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Effects of accidental hypothermia on posttraumatic complications and outcome in multiple trauma patients

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ABSTRACT

Introduction: Accidental hypothermia seems to predispose multiple trauma patients to the development of posttraumatic complications, such as Systemic Inflammatory Response Syndrome (SIRS), sepsis, Multiple Organ Dysfunction Syndrome (MODS), and increased mortality. However, the role of accidental hypothermia as an independent prognostic factor is controversially discussed. The aim of the present study was to evaluate the incidence of accidental hypothermia in multiple trauma patients and its effects on the development of posttraumatic complications and mortality.

Patients and methods: Inclusion criteria for patients in this retrospective study (2005–2009) were an Injury Severity Score (ISS) $\geq$16, age $\geq$16 years, admission to our Level I trauma centre within 6 h after the accident. Accidental hypothermia was defined as body temperature less than 35 °C measured within 2 h after admission, but always before first surgical procedure in the operation theatre. The association between accidental hypothermia and the development of posttraumatic complications as well as mortality was investigated. Statistical analysis was performed with χ^2-test, Student's *t*-test, ANOVA and logistic regression. Statistical significance was considered at $p < 0.05$.

Results: 310 multiple trauma patients were enrolled in the present study. Patients' mean age was 41.9 (SD 17.5) years, the mean injury severity score was 29.7 (SD 10.2). The overall incidence of accidental hypothermia was 36.8%. The overall incidence of posttraumatic complications was 77.4% (SIRS), 42.9% (sepsis) and 7.4% (MODS), respectively. No association was shown between accidental hypothermia and the development of posttraumatic complications. Overall, 8.7% died during the posttraumatic course. Despite an increased mortality rate in hypothermic patients, hypothermia failed to be an independent risk factor for mortality in multivariate analysis.

Conclusions: Accidental hypothermia is very common in multiply injured patients. However, it could be assumed that the increase of mortality in hypothermic patients is primarily caused by the injury severity and does not reflect an independent adverse effect of hypothermia. Furthermore, hypothermia was not shown to be an independent risk factor for posttraumatic complications.

Introduction

Hypothermia is defined as a core temperature less than 35 °C.[1–9] Multiple trauma patients are predisposed to accidental hypothermia due to exposure to the environment, application of cold intravenous fluids and anaesthetic medication. Additionally, haemorrhagic shock with anaerobic metabolism and hypoperfusion of the thermoregulatory centres in the hypothalamus leads to a reduced thermogenesis.[10–13] At the time of admission, accidental hypothermia occurs in up to 66% in severely injured patients[3,14,15] having potentially serious physiological effects on coagulation and haemodynamic system. Especially, vascular, extremity, pelvic and abdominal injuries seem to be associated with the development of accidental hypothermia.[14,16] Furthermore, the extent of hypothermia correlates with overall injury severity of multiple trauma patients.[17]

Several studies have reported an association between accidental hypothermia and the risk for posttraumatic complications[11] and worse outcome.[10,18–20] In severely injured patients with a core temperature <32 °C, a mortality rate of 100% has been described.[19]

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Due to these negative effects of accidental hypothermia current trauma care guidelines recommend early and effective rewarming of hypothermic trauma patients. However, Steinemann et al. described an association between accidental hypothermia and increased mortality, but not after stratification by physiological and anatomic indicators of injury severity.[7] In a recent study, Beilman et al. reported accidental hypothermia to be a significant risk factor for Multiple Organ Dysfunction Syndrome (MODS), but not for mortality.[11]

Therefore, the role of accidental hypothermia as an independent predictor for the development of posttraumatic complications and mortality in multiple trauma patients is still controversially discussed. The question remains whether accidental hypothermia has a primary impact on trauma outcome or simply represents the result of injury severity and exposure. Therefore, the present study aimed to evaluate the incidence of accidental hypothermia in multiple trauma patients as well as the effects of accidental hypothermia on the development of posttraumatic complications, such as MODS, Systemic Inflammatory Response Syndrome (SIRS) and sepsis, and mortality.

Patients and methods

Ethical approval and informed consent

The present study has been approved by the local Ethical Committee. The need to obtain informed consent was waived by the local ethical committee.

