Clinical paper

The incidence and significance of accidental hypothermia in major trauma—A prospective observational study

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\textbf{Abstract}

\textbf{Background:} Serious sequelae have been associated with injured patients who are hypothermic (<35 °C) including coagulopathy, acidosis, decreased myocardial contractility and risk of mortality.

\textbf{Aim:} Establish the incidence of accidental hypothermia in major trauma patients and identify causative factors.

\textbf{Method:} Prospective identification and subsequent review of 732 medical records of major trauma patients presenting to an Adult Major Trauma Centre was undertaken between January and December 2008. Multivariate analysis was performed using logistic regression. Significant and clinically relevant variables from univariate analysis were entered into multivariate models to evaluate determinants for hypothermia and for death. Goodness of fit was determined with the use of the Hosmer–Lemeshow statistic.

\textbf{Main results:} Overall mortality was 9.15%. The incidence of hypothermia was 13.25%. The mortality of patients with hypothermia was 29.9% with a threefold independent risk of death: OR (CI 95%) 3.44 (1.48–7.99), \(P = 0.04\). Independent determinants for hypothermia were pre-hospital intubation: OR (CI 95%) 5.18 (2.77–9.71), \(P < 0.001\), Injury Severity Score (ISS): 1.04 (1.01–1.06), \(P = 0.01\), Arrival Systolic Blood Pressure (ASBP) < 100 mm Hg: 3.04 (1.24–7.44), \(P = 0.02\), and wintertime: 1.84 (1.06–3.21), \(P = 0.03\).

Of the 87 hypothermic patients who had repeat temperatures recorded in the Emergency Department, 77 (88.51%) patients had a temperature greater than the recorded arrival temperature. There was no change in recorded temperature for four (4.60%) patients, whereas six (6.90%) patients were colder at Emergency Department discharge.

\textbf{Conclusion:} Seriously injured patients with accidental hypothermia have a higher mortality independent of measured risk factors. For patients with multiple injuries a coordinated effort by paramedics, nurses and doctors is required to focus efforts toward early resolution of hypothermia aiming to achieve a temperature >35 °C.

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1. Introduction

Accidental hypothermia is likely to be harmful for seriously injured patients.\textsuperscript{1–7} Trauma patients are predisposed to hypothermia for a variety of reasons including exposure to the environment and disordered homeostasis. These patients have a decreased ability to maintain normothermia because of hypovolaemic shock, central nervous system injury, self administered drugs and alcohol or therapeutic medication including anaesthetic drugs and the administration of cold intravenous fluids including blood products.\textsuperscript{8} Serious sequelae for major trauma patients that remain hypothermic include coagulopathy and acidosis and an associated increased risk of mortality.\textsuperscript{3,9–13}

Whilst numerical cut-off points for temperature vary among authors,\textsuperscript{2,8,11,13–17} a core temperature (Tc) of <35 °C has been defined as accidental or exposure hypothermia by the American College of Surgeons Committee on Trauma\textsuperscript{12} and others.\textsuperscript{11,16,18–23} Significant physiological changes also become manifest at this temperature.
temperature\textsuperscript{9,24} For this study accidental hypothermia was defined as a Trauma Centre admission temperature of <35 °C.

In Australia hypothermia in major trauma patients has been identified as a potential contributing factor to preventable mortality.\textsuperscript{25} However, a prospective Australian study that reported a mortality rate of 23.5% in hypothermic trauma patients found no difference for risk of death when hypothermic and non-hypothermic trauma patients were compared. The study included children, did not adjust for potential confounders and did not include clotting profiles; the author’s acknowledged the small sample size (100 patients).\textsuperscript{19} Our prospective study of adults included more patients, accounted for potential confounders and investigated physiological and anatomical indices, including clotting profiles.

The aim of this study was to establish the incidence of accidental hypothermia in adult major trauma patients and to identify factors that influence the pre-hospital temperature of these patients. Pre-hospital factors, length of stay (LOS) to hospital discharge of survivors, discharge destination and mortality were determined for patients with accidental hypothermia and were compared to non-hypothermic controls. The influence on temperature of blood alcohol concentration (BAC), base deficit, blood replacement products and clotting profiles were also evaluated.

