

Title: Hypothermia and associated outcomes in seriously injured trauma patients in a predominantly sub-tropical climate

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Abstract

Aim: This study aimed to determine factors linked to hypothermia (< 35°C) in Queensland trauma patients. The relationship of hypothermia with mortality, admission to intensive care and hospital length of stay was also explored.

Methods: A retrospective analysis of data from the Queensland Trauma Registry was undertaken, and included all adults admitted to hospital for ≥ 24 hours during 2003 and 2004 with an Injury Severity Score (ISS) > 15. Demographic, injury, environmental, care and clinical status factors were considered.

Results: A total of 2182 patients were included; 124 (5.7%) had hypothermia on admission to the definitive care hospital, while a further 156 (7.1%) developed hypothermia during hospitalisation. Factors associated with hypothermia on admission included winter, direct admission to a definitive care hospital, an ISS ≥ 40 , a Glasgow Coma Scale of 3 or ventilated and sedated, and hypotension on admission. Hypothermia on admission to the definitive care hospital was an independent predictor of mortality (Odds Ratio [OR] = 4.05; 95% Confidence Interval [CI] 2.26-7.24) and hospital length of stay (Incidence Rate Ratio [IRR] = 1.22; 95% CI 1.03-1.43). Hypothermia during definitive care hospitalisation was independently associated with mortality (OR = 2.52; 95% CI 1.52-4.17), intensive care admission (OR = 1.73; 95% CI 1.20-2.93) and hospital length of stay (IRR = 1.18; 95% CI 1.02-1.36).

Conclusions: Trauma patients in a predominantly sub-tropical climate are at risk of accidental and endogenous hypothermia, with associated higher mortality and care requirements. Prevention of hypothermia is important for all severely injured patients.

Keywords: Emergency treatment; Hypothermia; Intensive care; Length of stay;
Mortality; Transport; Trauma

1. Introduction

Hypothermia is an independent predictor of mortality in the trauma setting.¹⁻⁴

Incidence varies, but hypothermia in United States of America and military populations has been reported between 5-47%.³⁻¹⁰ While most studies have been conducted in cold or temperate climates,³⁻¹⁰ data from Queensland suggest that hypothermia in the trauma setting may occur at similar levels even in a sub-tropical, tropical or desert / grassland climate.^{11, 12} Development of hypothermia in patients with severe trauma in warm climates is poorly recognised in the literature.

The cause of non-therapeutic hypothermia can be endogenous or accidental.¹³

Endogenous hypothermia results from decreased heat production associated with metabolic dysfunction, insufficient thermoregulation in patients with central nervous system dysfunction and dermal dysfunction, as in burn injury. Accidental hypothermia can occur without thermoregulatory dysfunction and generally occurs as a result of environmental exposure at either the injury site or during transport. Non-therapeutic hypothermia in the hospital environment can result from large volume resuscitation, prolonged surgical procedures and environmental exposure where active steps are not taken to maintain normothermia.

The pathophysiological changes associated with hypothermia vary depending on severity, but have been recognised for many years.¹⁴ Shivering and vasoconstriction occur early in hypothermia and can lead to increased oxygen consumption and progressive acidosis.¹⁵ Importantly in trauma patients, even mild hypothermia results in compromised coagulation possibly as a result of impaired clotting enzyme function and platelet dysfunction.^{10, 13, 15} This triad of hypothermia, acidosis and coagulopathy

has been shown to be a lethal combination in trauma patients.¹⁶ The level of hypothermia that has a clinical impact on patients has not been clearly identified, but mortality rises significantly in trauma patients with admission temperatures less than 35°C.^{2,4}

Despite multiple reports of hypothermia in trauma patients detailing the negative sequelae associated with being hypothermic,^{1,2,4} only a limited description of the predictors of hypothermia in trauma patients was identified in the literature, namely, increased Injury Severity Score (ISS), hypotension, low Glasgow Coma Scale (GCS) score and a penetrating injury.¹⁻⁴ Clear articulation of the predictors of hypothermia has the potential to inform targeted preventive and treatment interventions.

