Preventing Post-injury Hypothermia During Prolonged Prehospital Evacuation

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Abbreviations:
AUC = area under the curve
CI = confidence interval
ICU = intensive care unit
ISS = injury severity score
IV = intravenous
ROC = receiver operating characteristics

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Abstract

Introduction: Post-injury hypothermia is a risk predictor in trauma patients whose physiology is deranged. The aim of the present study was to examine the effect of simple, in-field, hypothermia prevention to victims of penetrating trauma during long prehospital evacuations.
Methods: A total of 170 consecutively injured landmine victims were included in a prospective, clinical study in Northern Iraq and Cambodia. Thirty patients were provided with systematic prehospital hypothermia prevention, and for 140 patients, no preventive measures were provided.
Results: The mean value for the time from injury to hospital admission was 6.6 hours (range: 0.2–72). The incidence of hypothermia (oral temperature <36°C) before prevention/rewarming was 21% (95% confidence interval: 15% to 28%). The Prevention Group had a statistically significant lower rate of hypothermia on hospital admission compared to the control group (95% confidence interval for difference: 6% to 24%).
Conclusion: Simple, preventive, in-field measures help to prevent hypothermia during protracted evacuation, and should be part of the trauma care protocol in rural rescue systems.

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Introduction

Trauma patients are predisposed to hypothermia unless precautions are taken.[1–3] Recent studies suggest that moderate hypothermia may be beneficial in traumatic brain injury due to a positive influence of hypothermia upon the cascades that may be responsible for the development of secondary damage.[4] However, deliberate transient hypothermia under close intensive care unit (ICU) monitoring and invasive control of physiological parameters is different fundamentally from protracted, uncontrolled hypothermia during long evacuations of exsanguinating patients with multiple, contaminated injuries. The immunologic response to injury is affected by hypothermia, the risk of wound infection increases when patients are exposed to light hypothermia before and during primary surgery.[5] Clinical studies show that core temperature <33°C (91°F), or a combination of light hypothermia and moderate acidosis are predictors of trauma death in major trauma victims.[6,7] The derangement of the coagulation system is significant at core temperatures below 35°C (95°F).[8–10] To avoid coagulopathic bleeding, surgery should be delayed until the patient is warm, and operations aborted before the core temperature goes below 35°C (95°F).[11] Consequently, even core temperatures at 35–36°C (95°F) on admission may interfere with the surgical management. This is in accordance with the revised classification of hypothermia by The Committee on Trauma of the American College of Surgeons: The Committee recommends that any core temperature <36°C (97°F) should be considered to be hypothermic.[12]

Once established, hypothermia is refractory in trauma patients who are in shock with diminished heat production. Even active and invasive rewarming techniques may be incapable of transferring significant quantities of heat.[10] On the other hand, preventive measures are simple. A recent study, Watts *et äl* found that a combination of reflective blankets, hot packs, and warm intravenous fluids significantly increased the body temperature during prehospital transport.[13] Watt's study was done on victims of blunt trauma with moderately severe injuries (median ISS at 9) and low prehospital transport times (one hour). The objectives of the present study were to study the effect of simple preventive measures in victims of penetrating trauma when prehospital transit times were prolonged.

Materials and Methods

In 1996, programs were initiated for prehospital assistance for victims of landmines in Cambodia and Kurdistan (Northern Iraq) in cooperation with local health authorities. In each country, districts with a high prevalence of landmine accidents were identified as target areas in which village, healthcare workers, ("mine medics") received 500 hours of training for the provision of supportive, trauma care and were equipped for the performance of advanced trauma life support.[14] Local mine medics reach mine victims in the rural catchment areas as soon as possible after injury, immediately start on-site life support, and continue to provide life support during the evacuation to an urban, referral hospital. Most landmine accidents occur far from towns and cities, and the site at which the injuries occur usually are off-road and require that the patients be carried in hammocks or on donkeys. There only are a few cars, and there is no ambulance system. In December and January, there are freezing temperatures in Northern Iraq, and the landmine fields are covered with snow; during the six summer months, the temperatures may reach 40°C (104°F). The average range of the ambient temperatures in Cambodia is 30–35°C (86-95°F). During the rainy season (July-September), large parts of the country are under water and many roads are blocked.

