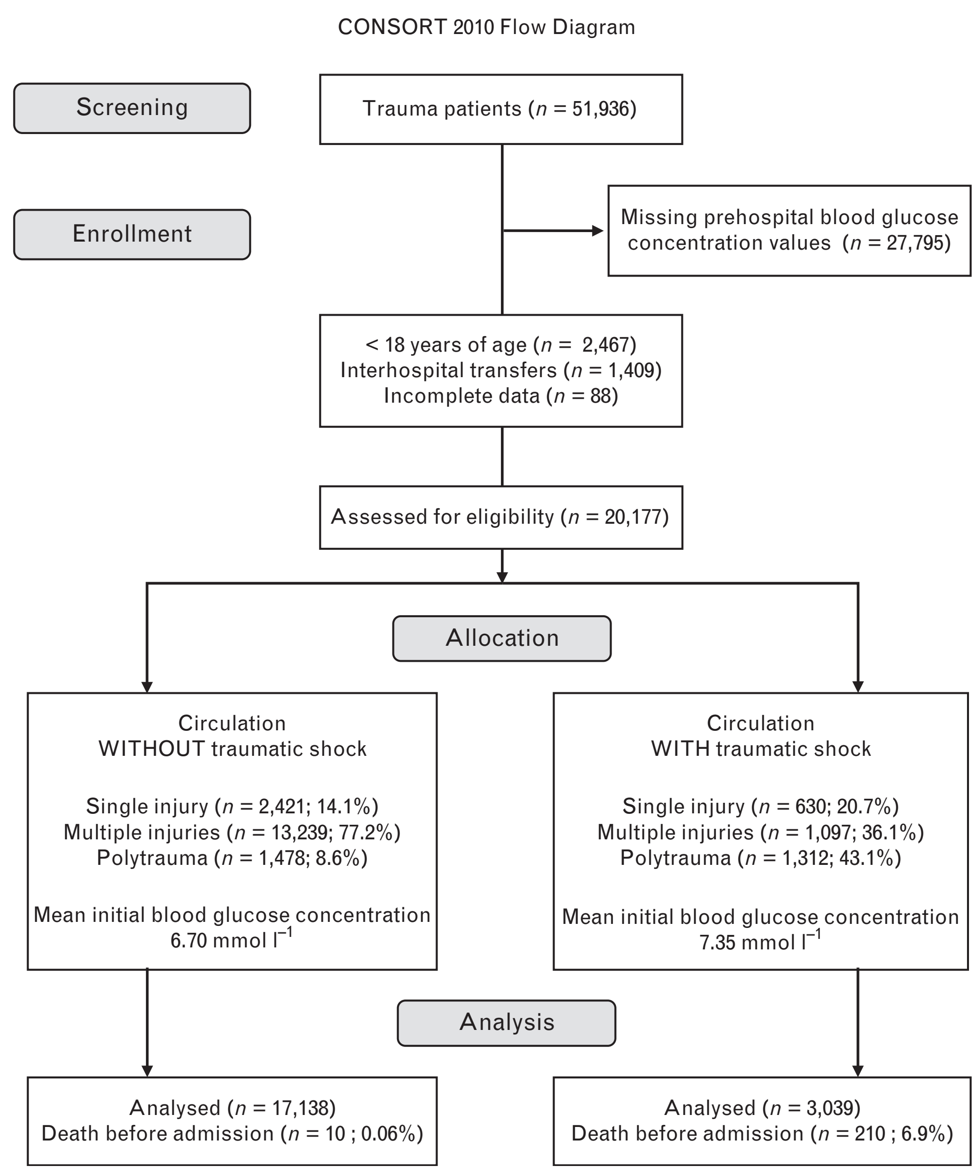
Statistical analysis was conducted with International Buisness Machines; SPSS Statistics (Release 22.0, 2013, Armonk, New York, USA). The null hypothesis was that prehospital blood glucose concentration does not differ in patients with single injuries, multiple injuries or polytraumatised patients with and without traumatic shock. The Shapiro–Wilk test was used to test for normal distribution. Following descriptive analysis, the Mann–Whitney U test was used to compare group differences and the χ^2 test was performed to detect frequency differences. Multivariable logistic regression analysis for prediction of traumatic shock necessitating fluid resuscitation and administration of catecholamines was performed using common vital parameters for model 1 common vital parameters (HR, respiratory frequency, SBP, GCS) and for model 2 common vital parameters and blood glucose on-site and blood glucose squared, respectively. Receiver operating characteristics (ROC) and comparison of ROC curves (area under the curve) to find the best fitting model were performed by MedCalc (Version 15.8, Ostend, Belgium) analysis. The Youden index[17] was calculated to investigate blood glucose concentration thresholds. The Youden index is a single statistic ((sensitivity + specificity) − 1) that captures the performance of a dichotomous diagnostic test by the ROC. Its value ranges from −1 to 1, and has a zero value when a diagnostic test gives the same proportion of positive results for groups with and without the disease, that is, the test is useless. A value of 1 indicates that there are no false positives or false negatives, that is, the test is perfect. The index gives equal weight to false positive and false negative values, so all tests with the same value of the index give the same proportion of total misclassified results. The value correspond to a value of the influencing factor, which is then defined as the cut-off value for this test (in this case upper and lower blood glucose concentration thresholds more commonly associated with traumatic shock). Integrated discrimination improvement and net reclassification improvement were used to assess the improvement of outcome prediction comparing model 1 and model 2 (Statistics and Data, STATA/MP, release 13, College Station, Texas, USA). Confidence intervals in this study were 99%. A P value of 0.01 was deemed to be statistically significant.