2. Methods

The Emergency and Trauma Centre (E&TC) The Alfred, Melbourne Australia, is a Level 1 adult tertiary referral service that provides emergency services for approximately 47,000 adult patient presentations per year including 1100 adult major trauma patients.

Major trauma patients (MTPs) were defined as the presence of at least one of the following: death after injury; admission to an Intensive Care Unit for more than 24 h requiring mechanical ventilation; serious injury to two or more body systems (excluding integumentary): Injury Severity Score (ISS) >15 and urgent surgery for intracranial, intrathoracic, or intraabdominal injury or for fixation of pelvic or spinal fractures.\textsuperscript{26}

Screening arrival temperature was defined as a documented temperature within 15 min of patient presentation and confirmed by the arrival registration time and date. This was performed using either the tympanic (ear-based) infra-red thermometer (Genius Model 3000ATympanic Thermometer) or the general purpose temperature probe (Tyco Thermistor 400 Series) for the oesophageal route. As soon as practical and safe, continuous core temperature (Tc) monitoring was commenced using the oesophageal route for intubated patients or the bladder (Tyco Mon-a-therm Foley Catheter Thermistor YSI 400 Series) in conscious patients.

Prior to using ear-based thermometry, assessment of the integrity of the tympanic membrane is recommended.\textsuperscript{4} Operator technique, the presence of blood, cerebrospinal fluid (CSF) or cerumen in the auditory canal may influence the recorded temperature.\textsuperscript{27,28} There is no provision for continuous temperature measurement. Both the oesophageal and the bladder routes are considered reliable methods for continuous Tc monitoring as they correlate with the pulmonary artery; considered the ‘gold standard’.\textsuperscript{29} Both methods have limitations. Clinical priorities or a base of skull fracture may prevent or delay the insertion of an oesophageal probe and urethral or pelvic injuries or the anticipated need for magnetic resonant imagery may preclude the insertion of an indwelling urethral catheter with thermistor. In these circumstances, ongoing temperature monitoring in the E&TC was performed using ear-based thermometry.

A subsequent review of 820 medical records of adult MTPs prospectively identified from Alfred Health’s trauma registry was conducted over a 12-month period from January to December 2008. Of these, 732 patients met the study inclusion criteria.

2.1. Inclusion criteria

All patients included on the trauma registry at Alfred Health aged ≥18 years of age that presented seriously injured and who met the Major Trauma Patient criteria as defined.

2.2. Exclusion criteria

Any Major Trauma Patient who was <18 years of age and all non-traumatic cardiac arrest patients were excluded.

2.3. Data collection

A data collection tool designed by members of the research team was used to collect raw data from the medical record of all patients who met the inclusion criteria. The raw data were entered unchanged into Microsoft Excel 2002 SP-1. Data entry was checked on three occasions by independent reviewers for accuracy. An independent statistician completed the statistical analysis.

2.4. Statistical analysis

Analysis was performed using SAS version 9.2 (SAS Institute Cary, NC, USA). Univariate analysis was conducted using Student t-tests, chi-square test for equal proportion or non-parametric tests where appropriate. Multivariate analysis was performed using logistic regression. Significant and clinically relevant variables from univariate analysis were entered into the model to evaluate determinants for hypothermia and for death. Confounders included age, gender, season of the year, motorbike accident, major burn injury, falls, pedestrians, pre-hospital intubation, time spent at the scene, transport time from scene to hospital, transport by rotary wing, pre-hospital intravenous fluid (IVF) administered, arrival respiratory rate (ARR), activated partial thromboplastin time (APTT), international normalized ratio (INR), prothrombin time (PT), ISS and ASBP <100 mm Hg. Goodness of fit was determined with the use of the Hosmer–Lemeshow statistic. A two-sided P-value of 0.05 was considered to be statistically significant. Normally distributed outcomes are reported as means (±Standard Deviation (SD)), whilst non-normal data are reported as medians (Inter Quartile Range (IQR)). Categorical data are reported as count and proportions.