Given the prevalence and potential consequence of hypothermia, this study aimed to determine factors linked to hypothermia in a predominantly sub-tropical climate and explore its association with hospital mortality, admission to the Intensive Care Unit (ICU) and hospital length of stay (LOS).

2. Methods

Study design and data source

This study was a retrospective analysis of data collected by the Queensland Trauma Registry (QTR) as part of ongoing trauma surveillance. The QTR collect data on all patients admitted for ≥ 24 hours to participating hospitals across the state for the acute treatment of injury and for those who died during the first 24 hours of admission as a result of injury. Patients with injuries coded as S00-S99, T00-T71 or T75 using the International Statistical Classification of Disease and Related Health Problems (10th

Revision) – Australian Modification (ICD 10-AM) were included. Patients were excluded from the QTR if admission exceeded 24 hours for a non-trauma-related cause, including medical, social or psychiatric reasons, elective surgery, medical complications and non-traumatic pathological injury. Fifteen hospitals participated in the QTR, including all tertiary referral hospitals, all paediatric speciality hospitals and 85% of regional hospitals providing definitive care of trauma patients in the state. Injury details were coded according to the Abbreviated Injury Scale – 1990.¹⁷

Inclusion and exclusion criteria

Specific criteria for inclusion in this study included hospital admission during 2003 and 2004 with QTR inclusion, age ≥ 18 years and an ISS > 15 or death during the first 24 hours of hospital admission regardless of ISS. Patients who were actively cooled were excluded from the study. Hypothermia was defined as a temperature $< 35^{\circ}\text{C}$ prior to or during the hospitalisation period. Time of admission to hospital was recorded as the first point of contact with each institution, i.e. admission to the Emergency Department (ED) or to the ward/unit, if the patient bypassed the ED. Details on the method of temperature measurement were not recorded, but comprised a range of methods used in clinical decision making, including tympanic, intravesical and intravascular.

Data quality

Data quality within the QTR was optimised by using trained coders and direct extraction from the health care record. Coders were either Registered Nurses with ED experience or Health Information Managers. A series of education and audit processes

were conducted to ensure data reliability. Logic and range checks were performed on the data prior to analysis.

Ethics

The operation of the QTR has been approved by the Human Research Ethics Committee (HREC) of the relevant university and hospitals and is recognised within the provisions of the Health Legislation Amendment Regulation (no. 7) 2006, under the Health Services Act 1991 (Queensland). Approval for this study was obtained from the HRECs of Princess Alexandra Hospital and Griffith University.

Statistical analysis

Data fields used in the analysis included:

- Hypothermia status – the presence of hypothermia prior to or on admission to the definitive care hospital (Hypothermia 1) and the presence of hypothermia during definitive care hospitalisation (Hypothermia 2)
- Demographic details – age and sex
- Injury details – number of regions injured, number of injuries, region of injury and ISS
- Environmental details – season and climate zone (sub-tropical, tropical and desert/ grassland) at the time and place of injury (Bureau of Meteorology, <http://www.bom.gov.au/climate/>)
- Care details – direct or indirect transportation to the definitive care hospital and need for an operation
- Clinical status – hypotension (systolic blood pressure [SBP] < 90 mmHg) and GCS on admission to the definitive care hospital

- Outcome data – in-hospital mortality, ICU admission and hospital LOS.

Univariate analyses investigated the antecedent or concurrent relationship of demographic, injury, environmental, care and clinical status variables on the presence of hypothermia and the consequent outcomes, as well as the effect of hypothermia on these outcomes. Age was centred in order to examine the polynomial effects of age² and age³. A $p < 0.10$ was used to identify factors for inclusion in the multivariate models. Generalised linear modelling methods were used for all analyses and outcomes were modelled as follows:

1. Multinomial logistic regression for hypothermia (reference group = normothermic): Relative Risk Ratio (RRR) and 95% Confidence Interval (CI) are reported for each variable
2. Negative binomial regression for LOS (days): Incidence Rate Ratio (IRR) and 95% CI reported
3. Logistic regression for hospital mortality (died = 1) and ICU admission (yes = 1): Odds Ratio (OR) and 95% CI reported.