Results

During the study period 51 936 trauma patients were registered in the ADAC-HEMS database. In 24 141 (46.5%) patients blood glucose concentration was measured and recorded. Ultimately, 20 177 patients were included resulting in an inclusion rate of eligible patients of 83.6% (Fig. 1). SBP 90 mmHg or less was found in 1638 patients, and traumatic shock was noted in 3039 (15.1%) patients (Table 1).

In total, 18 737 patients (92.9%) had initial blood glucose concentrations between 2.81 and 10.0 mmol l^{-1}. Blood glucose concentration 2.80 mmol l^{-1} or less was detected

Fig. 1



Enrolment, allocation and analysis of patients with traumatic shock in whom blood glucose concentrations were measured on-site.

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Table 1 **Characteristics of study population**

	Without traumatic shock *n* (%) or mean ± SD	With traumatic shock *n* (%) or mean ± SD	*P* value
Number of patients	17 138 (84.9)	3039 (15.1)	
Demographics			
Age	50.5 ± 19.8	51.8 ± 21.7	0.076
Sex			
Male	11 943 (69.7)	2094 (68.9)	0.386
Female	5195 (30.3)	945 (31.1)	
Blunt trauma	16 587 (96.7)	2903 (95.6)	0.0006
Penetrating trauma	551 (3.2)	136 (4.4)	
Vital signs			
Respiratory rate	14.7 ± 3.9	13.1 ± 6.2	<0.0001
Heart rate	89 ± 18	90 ± 37	<0.0001
SBP	139 ± 26	93 ± 45	<0.0001
State of consciousness			
Analgosedation	1559 (9.1)	766 (25.2)	<0.0001
Orientated	10 752 (62.7)	425 (14.0)	<0.0001
Somnolent	2904 (16.9)	680 (22.4)	<0.0001
Unconscious	782 (4.6)	1019 (33.5)	<0.0001
Scores			
GCS 13 to 15	13 600 (79.4)	613 (20.2)	<0.0001
GCS 8 to 12	1410 (8.2)	508 (16.7)	<0.0001
GCS 3 to 7	2128 (12.4)	1918 (63.1)	<0.0001
NACA 1 to 3	4376 (25.5)	65 (2.1)	<0.0001
NACA 4,5	12 633 (73.7)	2510 (82.6)	<0.0001
NACA 6,7	129 (0.8)	464 (15.3)	<0.0001
Injury pattern			
Single injury	2421 (14.1)	630 (20.7)	<0.0001
Multiple injury	13 239 (77.2)	1097 (36.1)	<0.0001
Polytrauma	1478 (8.6)	1312 (43.1)	<0.0001
Injury regions and severity if injured			
Head/brain	12 175 (71.0)	2578 (84.8)	<40.0001
	3.32 ± 1.43	4.93 ± 1.24	<0.0001
Neck	3841 (22.4)	763 (25.1)	0.001
	2.98 ± 0.89	3.96 ± 1.30	<0.0001
Face	3438 (20.0)	774 (25.5)	<0.0001
	3.11 ± 0.98	3.86 ± 1.28	<0.0001
Chest	6215 (36.3)	1443 (47.5)	<0.001
	3.47 ± 0.98	4.64 ± 1.24	<0.0001
Abdomen	2489 (14.5)	784 (25.8)	<0.0001
	3.53 ± 1.07	4.55 ± 1.25	<0.0001
Thoracic and lumbar spine	4334 (25.3)	620 (20.4)	<0.0001
	3.45 ± 0.89	4.01 ± 1.07	<0.0001
Pelvis	2537 (13.8)	609 (20.0)	<0.0001
	3.47 ± 1.03	4.47 ± 1.24	<0.0001
Upper extremities	5598 (32.7)	858 (28.2)	<0.0001
	3.22 ± 0.89	3.69 ± 1.04	<0.0001
Lower extremities	4948 (28.9)	984 (32.4)	<0.0001
	3.51 ± 1.03	4.29 ± 1.10	<0.0001
External	225 (1.3)	39 (1.3)	0.888
	1.29 ± 0.65	1.36 ± 0.73	0.937
Others			
Blood glucose	6.70 ± 2.12	7.35 ± 2.98	<0.0001