2.5. Ethical consideration

The protocol was approved by Alfred Health and La Trobe University Human Ethics Committees.

3. Results

Of 820 eligible patients, 88 patients were excluded, leaving 732 patients included in this study. Of those excluded, 37 patients were transferred to the E&TC greater than 24 h following injury, 24 (2.9%) patients had no recorded arrival temperature, 13 patients were less than 18 years of age, 10 patients on final review were considered minor trauma, two patients had no E&TC paperwork filed in the medical record and two patients had no trauma. Hypothermia on arrival was present in 97 (13.25%) patients and of these, 88 (90.7%) were referred directly from the scene of the injury (pre-hospital cases). Demographic data are presented in Table 1.

Greater than 50% of patients were involved in either motor vehicle accidents (210) or falls (168). There were 87 (11.89%) motorbike collisions, of these, most (77%) were ≤50 years old and 10 (11.5%)
presented during winter months. There were 63 (8.61%) pedes-
trians, 50 (6.83%) assaults, 30 (4.1%) cyclist, 25 (3.42%) burns, 24
(3.28%) stabdings and 16 (2.19%) horse related presentations. Of
the remaining 59 (8%) patients, mechanisms of injury included, being
crushed, sporting and boating accidents (including submersion),
gun related injuries, hangings as well as aircraft accidents (including
explosion). Unadjusted odds ratio (UOR) for mechanisms of
injury and type of head injury are presented (atTable 2). There were

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-hypothermic</th>
<th>Hypothermic</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>157 (24.72)</td>
<td>11 (11.34)</td>
<td>0.39 (0.20–0.75)</td>
<td>0.005</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>48 (7.56)</td>
<td>15 (15.46)</td>
<td>2.24 (1.99–4.18)</td>
<td>0.011</td>
</tr>
<tr>
<td>Motorbike</td>
<td>83 (13.07)</td>
<td>4 (4.12)</td>
<td>0.29 (0.10–0.88)</td>
<td>0.017</td>
</tr>
<tr>
<td>Burns</td>
<td>18 (2.83)</td>
<td>7 (7.22)</td>
<td>2.66 (1.08–6.56)</td>
<td>0.033</td>
</tr>
<tr>
<td>Blunt head injury and multi-trauma</td>
<td>412 (64.88)</td>
<td>66 (68.04)</td>
<td>1.15 (0.73–1.82)</td>
<td>0.543</td>
</tr>
<tr>
<td>Isolated blunt head injury</td>
<td>149 (23.46)</td>
<td>15 (15.46)</td>
<td>0.60 (0.33–1.07)</td>
<td>0.081</td>
</tr>
<tr>
<td>Blunt head injury (BHI) only</td>
<td>107 (17.8)</td>
<td>11 (7.33)</td>
<td>1.08 (0.33–3.58)</td>
<td>0.910</td>
</tr>
<tr>
<td>BHI including faciomaxillary injury</td>
<td>42 (28.19)</td>
<td>4 (26.67)</td>
<td>0.93 (0.28–3.07)</td>
<td>0.501</td>
</tr>
</tbody>
</table>

Values are n (%).
Independent determinants for death were hypothermia, pre-hospital intubation, major burn injury, coagulopathy, falls, injury severity score and age. Arrival at patient to arrival at hospital time independently reduced the risk for death (Table 6). The data were well fitted by the model (P=0.35) using the Hosmer–Lemeshow test.

4. Discussion

This study demonstrated accidental hypothermia in seriously injured patients was associated with a threefold increase in risk of death, independent of measured risk factors. Arrival hypothermia was relatively common (13.25%). Further, pre-hospital intubation, ISS, ASBP<100 mm Hg and winter time were independently associated with arrival hypothermia.