Inclusion and exclusion criteria

Multiple trauma patients [Injury Severity Score (ISS) $\geq$16] aged $\geq$16 years treated at our Level 1 trauma centre between January 2005 and March 2009 were included in the present study. Further inclusion criteria were primary admission to our hospital within 6 h after injury and documentation of temperature within 2 h after admission, but before the first surgical procedure in the operation theatre. Exclusion criteria were steroidal and non-steroidal anti-inflammatory medication, hormone therapy, vascular obstruction (cardiac coronary disease, renal dysfunction, diabetes), malignancy or chronic diseases of the liver, kidneys or lung due to their marked impact on posttraumatic complications and outcome (Table 1).

Definitions

MODS was defined according to Marshall et al.[21] According to the literature, manifest MODS was considered at a Marshall Score >8 points on at least 1 day during the observation period.[21,22] Diagnosis of SIRS was related to the criteria of the Consensus Conference of the American College of Chest Physicians and Society of Critical Care Medicine [ACCP/SCCM] on at least 2 consecutive days.[23] Hypothermia was defined as a documented temperature less than 35 °C within the first 2 h after admission to our trauma centre, but at least before operative interventions in order to exclude a perioperative loss of body temperature. This temperature limit is well accepted in the medical literature.[2,3,5–9,24] Body temperature was determined by bladder or oesophageal probe (in case of urethral or pelvic injuries), both representing reliable methods for the measurement of core temperature.[10,25–29] Temperature data was recorded electronically.

Table 1
Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Age $\geq$16	Steroidal and non-steroidal
ISS $\geq$16	anti-inflammatory medication
Primary admission within 6 h after trauma	Hormone replacement
	Malignancies
Documentation of temperature within 2 h after admission	Chronic diseases of liver, kidneys or lung
	Vascular obstruction

Clinical parameters and outcome evaluation

Clinical data including demographics, mechanism of injury, distribution of concomitant injuries according to the Abbreviated Injury Scale (AIS), as well as duration of intensive care and mechanical ventilation, and mortality were recorded. Laboratory, haemodynamic and respiratory parameters were documented. The results of clinical examination and blood chemistry were recorded up to 14 days after admission.

Statistical analysis

In the present explorative study the influence of hypothermia on the development of posttraumatic complications and mortality was modelled with χ^2-test and multivariable logistic regression. For the adjustment of potential confounders, clinically relevant and statistically significant variables (p-value $\leq$0.2) were entered into the multivariable model. Confounders in all analyses included age, transfusion of PRBC (packed red blood cells), plasma (FFP) and platelets (PLT) as well as ISS, traumatic brain injury (AIS_{head}) and further concomitant injuries (AIS_{face}, AIS_{chest}, $AIS_{abdomen}$, $AIS_{extremity}$, $AIS_{external}$). Differences in the duration of ventilation, length of ICU and hospital stay between hypothermic and non-hypothermic patients were analysed using ANOVA following pairwise t-test. Again, the analytic model included the aforementioned confounding factors from univariate analyses. Results are presented as two-sided 95% confidence intervals for the difference in means or the odds ratio. The level of statistical significance was considered at $p < 0.05$. Due to the explorative character of the present study, a multiplicity correction was omitted. Statistical analysis was performed using SPSS computer software (SPSS 11.5, Chicago, IL, USA) and SAS (Version 9.2, Cary, NC, USA).

Results

Demographics and hypothermia

310 patients with multiple injuries [mean age 41.9 years, standard deviation (SD) 17.5] were included in the present study. 220 patients (71.0%) were male and 90 (29.0%) were female. The mean ISS was 29.7 (SD 10.2). Overall demographic data are summarised in Table 2. The overall incidence of accidental hypothermia was 36.8% (Table 3). 70 patients (22.6%) showed a body temperature between 35 °C and 34 °C (mild hypothermia). 42 patients (13.6%) suffered from a moderate hypothermia (body temperature between 34 °C and 32 °C) and 2 patients (0.6%) developed a body temperature less than 32 °C (severe hypothermia). Hypothermic patients were shown to have a higher ISS (p-value 0.048, t-test) and AIS_{head} (p-value 0.033, t-test) compared to non-hypothermic patients. In addition, hypothermic patients received more PRBC (p-value 0.005, t-test), FFP (p-value <0.001, t-test) and PLT (p-value <0.001, t-test). No differences could be observed concerning age and gender distribution between hypothermic and non-hypothermic patients. Demographic data in patients with or without hypothermia are presented in Table 2.