NACA parameter is assigned at the end of the Helicopter Emergency Medical Service mission. SD: standard deviation; injury severity 1 to 6 for definition see method section. Polytrauma: multiple injuries, of which one or the sum of them is life threatening according to the clinical assessment of the emergency physician. GCS, Glasgow Coma Scale; NACA, National Advisory Committee for Aeronautics.

in 132 (0.7%) patients, including 56 (0.3%) patients with severe hypoglycaemia, 2.20 mmol l^{-1} or less. This severe hypoglycaemia was more frequently seen in patients with polytrauma [20/2790 (0.7%)]. Hyperglycaemia exceeding 15 mmol l^{-1} was documented in 265 (1.3%) patients and most frequently detected in 57 single-injury patients with severe traumatic brain injury [57/3051 (1.9%)]. Of the 132 hypoglycaemic patients, 64 (48.5%) received glucose infusions on scene (Table 2).

Traumatic shock was noted in 377/1308 patients (28.8%) with hyperglycaemia (>10.0 mmol l^{-1}), in 83/265 patients (31.3%) with excessive hyperglycaemia (≥15.01 mmol l^{-1}) and in 44/132 patients (33.3%) with hypoglycaemia (≤2.80 mmol l^{-1}).

In polytraumatised patients with traumatic shock, the blood glucose concentration profiles had significant U-shaped characteristics ($P < 0.0001$): in 47/66 patients (71.2%) with blood glucose concentrations 4.0 mmol l^{-1} or less and in 44/62 patients (71%) with blood glucose concentrations more than 14.0 mmol l^{-1} the frequency of traumatic shock was more than 60% (Fig. 2). This U-shaped pattern was less marked in patients with single injuries and was not observed in patients with multiple injuries (Fig. 2). In patients older than 65 years, traumatic shock was diagnosed even more frequently when blood glucose concentration was 4.0 mmol l^{-1} or less than in younger patients (Fig. 3).

The Youden index for traumatic shock was highest at 3.35 mmol l^{-1} ($P < 0.001$) for patients with low blood glucose concentrations in the left segment of the curve and at 7.75 mmol l^{-1} ($P < 0.001$) for patients with high blood glucose concentrations in the right segment of the curve (Fig. 2).