The likelihood-ratio (LR) chi-square test was used for other univariate tests of association and for testing the partial polynomial age effect. Missing data for independent variables were accounted for by inclusion of a missing values category in the multivariate analyses. SPSS 14.0 (Chicago, IL) and Stata/SE 9.2 (College Station, TX) were used for data analysis. A two-sided p -value < 0.05 was considered statistically significant for all analyses.

3. Results

Study population

A total of 2541 patients met the inclusion criteria. One hundred patients were excluded due to receiving active cooling, the majority (72/100) of these had head injuries. A further 258 patients were excluded due to absent temperature data with one additional patient excluded due to temperature being recorded as 28°C without a consistent clinical description. A final sample of 2182 patients was used in the analysis, including 124 (5.7%) patients with hypothermia by the time of admission to the definitive care hospital (Hypothermia 1), 156 (7.1%) patients who first developed hypothermia during definitive care hospitalisation (Hypothermia 2) and 1902 (87.2%) patients who did not develop hypothermia (Normothermia) (Table 1).

Variables associated with hypothermia

Univariate analysis identified that sex, age and climate zone were the only variables not significantly associated with hypothermia (Table 1). Of note, nature of injury was significantly associated with hypothermia (LR chi-sq. = 51.8, 20 df, $p < 0.001$), however, since it is strongly and significantly associated with region of injury (LR chi-sq. = 4127.5, 60 df, $p < 0.001$) it was not included in the multivariate analyses. Likewise, the number of injuries and region of injury were not included as they were strongly and significantly associated with the number of regions injured (LR chi-sq. = 210.2, 18 df, $p < 0.001$, and LR chi-sq. = 2195.7, 12 df, $p < 0.001$, respectively).

Only a small number of variables continued to demonstrate an association with hypothermia when they were included in the multivariate analyses (Table 2). Injury during winter, direct (rather than indirect) transfer to hospital, ISS ≥ 40 , GCS = 3 or ventilated and sedated, and SBP < 90 mmHg were significantly linked to hypothermia on admission to the definitive care hospital. Injury during winter, ISS ≥ 26 , GCS = 3

or ventilated and sedated, and SBP < 90 mmHg were significantly linked to hypothermia during hospital admission.

Relationship of hypothermia and other variables with outcomes

Hypothermia status was significantly associated with hospital LOS, need for ICU admission and hospital mortality (Table 3). Neither season of injury nor climate zone had significant links to any outcome in the univariate analyses. After accounting for the effect of significantly related variables, hypothermia was significantly related to both hospital LOS and mortality (Table 4), but was only related significantly to ICU admission in those who developed hypothermia during their definitive care hospitalisation.

Hospital length of stay

In the multivariate analysis, hypothermia at any stage was significantly associated with an increase in LOS, with patients likely to stay 1.2 times longer than those with no hypothermia (95% CI 1.0-1.4 for both Hypothermia 1 and Hypothermia 2). Compared to the factor reference groups, indirect transfer to hospital, ≥ 4 injured regions, ISS ≥ 26 , GCS ≤ 8 or the need for ventilation and sedation, need for operative intervention and age were significantly associated with longer hospital stays.

Intensive Care Unit admission

In the multivariate regression, hypothermia during hospital admission (Hypothermia 2) was significantly associated with ICU admission where patients were 1.7 times more likely to be admitted to the ICU than patients without hypothermia (95% CI 1.0-

2.9). In comparison to the factor reference groups, ≥ 4 injured regions, $ISS \geq 26$, $GCS \leq 8$ or need for ventilation and sedation, need for operative intervention and age were significantly associated with admission to the ICU.

Hospital mortality

In the multivariate regression, hypothermia at any stage was significantly and independently associated with mortality. Patients were 4.1 times more likely to die if they had hypothermia on arrival at the definitive care hospital, compared with patients without hypothermia (95% CI 2.3-7.2). For patients that developed hypothermia during hospital admission, the odds of death were 2.5 times the normothermic group (95% CI 1.5-4.2). When compared to the factor reference groups, $ISS \geq 26$, $GCS \leq 12$ or need for ventilation and sedation and age were significantly and independently associated with death, whereas ≥ 2 injured regions, indirect hospital transfer and need for operative intervention were significantly associated with survival.