Steinemann and colleagues reported hypothermia in 21% of patients and mortality for hypothermic patients of 37.84%. When stratified by ISS hypothermic cases in this study demonstrated a higher mortality than normothermic cases (P<0.001). Unlike others who reported hypothermia to have an independent association with death12,30,31 including our study, Steinmann et al. found no difference in mortality rates between normothermic and hypothermic patients when stratified by Ps which included both physiological and anatomical indices p. 201.21 Our data provide contrary evidence as potential confounding physiological parameters including ASBP<100 mm Hg, ARR, INR, PT and APTT were included in the multivariate model. Mortality for patients with admission temperatures of <32 °C has previously been reported as 100%.19,31–34 Our study demonstrated survival of four patients with temperatures below 32 °C. the lowest was 28.3 °C.

A number of the findings from this study confirm our previous understanding of admission hypothermia and the multiply injured. Hypothermic trauma patients have worse base deficits,10,33–35 increased length of stay of survivors34 and higher risk of infection.11,36,37 Like others, this study demonstrated coagulopathy increased the risk of death.34,38,39

Most (95.63%) presentations in this study involved blunt trauma. Being a motorbike rider was protective for the risk of hypothermia. A number of factors may have influenced this finding; for example wearing protective leather clothing and a helmet (pre-collision), weather conditions at time of injury and short transport times from the scene to hospital.

Table 3
Use of blood products and pre-hospital crystalloid infused.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-hypothermic</th>
<th>Hypothermic</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red blood cells (unit)</td>
<td>4 (2–6)</td>
<td>4 (3–9)</td>
<td>1.05 (0.99–1.10)</td>
<td>0.088</td>
</tr>
<tr>
<td>Fresh frozen plasma (ml)</td>
<td>600 (600–1500)</td>
<td>1500 (600–1800)</td>
<td>1 (0.99–1.00)</td>
<td>0.135</td>
</tr>
<tr>
<td>Platelets (unit)</td>
<td>4 (2–5)</td>
<td>2 (1–5)</td>
<td>0.95 (0.82–1.11)</td>
<td>0.531</td>
</tr>
<tr>
<td>Cryoprecipitate (unit)</td>
<td>5 (3–15)</td>
<td>5 (1–10)</td>
<td>0.94 (0.87–1.01)</td>
<td>0.097</td>
</tr>
<tr>
<td>Pre-hospital crystalloid infused (L)</td>
<td>0.5 (0–1.5)</td>
<td>1.5 (0.75–2.65)</td>
<td>1.66 (1.4–2.0)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are median (IQR). a n = 69; b n = 49; c n = 44; d n = 39; e n = 25; f n = 22; g n = 23; h n = 29; i n = 409; j n = 88.

Table 4
Biochemistry.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-hypothermic</th>
<th>Hypothermic</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood alcohol concentration</td>
<td>1 (1–3)</td>
<td>1 (1–24)</td>
<td>1.01 (1.00–1.02)</td>
<td>0.026</td>
</tr>
<tr>
<td>Activated partial thromboplastin time</td>
<td>28.7 (19.4–51.4)</td>
<td>31 (12.5–38.2)</td>
<td>1.01 (1.01–1.02)</td>
<td>0.001</td>
</tr>
<tr>
<td>International normalized ratio</td>
<td>1.0 (1.0–1.1)</td>
<td>1.2 (1.0–1.6)</td>
<td>1.11 (1.01–1.21)</td>
<td>0.022</td>
</tr>
<tr>
<td>Prothrombin time</td>
<td>13.7 (11.1–14.6)</td>
<td>15.2 (13.6–19.2)</td>
<td>1.01 (1.00–1.02)</td>
<td>0.071</td>
</tr>
</tbody>
</table>

Values are median (IQR). a n = 547; b n = 94; c n = 607; d n = 95; e n = 610; f n = 95; g n = 610; h n = 95.

Independent determinants for death were hypothermia, pre-hospital intubation, major burn injury, coagulopathy, falls, injury severity score and age. Arrival at patient to arrival at hospital time independently reduced the risk for death (Table 6). The data were well fitted by the model (P=0.35) using the Hosmer–Lemeshow test.

