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Inadvertent hypothermia and mortality in postoperative intensive care patients: retrospective audit of 5050 patients

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Summary

We proposed that many Intensive Care Unit (ICU) patients would be hypothermic in the early postoperative period and that hypothermia would be associated with increased mortality. We retrospectively reviewed patients admitted to ICU after surgery. We recorded the lowest temperature in the first 24 h after surgery using tympanic membrane thermometers. We defined hypothermia as < 36 °C, and severe hypothermia as < 35 °C. We studied 5050 consecutive patients: 35% were hypothermic and 6% were severely hypothermic. In-hospital mortality was 5.6% for normothermic patients, 8.9% for all hypothermic patients ($p < 0.001$), and 14.7% for severely hypothermic patients ($p < 0.001$). Hypothermia was associated with in-hospital mortality: OR 1.83 for each degree Celsius (°C) decrease (95% CI: 1.2–2.60, $p < 0.001$). Given the evidence for improved outcome associated with active patient warming during surgery we suggest conducting prospective studies of active warming of patients admitted to ICU after surgery.

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As a recent National Institute for Health and Clinical Excellence report [1] has highlighted, inadvertent hypothermia is common in the early postoperative period [1–5]. Current evidence, including randomised trials, indicates that a decrease in tympanic temperature of 1–3 °C is associated with physiological derangement and may lead to complications and that active warming may reduce these complications [1–4, 6–10]. This evidence has led to anaesthetists often trying to achieve normothermia for patients in the peri-operative period with active warming. Despite this evidence-based change in operating room practice [1] there are few studies in critical care journals or discussion in texts about hypothermia in Intensive Care unit (ICU) patients after surgery [11–14]. This limited work, including our own study, has indicated that hypothermia is common in patients admitted to intensive care after both cardiac [5, 15] and non-cardiac surgery [2, 16, 17]. The clinical importance of postoperative hypothermia in ICU patients is, however, unclear. Further there is little evidence about the association between peri-operative hypothermia and mortality [1].

In an audit conducted in an Australian ICU, we tested the hypotheses that hypothermia in patients admitted to ICU after surgery is common and may be associated with increased mortality.

Methods

The Austin Hospital is an Australian tertiary hospital affiliated with the University of Melbourne. The ICU had 17 open beds during the period of the study and the unit cares for a broad range of general and specialty surgical patients including cardiac, as well as medical patients, but few multi-trauma patients. The ICU admits about 2000 cases per year. We analysed routine data collected from ICU patients, entered into the Australian and New Zealand Intensive Care Society (ANZICS) outcome database, (AORTIC: Australasian Outcomes Research Tool for Intensive Care, ANZICS, Melbourne, Australia). No additional sampling was required and collected data did not identify the patient. The Austin Health Human Research Ethics committee waived the need for informed consent.

Data were retrospectively collected from patients admitted to the ICU after surgery over a 5-year period between July 2002 and 2007. We included all consecutive patients whose admission source to the ICU was from the operating room. The lowest tympanic temperature within the first 24 h of ICU admission was the primary variable and in-hospital mortality was the primary outcome measure. All postoperative temperatures were measured using an infrared tympanic membrane thermometer (Genus R Model 3000A; Sherwood Company, St Louis, MO, USA) with an accuracy of ± 0.03% in the range 32.2–40.6 °C. The thermometers were calibrated according to manufacturers guidelines. Normothermia was defined as a tympanic temperature ≥ 36 °C, hypothermia as < 36 °C [3]. Moderate hypothermia was a lowest temperature of between 35.0 and 35.9 °C and severe hypothermia < 35 °C [2]. We recorded demographic characteristics, APACHE II score, type of surgery, and clinical variables which may be associated with increased mortality including plasma levels of glucose, bicarbonate, haemoglobin, and highest lactate and troponin [18–21].