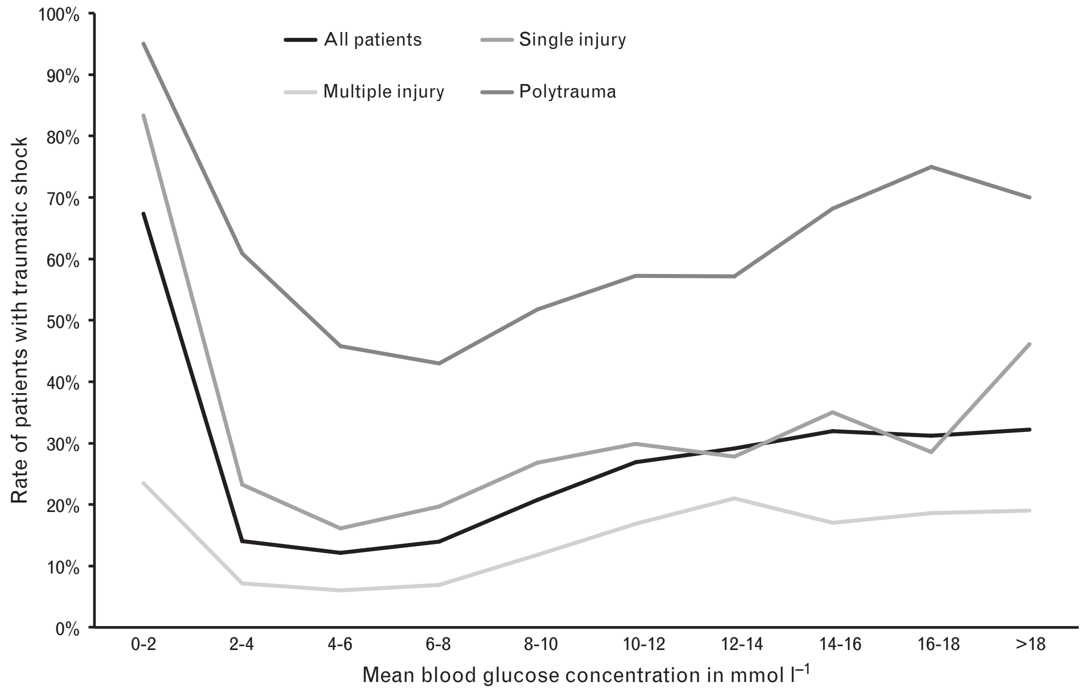
Prehospital blood glucose concentrations significantly improved the prediction of traumatic shock necessitating fluid resuscitation and administration of catecholamines (Integrated Discrimination Improvement $P < 0.0001$) compared with prediction by GCS, HR, respiratory rate and blood pressure alone (Table 3).

Discussion

This retrospective, multicentre analysis demonstrates that prehospital deranged blood glucose concentration is common in trauma patients. Hypo- and hyperglycaemia were associated with traumatic shock in our study. Hyperglycaemia was especially common in young polytraumatised patients with traumatic shock. Hypoglycaemia was more frequently observed in older patients (>65 years) with traumatic shock (Fig. 2). In our study, blood glucose concentration showed predictive value for patients with traumatic shock in addition to common vital parameters concordant with a recent investigation.[13] Thus, we recommend blood glucose concentration measurement in all trauma patients to get further information on the severity of trauma in the prehospital setting.

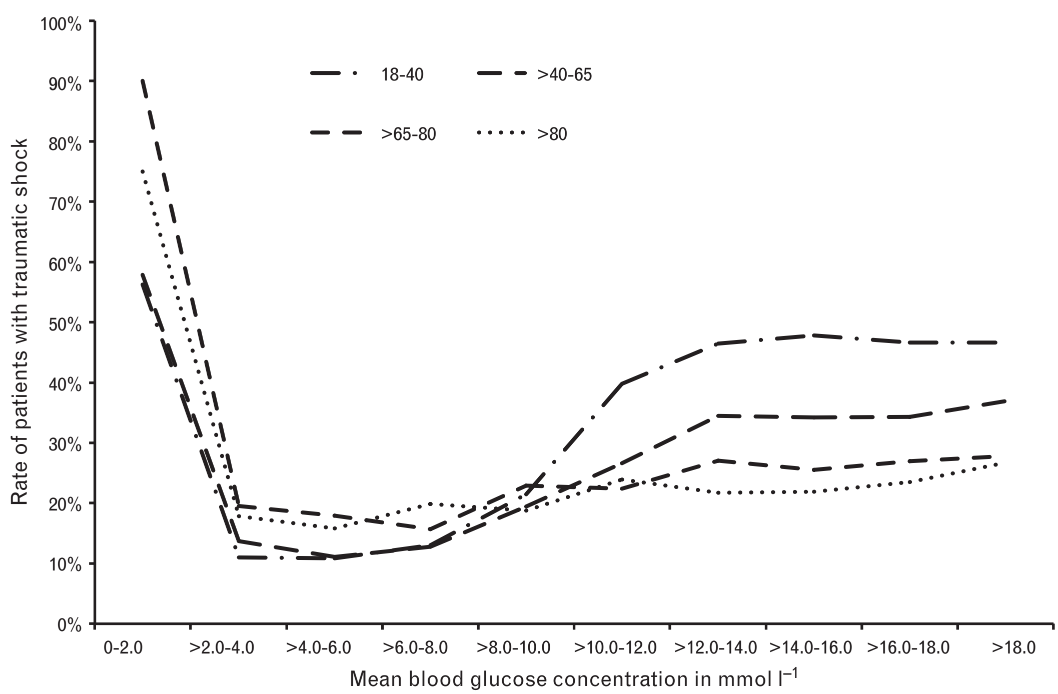
Hyperglycaemia may be a consequence of the hypothalamic–pituitary–adrenal stress response following trauma as levels of stress hormones correlate with injury severity and shock.[19,20] In animal studies, severe haemorrhage and haemorrhagic shock are among the