The subjects of the study were survivors of landmine accidents who were evacuated to the referral hospitals in the city of Suleimaniah, Northern Iraq and the city of Battambang, Cambodia during the period from June 1999 to June 2000. The referral hospitals in both countries are operated by the Italian medical relief organization, "Emergency". Both hospitals are professional surgical centers that use standardized, current protocols for the provision of trauma surgery.[15] Those patients that were evacuated from the scene of accident to the referral center by mine medics comprise the Prevention Group. These patients were provided with life support throughout their evacuation according to established principles. The prehospital protocol included the use of simple hypothermia prevention such as removal of wet clothes, buddy warming, wrapping in blankets, shielding from wind, and the intravenous infusion of temperate (40°C; 104°F) crystalloid fluids. The other group of patients consisted of persons injured in those districts in which prehospital trauma care was not available or was provided randomly, and precautions against in-field heat loss were not taken (Control Group). In the Prevention Group, oral temperatures were taken at the site of injury by the mine medics. All of the patients included had oral temperatures registered immediately on hospital admission by experienced emergency department staff. The temperatures were registered with plain digital thermometers left in place for two minutes.[16] All thermometers were calibrated monthly during the study period. Anatomical severity grading of the study patients (Injury Severity Score) was abstracted retrospectively by the authors.[17] All of the data elements required for the computation of physiological severity scoring were not abstracted.

Criteria for patient exclusion included unclear temperature data or insufficient available data for severity scoring. Twenty-two patients with incomplete temperature data, and four patients with insufficient data for severity scoring were excluded. Eight patients, all of them in Cambodia, had oral temperatures >38°C on hospital admission. These patients also were excluded, since the rate of post-injury malaria is high in trauma victims from this area. Thus, the study group consisted of 170 patients, 94 in Northern Iraq (55.3%) and 76 in Cambodia (44.7%). Of the 170 patients, 30 had in-field hypothermia prevention (17.6%; Prevention Group) and 140 patients (82.4%) had not (Control Group).

Hypothermia was defined as an oral temperature of <36°C (97°F). The ANOVA and Kruskall-Wallis tests were used for bivariate analysis of continuous and ordinal variables respectively.[18] The "Exact Method" was used for estimation of confidence intervals.[19] The null-hypothesis (no difference between groups) was rejected if the 95% confidence interval (95% CI) for the difference of means and proportions did not include zero. MedCalc (MedCalc, V5.0, Maria Kerke, Belgium) was used for determination of the Receiver Operating Characteristics (ROC) analysis of risk factors.[20] By definition, a test/risk factor has high accuracy/impact if the area under the ROC plots (AUC) is 0.9.[21] An AUC value of 0.5 signifies a useless test.

Results

The study group consisted predominantly of young males. The Prevention and the Control Groups, as well as the country groups were similar regarding gender, age, and injury severity score (ISS). Half of the patient population (51.8%) had serious injuries (ISS ≥9). Prehospital transit times were prolonged with a mean value for the evacuation times of 6.6 hours. The Prevention Group had longer evacuation times than did the Control Group (Table 1).

Prevalence of hypothermia: Of the study patients, 21.2% was hypothermic before prevention and/or rewarming were initiated — measured either at the first medical contact in the field (10 patients in the Prevention Group, 33.3%) or on hospital admission (26 patients in the Control Group,

	All Patients	Prevention Group	Control Group	Comparisons
Number	170	30	140	
Gender				
female	9	1	8	$p = 0.7$
male	161	29	132	
Age (years) (mean ±sd)	26.5 ±12.2	27.2 ±11.2	26.8 ±11.2	$p = 0.8$
Children (% <15 years)	11.7	13.3	11.4	$p = 0.8$
ISS* (mean (range))	7.1 (1–43)	8.0 (1–25)	6.9 (1–43)	95%CI diff =-1.4 to 3.6
Time (injury to admission hours, mean range)	6.6 (0.2–72)	10.6 (2–72)	5.8 (0.2–72)	95%CI diff = 1.1 to 8.5
Temperature (95% CI, °C)	36.8 (36.6 to 37.0)	37.3 (37.1 to 37.5)	36.7 (36.5 to 36.9)	95%CI diff = 0.2 to 1.0
Patients with hypothermia (%)**	15.9	3.3	18.6	95%CI diff = 24.3 to 6.1

*ISS = Injury Severity Score
95%CI diff= 95% confidence interval for the difference in mean values and proportions
** hypothermia = oral temperature <36°C on hospital admission

Table 1—Oral temperatures in the Prevention and Control Groups following injuries from landmine explosions (values in parentheses = 95% confidence intervals [CI])

18.6%). The mean value for the oral temperatures in the group of hypothermic cases was 35.1°C (95.2°F) (range: 31.0 to 35.9°C; 87.8 to 96.6°F). The rate of hypothermia in North Iraq was 25.5%, and, in Cambodia, was 15.8% (95% CI for difference: –2.3% to 21.8%).