Data are presented as mean with standard deviation and median with interquartile ranges for variables not normally distributed. We compared nominal data using chi-square test or Fisher's exact test. We compared numerical data using Student's *t*-test or Mann–Whitney *U*-test. We conducted univariate comparison of survivors and non-survivors analysing patient characteristics and we considered a $p < 0.1$ as sufficient to insert a variable into a multivariate model. Multivariate logistic regression analysis was performed using hospital mortality as the dependent variable. We reported odds ratio (OR) with 95% confidence intervals (95% CI) and p values. We considered $p < 0.05$ as significant. We used SPSS software, version 13 for Windows (SPSS Inc, Chicago, IL, USA).

Results

We studied 5050 consecutive patients admitted to the general intensive care unit from the operating room. The average age of the patient was 65 years and 64% were male. The average APACHE II score was 48.2. The two largest surgical groups were cardiac and general surgery (Table 1).

The median lowest temperature within 24 h of ICU admission or all patients was 36 °C (IQR: 35.1–36.9 °C). About two-thirds of patients were normothermic, 35% had hypothermia: 29.5% had moderate hypothermia and 5.8% severe hypothermia. The median temperature for cardiac surgery patients was 36.2 °C (IQR: 35.2–37.2 °C). This was significantly higher than the median temperature for non-cardiac surgery patients which was 36 °C ($p < 0.001$). A greater proportion of patients were hypothermic after non-cardiac surgery (36%) than cardiac surgery (31%), difference 5% (95% CI: 3–8%, $p < 0.001$). The rate of hypothermia varied between non-cardiac specialties from 25% after liver transplantation to 48% after vascular surgery (Table 1).

Table 1 Patient groups by type of surgery.

Surgery group	Number	% of Total	% Hypothermic
Cardiac	1204	23.8	31
General surgery	1200	23.8	35
Vascular	484	9.6	48
Orthopaedics	458	9.1	32
Thoracic	417	8.3	35
Urology	222	4.4	34
Plastics ⁄ ENT	210	4.2	31
Neurosurgery	206	4.1	35
Liver transplant	161	3.2	25
Spinal	76	1.5	30
Gastroenterology	71	1.4	44
Obsteterics and Gynaecology	18	0.4	39
Others	323	6.4	40

Overall, 341 patients (6.8%) died in hospital. In-hospital mortality was 184 of 3284 normothermic patients (5.6%), and 157 of 1766 hypothermic patients (8.9%). For patients with moderate hypothermia (between 35.0 and 35.9 °C) 114 of 1474 (7.7%) died. This was an increase of 2.1% (95% CI: 0.9–3.5%, $p < 0.001$) from the normothermic group. For severely hypothermic patients (< 35.0 °C) 43 of 292 (14.7%) died. This was an increase of 7.0% (95% CI: 3.7–10.9% increase, $p < 0.001$) from those with moderate hypothermia. Patients who died in addition to being colder were also older, sicker, and had longer stays in ICU (Table 2).

Table 2 Characteristics of hospital survivors and non-survivors. Values are mean (SD) for normally distributed variables or median (interquartile range) for variables not normally distributed.

	Hospital survivors	Died in hospital	p value
Gender (male)	3047 ⁄ 4709 (65%)	20 ⁄ 341 (59%)	0.024
Cardiac surgery	1167 ⁄ 4709 (25%)	37 ⁄ 341 (11%)	< 0.001
Temperature; °C	36.1 (0.7)	35.8 (1.0)	< 0.001
Age; years	65 (15)	70 (15)	< 0.001
Lactate; mmol.l^{-1}	2 (1.8)	3 (4.7)	< 0.001
Troponin	0.1 (10.8)	0.3 (1.1)	0.004
Glucose high	9.4 (2.55)	10.2 (4.6)	0.094
Glucose low	6.2 (1.5)	6.4 (2.2)	0.03
Hb high; g.l^{-1}	112 (18)	110 (21)	0.005
Hb low; g.l^{-1}	96 (20)	92 (20)	0.005
Bicarbonate high; mmol.l^{-1}	25.8 (3.0)	24.3 (3.8)	< 0.001
Bicarbonate low; mmol.l^{-1}	23.0 (2.9)	20.9 (5.3)	< 0.001
Hospital LOS; days	11 (25)	9 (33)	0.001
ICU LOS; days	1.0 (3.8)	1.6 (7.8)	< 0.001
APACHE	46 (18)	48 (20)	< 0.001

LOS, length of stay.