Fig. 2



Rate of patients with traumatic shock in relation to injury pattern and blood glucose concentrations; polytrauma: multiple injuries, of which one or the sum of them is life threatening according to the clinical assessment of the emergency physician.

Fig. 3



Rate of patients with traumatic shock in relation to age and blood glucose concentrations.

Table 2 Patients categorised according to initial blood glucose concentration

Blood glucose concentration	≤2.8 mmol l⁻¹ *n* (%)	2.81 to 10.0 mmol l⁻¹ *n* (%)	>10 mmol l⁻¹ *n* (%)	*P* value
Number of patients	132 (0.7)	18 737 (92.9)	1308 (6.5)	
Scores				
GCS 13 to 15	68 (51.5)	13 440 (71.3)	705 (53.9)	<0.0001
GCS 8 to 12	22 (16.7)	1729 (9.2)	167 (12.8)	0.008
GCS 3 to 7	42 (31.8)	3568 (19.0)	436 (33.3)	<0.0001
NACA 1 to 3	21 (15.9)	4191 (22.4)	226 (17.3)	0.106
NACA 4,5	84 (63.6)	14 058 (75.0)	1001 (76.5)	0.005
NACA 6,7	27 (20.5)	488 (2.6)	78 (6.0)	<0.0001
Injury pattern				
Single injury	24 (18.2)	2733 (14.6)	294 (22.5)	0.325
Multiple injury	77 (58.3)	13 481 (71.9)	778 (59.5)	0.001
Polytrauma	31 (23.5)	2523 (13.5)	236 (18.0)	0.002
Others				
Traumatic shock	44 (33.3)	2618 (14.0)	377 (28.8)	<0.0001
Glucose infusion	64 (48.5)	139 (0.7)	3 (0.2)	<0.0001

NACA parameter is assigned at the end of the Helicopter Emergency Medical Service mission. SD: standard deviation; injury severity 1 to 6, definition see method section; Polytrauma: multiple injuries, of which one or the sum of them is life threatening according to the clinical assessment of the emergency physician; GCS, Glasgow Coma Scale; NACA, National Advisory Committee for Aeronautics index.

strongest stressors leading to the highest catecholamine concentrations.[20–22] High catecholamine concentrations lead to massive release of pro-inflammatoric cytokines in the liver[23,24] and trigger glycogenolysis and gluconeogenesis by degradation of muscle lactate and glucoplastic amino acids[25] and lipolysis.[26] In severe trauma and shock, renal gluconeogenesis produces up to 40% of blood glucose by renal degradation of lactate and glycerol.[27,28] In parallel, tumor necrosis factor alpha mediates a peripheral insulin resistance mainly in muscles producing glucose from muscle glycogen.[29–31] In addition, the stress response has impacts on immune defence and wound healing.[32–34.] Furthermore, hyperglycaemia facilitates glucose uptake because of a higher concentration gradient in tissue with disturbed microcirculation and increased need especially in the brain following injury,[34–36] and improves cardiac function and resistance during stress.[37–39]

Hypoglycaemia in trauma patients may result from antihyperglycaemic drug overdose from insulin, antidiabetic drugs or glucagon. In some cases, hypoglycaemia may even be the cause of the accident and not a consequence. Other causes of hypoglycaemia may be from shivering because of hypothermia,[40,41] chronic liver disease with limited functional reserves and organ failure of liver and kidney in patients with traumatic shock.[13,42–44]

Up to now, blood glucose concentration measurements are not advocated as routine investigation in Prehospital Trauma Care, Advanced Trauma Care and in German guidelines for the treatment of multiple-injured patients.[45] In addition to standard vital parameters, blood glucose concentrations may provide advanced information on the volume state of patients, depending on age