4. Discussion

Hypothermia has previously been described in trauma patients in cold and temperate climates,^{4,6,7} but our study confirms the presence and impact of hypothermia in trauma patients in sub-tropical, tropical and desert/grasslands climates, such as Queensland. The 17% incidence of hypothermia reported in a small sample in Sydney, Australia, is similar to our finding.¹¹ While 13% of trauma patients in our study developed hypothermia at some point following injury, it should be noted that 7% developed hypothermia during hospitalisation, suggesting an important quality control indicator. The identification of hypothermia occurring in both pre-hospital and hospital settings is consistent with earlier reports in this area and raises important

considerations for prevention and treatment.¹³ In the current study, the climatic season, severity of injury as measured by ISS, hypotension (SBP < 90 mmHg), low GCS and the transfer patterns for patients to reach definitive care were identified as independent predictors of hypothermia.

Importantly, hypothermia experienced at any stage throughout the care process was related to an increased mortality and hospital LOS, while post-admission hypothermia was associated with an increased incidence of ICU admission. The relationship of hypothermia with admission to ICU has not been reported before, while the relationship with mortality is consistent with previous reports.^{3, 4}

The association of accidental hypothermia with poor outcomes in the trauma setting is not unexpected given the significant pathophysiological changes that occur.^{10, 13-16} Vasoconstriction, increased oxygen consumption, acidosis and reduced clotting function combine to create significant physiological compromise. Of particular note, increased bleeding as a result of clotting dysfunction can present significant challenges in the care of the trauma patient.^{19,22}

Consistent with earlier work,^{3, 4, 7, 11} we identified increasing ISS as being associated with the development of hypothermia, increased care requirements of ICU admission and longer hospital LOS, as well as the detrimental outcome of increased mortality. While ISS has previously been recognised as being associated with an increased incidence of hypothermia and increased risk of mortality,^{3, 4, 7, 11} the calculation of ISS is not something that takes place immediately on admission of a trauma patient.

Therefore, ISS is not necessarily a factor that offers value in identifying patients at risk of poorer outcomes.

Multiple transfers between hospitals for the treatment of trauma have previously been proposed as a contributor to the incidence and impact of hypothermia,¹⁸ although the results of the current study do not lend support to this theory. We found that patients transported directly to definitive care hospitalisation were at increased risk of hypothermia. The extensive geographical catchment area of Queensland and potential longer transportation times to a tertiary hospital may explain this finding.

Furthermore, patients who attended at least one hospital prior to their definitive care experienced a longer hospital LOS but, in contrast, were less likely to die. One of the possible reasons for this impact on mortality is the death of severely injured hypothermic patients prior to admission to a hospital, which may bias the QTR through lack of inclusion of the most severely injured patients.

Limitations

This study does have a number of limitations which relate primarily to the retrospective nature of data collection for the trauma registry, rather than for the specific purposes of this study. As described above, it was not possible to estimate the number of patients lost to the trauma registry due to death prior to hospital admission. Temperature recordings were those that were recorded as a routine component of care and may have included multiple measurement techniques with inherent variation in accuracy and precision. Furthermore, for patients admitted to the ICU, we were unable to determine whether episodes of hypothermia (Hypothermia 2) preceded ICU admission or not, thereby limiting interpretation of the relationship between

hypothermia and admission to the ICU. In regard to the specific nature of this study, it should be noted that identification of an association between hypothermia and the outcomes assessed does not establish causality. However, conduct of a similarly large prospective study to explore the temporal relationship of events in further detail remains unfeasible due to the time commitment and expense involved.