Clinical data

The overall mean duration of mechanical ventilation was 11.3 (SD 15.4) days, the overall mean length of intensive care unit and

Table 2
Demographic and clinical data.

	Overall	No hypothermia	Hypothermia	*p*-Value
Patients [*n*]	310	196	114	–
Gender [male:female]	220:90	145:51	75:39	0.161
Age [years]	41.9 (17.5)	41.4 (16.5)	42.8 (19.1)	0.483
ISS	29.7 (10.2)	28.8 (9.8)	31.2 (10.7)	0.048*
AIS_{head}	1.7 (1.7)	1.5 (1.7)	1.9 (1.8)	0.033*
AIS_{face}	0.9 (1.2)	0.82 (1.2)	1.1 (1.2)	0.076
AIS_{chest}	2.7 (1.5)	2.71 (1.5)	2.8 (1.5)	0.783
$AIS_{abdomen}$	1.3 (1.7)	1.2 (1.7)	1.4 (1.7)	0.325
$AIS_{extremity}$	2.4 (1.4)	2.4 (1.4)	2.3 (1.3)	0.647
$AIS_{external}$	1.5 (1.1)	1.4 (1.1)	1.6 (1.1)	0.076
Mortality [*n*]	27 (8.7%)	11 (5.6%)	16 (14.0%)	0.020*
SIRS [*n*]	240 (77.4%)	144 (73.5%)	96 (84.2%)	0.091
Sepsis [*n*]	133 (42.9%)	77 (39.3%)	56 (49.1%)	0.188
MODS [*n*]	23 (7.4%)	13 (6.6%)	11 (9.6%)	0.486
Duration of ventilation [days]	11.3 (15.4)	8.0 (11.5)	17.0 (19.3)	<0.001*
Intensive care unit stay [days]	13.3 (16.5)	10.3 (12.8)	18.6 (20.4)	<0.001*
Hospital stay [days]	28.8 (23.3)	27.0 (19.9)	32.0 (28.0)	0.064
PRBC [*n*]	14.0 ± (16.6)	11.5 (14.4)	18.2 (19.2)	0.005*
FFP [*n*]	9.4 ± (12.7)	7.6 (11.5)	12.5 (14.1)	<0.001*
PLT [*n*]	1.5 ± (3.6)	1.1 (3.6)	2.1 (3.4)	<0.001*

* Statistical significance ($p < 0.05$) as indicated by χ^2-test (categorical variables) or *t*-test (continuous variables).

hospital stay 13.3 (SD 16.5) and 28.8 (SD 23.3) days, respectively (Table 2). In comparison to patients without hypothermia, hypothermic patients were longer ventilated (*p*-value <0.001, *t*-test) and had an increased length of ICU stay (*p*-value <0.001, *t*-test). In accordance, multivariable analysis with ANOVA revealed hypothermia to be an independent predictor for duration of mechanical ventilation (*p*-value <0.001, 95% CI −9.43; −2.71) and ICU stay (*p*-value 0.002, 95% CI −9.66; −2.28). In contrast, patients with hypothermia showed no prolonged hospital stay compared to non-hypothermic patients (*p*-value 0.064, *t*-test). Additionally, multivariable analysis failed to show an association between hypothermia and the length of hospital stay (*p*-value 0.390, 95% CI −7.56; 2.96).

Posttraumatic complications and outcome

The overall incidence of SIRS, sepsis and MODS was 77.4%, 42.9% and 7.4%, respectively. As presented in Table 2, the incidence of these posttraumatic complications was not significantly different depending on the presence of hypothermia (*p*-value >0.05, χ^2-test). Accordingly, hypothermia failed to be an independent prognostic factor for the development of SIRS (*p*-value 0.337, OR 1.43, 95% CI .69; 2.95), sepsis (*p*-value 0.868, OR 1.05, 95% CI 0.58; 1.91) and MODS (*p*-value 0.952, OR 0.97, 95% CI 0.36; 2.59) in the logistic regression. In overall, 27 patients (8.7%) died during the posttraumatic course (Table 2). Hypothermic multiple trauma patients showed a higher mortality rate (14.0%) compared to non-hypothermic patients (5.6%) (*p*-value 0.011, χ^2-test). However, multivariable analysis with logistic regression including potential confounders revealed that other clinical parameters are more associated to mortality than hypothermia (*p*-value 0.107, OR 2.05, 95% CI 0.86; 4.92). The results of the logistic regression are summarised in Table 4.