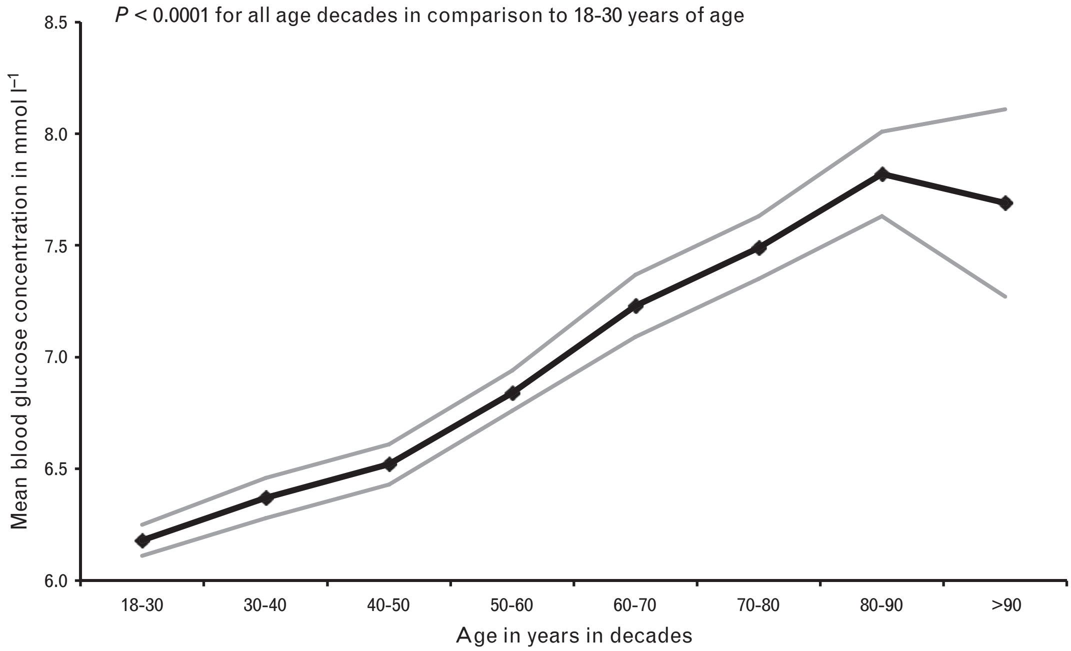
Table 3 Estimation of the predictive accuracy in all patients with documented circulation (heart rate >30 min⁻¹ and SBP >40 mmHg)[18] using logistic regression models and additional predictive value of model 2 in comparison to model 1 using integrated discrimination improvement and net reclassification improvement

Prediction of	Model 1: common vital parameters AUC: All patients *n* = 19 854	Single injury *n* = 2986	Multiple injury *n* = 14 285	Poly-trauma *n* = 2583	Model 2: common vital parameters and prehospital blood glucose AUC: All patients *n* = 19 854	Single injury *n* = 2986	Multiple injury *n* = 14 285	Poly-trauma *n* = 2583	Significance AUC both models: All patients *P*	Single injury *P*	Multiple injury *P*	Polytrauma *P*
Admin. of Catecholamines	0.842	0.796	0.837	0.719	0.845	0.800	0.843	0.721	<0.001	0.088	0.009	0.210
Admin. of >500 ml of fluids	0.557 *n* = 3765	0.679 *n* = 514	0.601 *n* = 2757	0.703 *n* = 494	0.645 *n* = 3765	0.680 *n* = 514	0.719 *n* = 2757	0.725 *n* = 494	<0.001	0.960	<0.001	0.010

	IDI: All patients *P*	Single injury *P*	Multiple injury *P*	Polytrauma *P*	NRI: All patients *P*	Single injury *P*	Multiple injury *P*	Polytrauma *P*
Admin. of Catecholamines	<0.0001	0.0002	<0.0001	0.001	0.043	0.219	0.072	0.034
Admin. of >500 ml of fluids	<0.0001	0.001	<0.0001	0.001	<0.0001	0.006	<0.0001	0.001

AUC (area under the curve) is part of receiver operating characteristics analysis; common vital parameters are: SBP, heart rate, breathing frequency and Glasgow Coma Scale at accident site; cardiac arrest: surrogate parameters. NACA index 6,7: National Advisory Committee for Aeronautics index: 6 = apnoea and circulatory arrest/resuscitation; 7 = deceased; IDI: integrated discrimination improvement; NRI, net reclassification improvement.