Recommendations for practice

This study demonstrated that hypothermia is a real issue in the management of trauma patients in a predominantly sub-tropical climate and is significantly associated with negative outcomes. Despite mounting evidence to this effect, assessment of temperature and maintenance of normothermia is rarely listed as a priority in trauma management guidelines. Effective methods of preventing heat loss and rewarming patients who have become hypothermic are essential and should occur concurrently with other priorities of care. Such methods include regular assessment of temperature and implementation of external techniques such as the use of warmed, air warming or reflective blankets, warm humidified air and appropriate heating of care environments, as well as internal rewarming strategies, including the rapid infusion of warmed fluids and cavity lavage.¹⁸⁻²¹ Extracorporeal strategies such as arteriovenous rewarming and cardio-pulmonary bypass may be appropriate in severe hypothermia.¹⁹ In the current study, in-hospital hypothermia occurred at a similar rate to transfer-associated hypothermia and given the range of options available to maintain normothermia is seen as an important quality control measure. Multidisciplinary education to raise awareness of the impact of hypothermia, as well as knowledge of the range of warming mechanisms, is essential.

5. Conclusions

Trauma patients in warmer climates are at risk of endogenous or accidental hypothermia that, importantly, is associated with detrimental outcomes including increased mortality, more frequent admission to the ICU and a longer duration of hospital stay. Adequate prevention and treatment mechanisms for hypothermia are essential for all severely injured patients.

6. Conflict of Interest

There are no conflicts of interest.

7. Acknowledgements

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8. References

1. Arthurs Z, Cuadrado D, Beekley A, et al. The impact of hypothermia on trauma care at the 31st combat support hospital. *Am J Surg* 2006; 191(5):610-4.
2. Martin RS, Kilgo PD, Miller PR, Hoth JJ, Meredith JW, Chang MC. Injury-associated hypothermia: an analysis of the 2004 National Trauma Data Bank. *Shock* 2005; 24(2):114-8.
3. Shafi S, Elliott AC, Gentilello L. Is hypothermia simply a marker of shock and injury severity or an independent risk factor for mortality in trauma patients? Analysis of a large national trauma registry. *J Trauma* 2005; 59(5):1081-5.
4. Wang HE, Callaway CW, Peitzman AB, Tisherman SA. Admission hypothermia and outcome after major trauma. *Crit Care Med* 2005; 33(6):1296-301.
5. Bernabei AF, Levison MA, Bender JS. The effects of hypothermia and injury severity on blood loss during trauma laparotomy. *J Trauma* 1992; 33(6):835-9.
6. Jurkovich GJ, Greiser WB, Luterman A, Curreri PW. Hypothermia in trauma victims: an ominous predictor of survival. *J Trauma* 1987; 27(9):1019-24.
7. Luna GK, Maier RV, Pavlin EG, Anardi D, Copass MK, Oreskovich MR. Incidence and effect of hypothermia in seriously injured patients. *J Trauma* 1987; 27(9):1014-8.
8. Rutherford EJ, Fusco MA, Nunn CR, Bass JG, Eddy VA, Morris JA Jr. Hypothermia in critically ill trauma patients. *Injury* 1998; 29(8):605-8.
9. Steinemann S, Shackford SR, Davis JW. Implications of admission hypothermia in trauma patients. *J Trauma* 1990; 30(2):200-2.

10. Watts DD, Trask A, Soeken K, Perdue P, Dols S, Kaufmann C. Hypothermic coagulopathy in trauma: effect of varying levels of hypothermia on enzyme speed, platelet function, and fibrinolytic activity. *J Trauma* 1998; 44(5):846-54.
11. Gunning KA, Sugrue M, Sloane D, Deane SA. Hypothermia and severe trauma. *Aust N Z J Surg* 1995; 65(2):80-2.
12. Aitken LM, Lang JH, Bellamy N. Queensland Trauma Registry: Description of Serious Injury Throughout Queensland - 2003. Herston: Centre of National Research on Disability and Rehabilitation Medicine, 2004.
13. Hildebrand F, Giannoudis PV, van Griensven M, Chawda M, Pape HC. Pathophysiologic changes and effects of hypothermia on outcome in elective surgery and trauma patients. *Am J Surg* 2004; 187(3):363-71.
14. Moore EE, Thomas G, Orr Memorial Lecture. Staged laparotomy for the hypothermia, acidosis, and coagulopathy syndrome. *Am J Surg* 1996; 172(5):405-10.
15. Tsuei BJ, Kearney PA. Hypothermia in the trauma patient. *Injury* 2004; 35(1):7-15.
16. Holcomb JB, Jenkins D, Rhee P, et al. Damage control resuscitation: directly addressing the early coagulopathy of trauma. *J Trauma* 2007; 62(2):307-10.
17. Association for the Advancement of Automotive Medicine. Abbreviated Injury Scale – 1990 Des Plaines, IL: Association for the Advancement of Automotive Medicine, 1998.
18. Tisherman SA. Hypothermia and injury. *Curr Opin Crit Care* 2004; 10(6):512-9.