Table 3
Incidence of hypothermia.

Hypothermia (overall) [%]	36.8
Mild (<35–34 °C) [%]	22.6
Moderate (<34–32 °C) [%]	13.6
Severe (<32 °C) [%]	0.6

Discussion

The present study aimed to evaluate the incidence of accidental hypothermia in multiply injured patients and its impact on the development of posttraumatic complications and mortality in a European Level I trauma centre. In the present study population of multiply injured patients, accidental hypothermia was found in 36.8% with no differences in regards to age and gender distribution depending on the presence of accidental hypothermia.[10,11] These results are in accordance to the current literature reporting an incidence of accidental hypothermia in up to 66% depending on the definition of hypothermia and the enrolled trauma population.[10,11,14,15,30] Supporting the association between the injury severity and the development of hypothermia described in previous studies,[10,11,14,16,17] we found a significantly increased ISS in hypothermic patients compared to non-hypothermic patients ($p = 0.048$). In accordance to previous studies,[10,20] hypothermic patients suffered more often from severe traumatic brain injuries (TBI) in the present study. In this context, these results support impaired thermoregulation due to damage to thermo-regulative, hypothalamic areas as one cause of accidental hypothermia. In contradiction, Steinemann et al. reported no differences concerning TBI between hypothermic and non-hypothermic trauma patients.[7] Hypothermic patients received significantly more blood products compared to non-hypothermic patients in the present study ($p < 0.05$) probably indicating more severe haemorrhage in hypothermic patients due to increased injury severity. Accordingly, Beilman et al. described a significantly increased transfusion rate of PRBCs in case of hypothermia.[11] In contrast, Ireland et al. found no difference in transfused blood products depending on the presence of hypothermia.[10] In the study of Ireland et al., the overall injury severity as well as the injury severity of the hypothermic and non-hypothermic subgroup was lower compared to the investigation of Beilman et al.[11] and our study. As we found the ISS (PRBC: *p*-value 0.0055, OR 1.349; FFP: *p*-value 0.033, OR 1.655; PLT: 0.005, OR 2.040) to be an independent factor for the transfusion of blood products, this might be an explanation for the missing differences concerning transfused blood products in the aforementioned study.[10]

Despite a significantly increased mortality rate in hypothermic patients compared to non-hypothermic patients ($p = 0.02$), multivariable analysis with logistic regression demonstrated

Table 4
Results of logistic regression.

Logistic regression	Frequency of poor outcome [%]		Odds ratio [95% confidence interval]	*p*-Value
	1st category[a]	2nd category		
Mortality				
Hypothermia (no:yes)	5.6	14.0	2.05 [0.86; 4.92]	0.107
ISS (≤27:>27)	3.1	14.9	4.09 [1.44; 11.62]	0.008
AIS_{head} (≤1:>1)	3.6	14.5	3.61 [1.34; 9.73]	0.011
$AIS_{external}$ (≤2:>2)	9.7	3.9	0.32 [0.07; 1.49]	0.147
FFP (≤6:>6)	4.7	13.8	3.20 [1.27; 8.08]	0.014
SIRS				
Hypothermia (no:yes)	73.5	84.2	1.43 [0.69; 2.95]	0.337
ISS (≤27:>27)	72.3	82.2	1.58 [0.84; 2.99]	0.158
FFP (≤6:>6)	69.2	86.9	2.59 [1.29; 5.21]	0.007
Sepsis				
Hypothermia (no:yes)	39.3	49.1	1.05 [0.58; 1.91]	0.868
ISS (≤27:>27)	36.2	49.6	1.57 [0.91; 2.73]	0.108
$AIS_{external}$ (≤2:>2)	38.4	62.8	2.57 [1.26; 5.23]	0.010
FFP (≤6:>6)	30.7	57.6	2.87 [1.62; 5.08]	<0.001
MODS				
Hypothermia (no:yes)	6.6	9.6	0.97 [0.36; 2.59]	0.952
ISS (≤27:>27)	3.7	11.6	2.79 [0.96; 8.10]	0.059
PLT (0:>0)	3.4	15.9	4.74 [1.68; 13.38]	0.003

[a] First category is reference.