Fig. 4



Mean blood glucose concentration by age including 99% confidence interval.

and injury pattern. (Table 1, Figs. 2 and 3) The large number of patients treated during a 9-year observation period in a nationwide study permits reliable interpretation of study results. However, there is no colinearity between blood glucose concentrations and arterial blood gas sample results.[10,11,13] Furthermore, blood glucose concentrations seem to be independent of the volume administered on-site, but may be influenced by impaired circulation.[13] The results of our study underline that there is a marked relation between blood glucose concentration and outcome in patients with trauma of varying severity.[5–13]

Although excessive hyperglycaemia and hypoglycaemia were predictive for traumatic shock in our study, we have no information on the impact that glucose infusion has on survival in trauma patients with proven hypoglycaemia.

Limitations of this study are because of its retrospective nature. No information on laboratory examination results after hospitalisation is available, including course of the disease, confirmed diagnoses, trauma scores and outcome at hospital discharge. No information on previous illnesses, especially diabetes mellitus, was obtainable. According to the German Diabetes Report,[46] the prevalence of diabetes mellitus among adults averaged about 7 to 8% with increasing prevalence depending on age. Approximately, 1500 patients in that study population may have had diabetes mellitus in addition to the known increase in insulin resistance with age.[47] This could in part explain why the age-dependent increase in initial blood glucose concentration did not depend on injury severity in our study (Fig. 4). No information on chronic medication, especially antidiabetic drugs and insulin, was obtainable. Blood glucose concentration may vary individually depending on the time of drug ingestion/administration, the extent of recent oral carbohydrate intake and the individual stress response after trauma. In addition, blood glucose concentrations in traumatised patients may increase during initial care with ongoing stress response and development of traumatic shock until hospital admission, especially in polytraumatised patients. The incidence of polytraumatised patients with blood glucose concentration exceeding 10.0 mmol l^{-1} increased from 376/2790 (13.5%) in the prehospital population to 195/834 (23.4%) on hospital admission ($P < 0.0001$).[10,11,13]

The number of patients in the included and excluded study population was similar and both populations were clinically comparable. (Table 4) However, those excluded because of missing documented blood glucose concentration contained nine-fold more patients who were declared dead or did not survive resuscitation on scene (NACA 7) [220/20 177 patients (1.1%) vs. 1970/20 479 patients (9.6%), $P < 0.0001$] compared with the study group. Consequently, this population differed in initial vital signs, state of consciousness and initial GCS, and included more severely injured patients.

Table 4 Comparison of characteristics between included patients and excluded (missing blood glucose concentration measurement) patients