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Out-of-hospital endotracheal intubation (ETI) by paramedics remains controversial with different effects on outcome reported for patients with traumatic brain injury.40–43 It appears that
increasing experience/exposure to the procedure of ETI, training, and the use of neuromuscular blocking agents are important to optimise successful ETI by paramedics in the pre-hospital setting.41 In Victoria, Australia, flight paramedics have been authorized to perform rapid sequence intubation (RSI) since 1999 with a reported success rate of 97%.43 Flight paramedics described by Bernard43 transport seriously injured trauma patients to our Trauma Centre. Intubation was required for 93 pre-hospital cases; of these, 84 patients received paralysing drugs to assist with RSI. Pre-hospital intubation was an independent determinant for both hypothermia and death. It is likely in our setting seriously injured patients who require RSI pre-hospital are sicker and thus more likely to die as there was a sevenfold increased risk for death for these patients. Nine patients in this study required no drugs to facilitate pre-hospital intubation. It seems that drug assisted intubation is not associated with hypothermia, or worsening of measured physiological parameters. Also, patients who were anaesthetised and paralysed did not receive warmed, humidified oxygen. This coupled with the inability to shiver and the associated iatrogenic vasodilation could potentiate heat-loss.

The relationship between traumatic shock and onset of hypothermia remains unclear.15,31,34,44 However, a spontaneous decrease in temperature following injury has been correlated with a poor prognosis.3,37 In both human and animal studies, hypothermia in the setting of severe injury is different to accidental hypothermia37,45 and is likely a secondary consequence of injury rather than to exposure or volume of resuscitation fluids administered, including blood products.32–34 It is unclear whether hypothermia or the severity of injury producing hypothermia is responsible for the high mortality reported in hypothermic injured patients.8,13,31,32

Arrival systolic blood pressure <100 mm Hg in this study had a fourfold increased risk for hypothermia and for the 26 (3.57%) patients with ASBP <90 mm Hg, the risk for hypothermia was five-fold.

As in the study by Steinemann and colleagues,21 there was no difference in the isolated blunt head injury group when comparing hypothermia vs. non-hypothermia. However, of the 164 patients with isolated blunt head injury in this study, most (84.15%) had a normal (≥35°C to <37.5°C) arrival temperature. Fifteen (9.15%) patients were hypothermic; of interest 11 (6.71%) patients with isolated blunt head injury were hypothermic (>37.5°C). This unexpected observation has implications for current research exploring the use of therapeutic hypothermia and improved neurological outcome in isolated blunt head injured patients. It would appear that for patients with isolated blunt head injury, treatment with hypothermia [therapeutic] would need to commence in the pre-hospital setting. A recently published Cochrane review concluded that “there is no evidence that hypothermia is beneficial in the treatment of head injury…” and “that high quality trials found no decrease in the likelihood of death with hypothermia” p. 2,40 Importantly, the authors highlighted that this outcome could have occurred by chance. They recommended that hypothermia be used only in the context of “a high quality randomised controlled trial with good allocation concealment” p. 2.40 It is anticipated that outcomes from current prospective clinical trials using therapeutic hypothermia in isolated blunt head injury patients will provide evidence to inform practice.

During winter 2008 in Melbourne, the mean minimum temperature recorded was 5.1–8.1°C.47 Similar to previous studies,11,14,16,19,21 this study provides evidence that hypothermia is more prevalent in winter months as there was increased risk for hypothermia during winter when compared to other seasons. Others15,22 report no seasonal variation. The time of day of presentation had no impact on the occurrence of admission hypothermia.

The legal BAC driving limit in Victoria is <0.05 g/dL.48 One hundred and fifty four (24.02%) patients had an illegal BAC (≥11 mmol/L or >0.05 g/dL). Of these, 30 (30.93%) patients had arrival hypothermia, most of whom survived (83.33%); 20 patients developed infection.