19. Jurkovich GJ. Environmental cold-induced injury. *Surg Clin North Am* 2007; 87(1):247-67.
20. Beekley AC, Watts DM. Combat trauma experience with the United States Army 102nd Forward Surgical Team in Afghanistan. *Am J Surg* 2004; 187(5):652-4.
21. Aslam AF, Aslam AK, Vasavada BC, Khan IA. Hypothermia: evaluation, electrocardiographic manifestations, and management. *Am J Med* 2006; 119(4):297-301.
22. DeLoughery TG. Coagulation defects in trauma patients: etiology, recognition, and therapy. *Crit Care Clin* 2004; 20:13-24.

Table 1 Univariate regressions of hypothermia on each baseline characteristic

Variable	Normothermia	Hypothermia 1	Hypothermia 2	Significance
	n = 1902	n = 124	n = 156	<i>p</i> -value
	<i>n</i> (%) ^a	<i>n</i> (%) ^a	<i>n</i> (%) ^a	
Gender				0.33
Male	1352 (71)	91 (73)	119 (76)	
Age (years)				0.73
Median (range)	39 (0-101)	41 (0-96)	42 (1-96)	
Season				0.035
Spring	492 (26)	30 (24)	35 (22)	
Summer	452 (24)	19 (15)	32 (21)	
Autumn	480 (25)	32 (26)	35 (22)	
Winter	478 (25)	43 (35)	54 (35)	
Climate zone				0.34
Sub-tropical	1566 (84)	110 (89)	128 (84)	
Tropical	226 (12)	12 (10)	18 (12)	
Desert/grassland	66 (4)	1 (1)	7 (4)	
Definitive care				0.003
Direct transfer	1117 (59)	83 (67)	74 (47)	
Injury severity score				< 0.001
< 16 (& deceased)	71 (4)	6 (5)	5 (3)	
16-25	1270 (67)	51 (41)	55 (35)	
26-39	480 (25)	40 (32)	63 (41)	
≥ 40	74 (4)	20 (16)	30 (19)	

Number of regions injured				0.012
1	579 (30)	30 (24)	41 (26)	
2-3	732 (38)	52 (42)	43 (28)	
4-5	468	30 (24)	47 (30)	
(25)		12 (10)	25 (16)	
≥6	123 (7)			
Number of injuries				0.036
1	249 (13)	18 (15)	21 (13)	
2-3	453 (24)	19 (15)	16 (10)	
4-5	419 (22)	14 (11)	18 (12)	
6-9	495 (26)	42 (34)	42 (27)	
≥ 10	286 (15)	31 (25)	59 (38)	
Region of injury				0.0010
Head & neck	126 (7)	12 (10)	13 (8)	
Thorax/abdomen	504 (26)	26 (21)	33 (21)	
Back & pelvis	93 (5)	3 (2)	7 (4)	
Upper limbs	33 (2)	6 (5)	1 (1)	
Lower limbs	75 (4)	1 (1)	5 (3)	
Multiple	107 (5)	17 (14)	18 (12)	
Not required ^b	964 (51)	59 (47)	79 (51)	
Nature of Injury				< 0.001
Open wound	5 (0.3)	1 (0.8)	0 (0)	
Fracture	316 (17)	12 (10)	23 (16)	
Strain/dislocation	2 (0.1)	0 (0)	0 (0)	
Nerve/vessel/muscle	97 (5)	13 (10)	10 (6)	
Crush/amputation	10 (0.5)	1 (0.8)	1 (0.7)	
Internal organ	406 (21)	21 (17)	26 (17)	
Burn/corrosion	50.. (3)	9 (7)	10 (6)	
Intracranial injury	946 (50)	51 (41)	75 (49)	