	All patients n (%) mean ± SD	Included patients n (%) mean ± SD	Excluded patients n (%) mean ± SD
Number of patients	40 656	20 177	20 479
Demographics			
Age	48.5 ± 19.5	50.4 ± 20.0	46.6 ± 18.1
Sex			
Male	28 650 (70.5)	14 037 (69.6)	14 613 (71.4)
Female	11 931 (29.3)	6140 (30.4)	5791 (28.3)
Missing	75 (0.2)	0	75 (0.4)
Vital signs			
Respiratory rate	14.1 ± 5.0	14.5 ± 4.5	13.7 ± 5.6
Missing	3451 (8.5)	0	3451 (16.9)
Heart rate	87 ± 26	89 ± 22	85 ± 30
Missing	816 (2.0)	0	816 (4.0)
SBP	125 ± 40	132 ± 34	119 ± 45
Missing	1161 (2.9)	0	1161 (5.7)
State of consciousness			
Analgosedation	5242 (12.9)	2325 (11.5)	2917 (14.2)
Orientated	22 847 (56.2)	11 177 (55.4)	11 670 (57.0)
Somnolent	6062 (14.9)	3584 (17.8)	2478 (12.1)
Unconscious	5194 (12.8)	1801 (8.9)	3393 (15.1)
Missing	1311 (3.2)	1290 (6.4)	21 (0.1)
Scores			
GCS 13 to 15	27 409 (67.4)	14 213 (70.4)	13 196 (64.4)
GCS 8 to 12	3251 (8.0)	1918 (9.5)	1333 (6.5)
GCS 3 to 7	9975 (24.5)	4046 (20.1)	5929 (29.0)
Missing	21 (0.05)	0	21 (0.1)
NACA 1 to 3	9403 (23.1)	4441 (22.0)	4962 (24.2)
NACA 4,5	28 690 (70.6)	15 143 (75.0)	13 547 (66.2)
NACA 6,7	2563 (6.3)	593 (2.9)	1970 (9.6)
Missing	0	0	0
Trauma cause			
Blunt	38 793 (95.4)	19 491 (96.6)	19 302 (94.3)
Penetrating	1722 (4.2)	686 (3.4)	1036 (5.1)
Missing	141 (0.3)	0	141 (0.7)
Single injury	5669 (13.9)	3051 (15.1)	2618 (12.8)
Multiple injury	28 095 (69.1)	14 336 (71.1)	13 759 (67.2)
Polytrauma	6892 (17.0)	2790 (13.8)	4102 (20.0)
Missing	0	0	0
Injury regions			
Head/brain	26 337 (64.8) 3.86 ± 1.58	14 753 (73.1) 3.60 ± 1.53	11 584 (56.6) 4.19 ± 1.59
Neck	8544 (21.0) 3.36 ± 1.31	4604 (22.8) 3.15 ± 1.04	3940 (19.2) 3.57 ± 1.55
Face	8310 (20.4) 3.36 ± 1.21	4212 (20.9) 3.25 ± 1.08	4098 (20.0) 3.47 ± 1.32
Chest	16 000 (39.4) 3.84 ± 1.29	7658 (38.0) 3.69 ± 1.13	8342 (40.7) 3.97 ± 1.42
Abdomen	7208 (17.7) 3.97 ± 1.36	3273 (16.2) 3.78 ± 1.19	3935 (19.2) 4.11 ± 1.51
Thoracic and lumbar spine	9557 (23.5) 3.57 ± 1.0	4953 (24.5) 3.52 ± 0.93	4604 (22.5) 3.60 ± 1.11
Pelvis	6289 (15.5) 3.79 ± 1.25	3146 (15.6) 3.67 ± 1.12	3134 (15.3) 3.89 ± 1.37
Upper extremities	13 167 (32.4) 3.35 ± 0.97	6456 (32.0) 3.29 ± 0.92	6711 (32.8) 3.40 ± 1.02
Lower extremities	12 757 (31.4) 3.74 ± 1.14	5932 (29.4) 3.64 ± 1.08	6825 (33.3) 3.82 ± 1.20
External	716 (1.8) 1.29 ± 0.64	264 (1.3) 1.23 ± 0.58	452 (2.3) 1.54 ± 0.69
Traumatic shock	7687 (18.9)	3039 (15.1)	4648 (22.7)

GCS, Glasgow Coma Scale; NACA, National Advisory Committee for Aeronautics.

(Table 4) When excluding these NACA 7 patients, the study population and the sample lacking blood glucose concentration documentation were even more comparable. Nevertheless, a biased selection of patients in both groups cannot be excluded. In more severe cases, HEMS physicians focus on vital functions and cardiorespiratory support rather than on laboratory investigations. As blood glucose concentration can provide further information on severity and prognostic outcome, we recommend that on-site blood glucose concentration measurement should become a standard investigation in trauma patients.

In our study, blood glucose concentration was measured before intravenous treatment was started. In patients with haemodynamic shock it may be more difficult to obtain venous blood for glucose concentration measurement. In venous blood, measured blood glucose concentration may be lower than in capillary blood,[48–50] but Ramachandran *et al.*[51] did not find significant differences between venous and capillary blood glucose concentrations in children with shock. In contrast, Pulzi Júnior *et al.*[52] found higher blood glucose concentrations in capillary blood from patients in shock who received noradrenaline (norepinephrine) or had diminished tissue perfusion. Furthermore, we do not know about the accuracy of glucose concentration measurements in different point-of-care devices[53–55] used during the study phase. However, a study testing reflectometer analysis of venous blood from venous access in prehospital emergency patients found a very high congruence of the results with laboratory analysis.[56] Nevertheless, especially when glucose concentrations are extremely low or high, repeated measurements are recommended.

Owing to rather short arrival intervals of the HEMS emergency physician, cases with delayed onset of shock may have been missed. Furthermore, the need for catecholamine administration during on-site treatment of critically injured patients is not always associated with bleeding and haemorrhagic shock. Patients with severe traumatic brain injury, for instance, may have received catecholamines to maintain cerebral perfusion pressure. However, in traumatic brain injury without clinical signs of hypovolaemia deranged blood glucose concentration is associated with poor outcome too.[8, 9]

In conclusion, blood glucose concentration measurements in addition to common vital parameters (GCS, HR, blood pressure, breathing frequency) may help identify patients at risk of traumatic shock in adult trauma patients.

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