Current practice in the E&TC for heat loss prevention includes, decreasing exposure, administration of warm IVF on patient arrival (discarding un-warmed pre-hospital IVF), applying two warmed cotton blankets and priority to record arrival temperature within 15 min. Re-warming using forced air warming (bair hugger) is commenced immediately for those identified with arrival hypothermia. Once the seriously injured patient is cold they are extremely difficult to warm.11,14–16,32,37,39 Unlike other studies15,16,34,37,49 suggesting hypothermia may worsen in the ED, this study provides evidence that re-warming hypothermic patients in ED is possible. It is likely that successful re-warming of hypothermic patients in ED is related to LOS, as time to re-warming using standard treatment is reported to take several hours.11,40 For the six patients who failed to warm in ED, LOS in ED ranged from 10 min to 2 h 50 min.

Ambulance Victoria (AV) recommends patients identified with hypothermia are sheltered from the wind, wet clothing is removed and the patient cocooned in a warm blanket including head covering. Warmed IVF should be administered if available, as IVF <37°C could be detrimental.50 In severe traumatic head injury maintaining normal temperature is recommended.51 Assessment of temperature and management as required is recommended for adult burn patients.52 No reference to the identification or management of hypothermia in major trauma patients was located in AV clinical practice guidelines. Heat moisture exchange filters are not used in the pre-hospital setting and ways to warm IVF are currently unavailable through AV (Bedford-Lee, 2010, pers. comm., 9th October).

It is important that heat-loss prevention commences immediately hypothermia is diagnosed and re-warming efforts commence as soon as practical.33,34 Ideally all patients should have a temperature recorded at the scene; efforts to manage patients identified with hypothermia including the administration of warmed IVF, minimising exposure, removal of wet clothing and the application of blankets should be commenced in the pre-hospital environment to improve arrival temperature.15,34 Most (90.72%) hypothermic patients in this study were transferred direct from the scene of injury.

4.1. Future research

Collaborative work with pre-hospital providers is required to evaluate the impact of heat-loss prevention measures including the administration of warmed pre-hospital IVF on hospital arrival temperature in the seriously injured, as this has the potential to reduce the number of accidental hypothermic referrals to our centre and influence patient outcome.

4.2. Limitations

This was an observational study and thus could not show a causal relationship between hypothermia and mortality. The association with mortality was strong, even after adjusting for measured confounders. Despite this study being undertaken at a single site, patients were prospectively identified and all seriously injured adult referrals for a 12-month period were included. Cases with a base deficit recorded were excluded from multivariate analysis due to missing data. The recruitment number was fixed so the sample size was insufficient to investigate the relationship between blunt head injured patients and hypothermia. For the nine pre-hospital cases intubated without drugs; the sample size was insufficient
to investigate any further association other than the observations reported.

5. Conclusion

In seriously injured patients, hypothermia was independently associated with death. Pre-hospital determinants for hypothermia include intubation, higher ISS, and arrival systolic blood pressure <100 mm Hg. Patients with isolated blunt head injury and a temperature <35°C were not at higher risk of death.

As hypothermia was strongly associated with death, the safest clinical approach would be to aim for a temperature >35°C in patients with multiple injuries. Coordinating efforts for the prevention of heat-loss and re-warming from the time of injury by paramedics, nurses and medical staff for early resolution of identified hypothermia is required.

Disclaimer

There are no disclaimers.

Authors’ contribution to the manuscript

Sharyn Ireland: Write-up and submission of ethics proposal to relevant Ethics Committees, design of data collection tool, collection of data, responsibility and accountability for storage of data according to ethical requirements, communication between project team members and supervisors, communication with statistician, write-up of draft preparation of manuscript and completion of manuscript for submission. Professor Ruth Endacott: Advice, critique, review and support during ethics application process, advice on data analysis and interpretation, preparation and contribution to write-up of manuscript for submission. Professor Peter Cameron: Advice, critique, review and support during ethics application process, advice on data analysis and interpretation, preparation and contribution to write-up of manuscript for submission. Associate Professor Mark Fitzgerald: Advice, critique, review and support during ethics application process, and critique and contribution to draft manuscript prior to submission. Mr. Eldho Paul: Statistical analysis in consultation with Sharyn Ireland. Critique and feedback on methods and results section in preparation of manuscript for publication submission.

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Conflict of interest statement

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