Poisoning	4 (0.2)	0 (0)	1 (0.7)	
Multiple	50 (3)	8 (6)	7 (6)	
Other	14 (0.7)	8 (6)	1 (0.7)	
GCS on admission				< 0.001
13-15	1245 (65)	47 (38)	48 (31)	
9-12	108 (6)	5 (4)	6 (4)	
6-8	68 (4)	5 (4)	7 (4)	
4-5	19 (1)	4 (3)	1 (1)	
3	85 (4)	20 (16)	32 (20)	
V&S	210 (11)	32 (26)	51 (33)	
Hypotension on admission (SBP mmHg)				< 0.001
≥ 90	1728 (91)	86 (69)	125 (80)	
< 90	78 (4)	30 (24)	22 (14)	
Operative intervention				
Yes	1003 (53)	61 (49)	59 (38)	0.0013

Hypothermia 1 = hypothermia prior to or on admission to definitive care hospital. Hypothermia 2 = hypothermia during definitive care hospitalisation. GCS, Glasgow Coma Scale; SBP, systolic blood pressure; LOS, length of stay; ICU, intensive care unit; V&S, ventilated and sedated.

^a Refers to column percentages (with missing values included in the total).

^b According to National Data Standards for Injury Surveillance (Version 2.1) region of injury is 'not required' for those injuries where the region is implied by the nature of main injury code, e.g. head injury.

Table 2 Variables related to hypothermia in multivariate analysis ($n = 2182$)

Factor	Hypothermia 1 v. Normothermia RRR (95% CI)	Hypothermia 2 v. Normothermia RRR (95% CI)
Season		
Spring v. Summer	1.56 (0.83-2.92)	1.03 (0.61-1.75)
Autumn v. Summer	1.83 (0.99-3.40)	1.13 (0.67-1.92)
Winter v. Summer	2.71 (1.50-4.93)**	1.82 (1.12-2.97)*
Definitive Care		
Indirect v. Direct	0.45 (0.28-0.75)**	1.08 (0.72-1.64)
Injury Severity Score		
< 16 (& deceased) v. 16-25	1.61 (0.63-4.14)	1.51 (0.56-4.07)
26-39 v. 16-25	1.62 (0.997-2.62)	2.30 (1.49-3.56)***
≥ 40 v. 16-25	3.48 (1.74-6.97)***	4.59 (2.50-8.43)***
Number of regions injured		
2-3 v. 1	1.38 (0.81-2.35)	0.66 (0.40-1.08)
4-5 v. 1	0.91 (0.49-1.71)	0.75 (0.44-1.26)
≥ 6 v. 1	0.86 (0.38-1.98)	0.99 (0.52-1.90)
GCS on admission		
9-12 v. 13-15	0.97 (0.37-2.58)	1.17 (0.48-2.84)
6-8 v. 13-15	1.55 (0.58-4.13)	1.99 (0.85-4.70)
4-5 v. 13-15	2.59 (0.74-9.04)	0.78 (0.10-6.23)
3 v. 13-15	3.24 (1.65-6.35)**	5.64 (3.25-9.80)***
V&S v. 13-15	5.26 (2.88-9.58)***	4.43 (2.69-7.28)***
Hypotension on admission (SBP mmHg)		
< 90 v. ≥ 91	4.96 (2.92-8.42)***	2.74 (1.55 - 4.84)**

Hypothermia 1 = hypothermia prior to or on admission to definitive care hospital. Hypothermia 2 = hypothermia during definitive care hospitalisation. RRR, relative risk ratio; CI, confidence interval; GCS, Glasgow Coma Scale; SBP, systolic blood pressure; V&S, ventilated and sedated

Significant difference indicated as follows: * ($p < 0.05$), ** ($p < 0.01$), and *** ($p < 0.001$).