hypothermia not to be an independent factor of mortality (*p*-value 0.138, OR 1.958) in the present study. These observations are in accordance with previous studies[7,11] suggesting that increased mortality in hypothermic trauma patients is primarily caused by injury severity and does not reflect an independent adverse effect of hypothermia. In contrast, several studies found accidental hypothermia to be an independent factor of mortality in multiple trauma patients.[10,18–20] However, comparison of data is difficult due to differences in study population characteristics and inclusion of confounding factors. In comparison to the present study, Ireland et al. included less severely injured and secondarily transferred patients.[10] In order to prevent a bias due to in-hospital interventions conducted by the referral department, we excluded secondarily transferred patients. Additionally, we entered the transfusion of blood products as a potential confounding factor of mortality to the model of multivariable analysis unlike the aforementioned studies.[10,20] In accordance to our study, Beilman et al., who failed to prove accidental hypothermia as an independent factor for mortality, also included the transfusion of PRBCs in their multivariable analytic model.[11] Therefore, it might be assumed that the in- or exclusion of transfused blood products as an indicator of haemorrhage and injury severity might be a further explanation for the contradicting results. In this context, we could demonstrate hypothermia to be an independent factor of mortality when using a reduced multivariable analytic model without transfused blood products (*p*-value 0.028, OR 2.580). Therefore, we conclude that accidental hypothermia reflects injury severity and haemorrhage rather than representing an independent factor for adverse outcome. In the present study, 73 patients were excluded due to missing temperature data. Stratifying characteristics (e.g. age, gender, injury severity) for patients without temperature data were similar to those for patients enrolled in the present study. However, patients with missing temperature data revealed more severe TBI (AIS_{head} 2.01 ± 1.83 vs. 1.66 ± 1.73; $p = 0.141$) and increased mortality (15.1% vs. 8.7%, $p = 0.102$), but without reaching statistical significance. Nonetheless, we performed an additional sensitivity analysis for mortality including patients with missing temperature data as a separate category. However, we could not include the transfusion of blood products in this multivariable logistic regression model due to unavailable data. As the in- or exclusion of transfused blood products seems to have a decisive influence, it is not surprising that the presence of hypothermia was found to be prognostic for mortality in this model. In overall, slightly underestimation of mortality when excluding the patients with missing temperature data may represent a potential limiting factor of the present study. However, the enrolled study population reflects the entire trauma population as no significant differences concerning stratifying characteristics were found between the included and excluded patients making our results reliable. Furthermore, incomplete documentation of temperature data seems to reflect routine clinical work. Accordingly, previous studies excluded comparable numbers of patients due to missing temperature data.[20]

In the present study, univariate and multivariable analyses showed no association between accidental hypothermia and the development of posttraumatic complications such as SIRS, sepsis and MODS. In contrast, Beilman et al. reported hypothermia to be an independent risk factor for the development of MODS.[11] However, the study of Beilman et al. only focused on trauma patients with manifest haemorrhagic shock with assumable hypoperfusion and subsequent organ dysfunction.[11] Therefore, the patients enrolled in the study of Beilman et al. do not represent the entire population of multiply injured patients, which might be an explanation for the different study results.

In the present study, we demonstrated hypothermia to be an independent factor for the duration of mechanical ventilation and length of ICU stay, but not for the length of hospital stay. In accordance, less ICU free days were reported in hypothermic trauma patients in a previous study.[11] Whereas Ireland et al. also found no association between accidental hypothermia and the length of hospital stay,[10] Beilman et al. reported an increased length of hospital stay depending on accidental hypothermia.[11] These contradicting observations could be explained by the differences in study design and population characteristics of the aforementioned investigations. As the excluded patients revealed decreased length of hospital stay probably due to more severe TBI and subsequently increased mortality (both without statistical significance, $p > 0.05$), there might be a slightly overestimation of the length of hospital stay in the included patients. This may represent an explanation for the missing association of accidental hypothermia and length of hospital stay in the present study.

Conclusions

Accidental hypothermia is very common in multiply injured patients. Despite an increased mortality rate in hypothermic patients, hypothermia failed to be an independent factor of mortality in multivariable analysis. Therefore, it could be assumed that the increase of mortality in hypothermic patients is primarily caused by the injury severity and does not reflect an independent adverse effect of hypothermia. Furthermore, hypothermia was not shown to be an independent risk factor for posttraumatic complications.

Conflict of interest statement

There is no conflict of interest. All authors disclose any financial or non-financial competing interests. The presentation of the issue is independent.

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