Effects of prevention: Only one of the patients in the prevention group had persisting hypothermia on hospital admission, while the rate of hypothermia in the Control Group was 18.6% (95% CI for difference: – 24.3% to – 6.1%).

Effects of prehospital transit times: In the Control Group, the risk of hypothermia increased with increasing prehospital transit times (95% CI for ROC plot AUC 0.62 to 0.76). For the Prevention Group, there was no association between prehospital transit times and hypothermia (95% CI for AUC including 0.5).

Discussion

This is the first report of the incidence of accidental hypothermia in landmine victims. The results indicate that at least one out of five patients with penetrating trauma from landmine explosions are hypothermic on hospital admission when prehospital transit times are prolonged and precautions are not taken to prevent the development of hypothermia. In cohorts of higher severity, the rate of hypothermia probably would be higher. Moderately injured patients — as were most patients in the study population — maintain a reasonable capacity to produce heat, they have a rewarming capacity around 1°C/hour when the loss of heat is prevented.[10,22] Shivering and increased metabolic rate are the two basic ways for thermogenesis in the hypothermic patient. These mechanisms are impaired or blocked in seriously injured patients who are in circulatory shock and/or unconscious. Consequently, it should be even more important to prevent in-field heat loss in casualties with a lowered capacity for heat generation.

The main risk factor for the development of hypothermia seems to be that nothing is done to prevent heat loss during the prehospital phase. In the study patients who did not receive hypothermia prevention interventions, the risk of hypothermia increased with increasing transport times. In the prevention group, there was no association between transport times and hypothermia on hospital admission, which demonstrates the utility of simple preventive measures.

The hypothermia prevention protocol used in this study, was based on passive rewarming. To reduce heat loss by conduction and radiation, wet clothes were removed, and the patient was wrapped in dry blankets. Buddy warming was encouraged. Convective losses were reduced by windshields of plastic or canvas during out-door transports. The bags of intravenous electrolytes solutions were warmed for five minutes in hot water to get an infusion temperature to approximately 40°C (104°F). Intravenous infusions of warm solutions are not considered as active rewarming, but as a measure used to prevent heat loss. A patient receiving intravenous infusions at ambient temperature would consume approximately 15 kcal to raise the temperature of 1 liter of electrolyte solutions to 37°C (98.6°F); for 4 liters around 60 kcal would be needed, which is the equivalent of 1 hour heat production in an adult.[22] Thus, the intravenous administration of 4 liters of

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electrolyte solutions at ambient temperature to patients who are not able to respond with increased thermogenesis, would cause a 1°C decrease in core temperature.

Two methodological problems in this study should be addressed. First, it was not possible to register true core temperatures on hospital admission. Clinical studies in critically ill patients, indicate that oral thermometry using plain digital thermometers, are more accurate than is the use of tympanic thermometry. The mean deviation from true core temperatures in oral registrations is small (mean = 0.02°C ±0.50°C,1sd).[23] Inaccuracies of this magnitude do not affect the conclusions from the current study. Second, patients in the Prevention Group had external limb bleeding controlled by subfascial gauze packing and long compressive dressings, while improvised tourniquets were used to manage such hemorrhage in the Control Group. Previous studies indicate that the application of improvised tourniquets is an inefficient method for hemostasis, and even may cause increased blood loss.[24,25] Thus, the two groups may differ regarding the physiological impact of the injury — even if they are similar in anatomical injury severity. However, since the Injury Severity Score is an accurate predictor of trauma outcome and correlates well with physiological severity for victims with penetrating injuries, the salient results in this study are based on sound evidence.[26]

Conclusion

The development of accidental hypothermia after penetrating injuries is not uncommon when prehospital evacuations are prolonged. Simple and low-cost techniques for passive rewarming help to prevent post-injury hypothermia, and should be part of rural, prehospital trauma care protocols.

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