Table 3 Description of outcome characteristics by hypothermia status

Variable	Normothermia	Hypothermia 1	Hypothermia 2	Significance
	n = 1902	n = 124	n = 156	p-value
LOS (days), median (range)	9 (1-189)	9 (1-163)	16 (1-129)	< 0.001
ICU admission, n (%)	960 (50)	90 (73)	129 (83)	< 0.001
Hospital mortality, n (%)	217 (11)	50 (40)	55 (35)	< 0.001

Hypothermia 1 = hypothermia prior to or on admission to definitive care hospital. Hypothermia 2 = hypothermia during definitive care hospitalisation. LOS, length of stay; ICU, intensive care unit.

Table 4 Variables related to hospital length of stay, intensive care unit admission and hospital mortality in multivariate analyses

Factor	Length of stay n = 2181 IRR (95%CI)	ICU admission n = 2181 OR (95%CI)	Hospital mortality n = 2082 OR (95%CI)
Hypothermia			
Hypothermia 1 v. Normothermia	1.22 (1.03-1.43)*	1.37 (0.81-2.32)	4.05 (2.26-7.24)***
Hypothermia 2 v. Normothermia	1.18 (1.02-1.36)*	1.73 (1.02-2.93)*	2.52 (1.52-4.17)***
Gender			
Female v. male	Not included ^a	0.80 (0.62-1.01)	0.75 (0.50-1.13)
Age ^d	***	***	***
Definitive Care			
Indirect v. Direct	1.11 (1.02-1.20)*	0.81 (0.65-1.02)	0.44 (0.28-0.69)***
Injury Severity Score			
< 16 v. 16-25	0.98 (0.79-1.21)	0.60 (0.32-1.13)	– ^c
26-39 v. 16-25	1.19 (1.08-1.31)***	2.61 (1.99-3.41)***	3.70 (2.35-5.83)***
≥ 40 v. 16-25	1.21 (1.02-1.44)*	2.93 (1.52-5.65)**	8.42 (4.27-16.61)***
Number regions injured			
2-3 v. 1	1.09 (0.99-1.20)	1.21 (0.93-1.57)	0.38 (0.24-0.60)***
4-5 v. 1	1.32 (1.18-1.47)***	1.67 (1.23-2.27)**	0.17 (0.10-0.31)***
≥ 6 v. 1	1.51 (1.28-1.78)***	2.12 (1.25-3.61)**	0.19 (0.09-0.41)***
GCS on admission			
9-12 v. 13-15	1.12 (0.95-1.32)	4.04 (2.54-6.42)***	3.37 (1.71-6.66)***
6-8 v. 13-15	1.61 (1.32-1.97)***	6.22 (3.30-11.71)***	6.14 (2.87-13.13)***
4-5 v. 13-15	1.62 (1.13-2.31)**	3.94 (1.38-11.25)*	24.6 (8.27-73.11)***
3 v. 13-15	1.23 (1.04-1.45)*	6.90 (3.94-12.09)***	30.9 (16.9-56.80)***
V&S v. 13-15	1.27 (1.12-1.44) ***	36.79 (19.2-70.60)***	17.35 (9.6-31.28) ***

Hypotension on admission (SBP mmHg)

< 90 v. ≥ 91	0.98 (0.84-1.15)	1.31 (0.79-2.19)	1.35 (0.70-2.61)
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Operative intervention

Yes v. No	2.09 (1.93-2.27) ***	3.45 (2.76-4.30)***	0.36 (0.25-0.53)***
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Hypothermia 1 = hypothermia prior to or on admission to definitive care hospital. Hypothermia 2 = hypothermia during definitive care hospitalisation. ICU, intensive care unit; IRR, incidence rate ratio; CI, confidence interval; OR, odds ratio; GCS, Glasgow Coma Scale; SBP, systolic blood pressure; V&S, ventilated and sedated

^a Not included as gender did not meet entry criteria in univariate analysis.

^b The polynomial effect of age was quadratic for LOS and cubic for ICU stay and mortality. Parameters not reported as age was centred and polynomial effects are not easily interpretable (significance indicated).

^c Parameter inestimable as no patient survived in the comparative group (ISS<16).

Significant difference indicated as follows: * (p < 0.05), ** (p < 0.01), and *** (p < 0.001).