Table 3 Univariate analysis for in-hospital mortality.

Variable	Odds ratio (95% CI)	p value
Gender (male)	1.29 (1.03–1.62)	0.025
Age	1.02 (1.01–1.03)	< 0.0001
Lactate	1.25 (1.17–1.32)	< 0.0001
Troponin	1.02 (1.01–1.04)	0.009
Temperature	1.54 (1.35–1.75)	< 0.0001
Glucose low	1.04 (1.01–1.07)	0.005
Glucose high	0.91 (0.85–0.98)	0.015
Haemoglobin low	0.91 (0.86–0.96)	0.002
Bicarbonate low	0.85 (0.82–0.87)	< 0.0001
Bicarbonate high	0.87 (0.84–0.90)	< 0.0001

Univariate analysis found 10 factors associated with in-hospital mortality (Table 3). Multivariate analysis, however, eliminated 6 of these leaving four factors independently associated with in-hospital mortality: temperature, troponin, lactate, and age. Lowest temperature over the first 24 h after surgery had an odds ratio of 1.83 per degree Celsius decrease, (95% CI: 1.28–2.60, p = < 0.001). Plasma lactate had an odds ratio of 1.19 for each $mmol.l^{-1}$ increase (95% CI: 1.04–1.36, p = 0.01). Plasma troponin had an odds ratio of 1.02 per $\mu g.l^{-1}$ increase (95% CI: 1.00–1.04, p = 0.04). Increasing age had an odds ratio of 1.04 per year increase in age (95% CI: 1.00–1.07, p = 0.026).

Discussion

In this retrospective study of 5050 consecutive patients admitted to an Australian Intensive Care Unit (ICU) from the operating rooms, about one-third of patients were hypothermic (< 36 °C) in the first 24 h after surgery. This was consistent with our first hypothesis that inadvertent hypothermia would be common in postoperative ICU patients. Consistent with our second hypothesis, we found on multivariate analysis that hypothermia in the first 24 h after surgery in the ICU was associated with in-hospital mortality. Further severe hypothermia was associated with greater mortality than moderate hypothermia.

The incidence of at least one temperature reading < 36 °C was 35% and < 35 °C was 6%. This is a lower incidence of hypothermia than reported by Kongsayreepong et al. [17], who found that 57% of 194 general surgical ICU patients had a tympanic temperature < 36 °C and 28% had a temperature < 35 °C. In another study, Abelha et al. [16], found that 58% of 185 surgical ICU patients had a tympanic temperature < 35 °C. This is also higher than our study. In another study conducted 20 years ago before the widespread use of intra-operative forced air warming, Slotman et al. [2] found that 53% of patients admitted to a surgical ICU had a temperature < 36.1 °C. One explanation for the lower incidence of hypothermia in our study may be more aggressive intra-operative warming in our hospital [1]. We found the incidence of hypothermia after cardiac surgery was 31%. This is similar to previous work by Insler et al. [15] who studied over 5000 cardiac surgical patients and found that 28% were hypothermic (< 36 °C) in the ICU. There are few studies comparing cardiac and non-cardiac surgery patients. We found that cardiac surgery patients were less likely to be hypothermic in the intensive care unit than those patients that had undergone non-cardiac surgery (36.2 vs 36 °C). This is consistent with our previous work and is likely to be related to the efficiency of cardiopulmonary bypass for rewarming [5].

Previous work including randomised controlled trials have indicated that intra-operative hypothermia (< 36 °C) is associated with increased morbid cardiac events (such as myocardial ischaemia and ventricular tachycardia), increased bleeding, increased wound infections, thermal discomfort and longer hospital stay [1]. We have previously found an association between hypothermia and age and disease severity [5]. Again, in this study, patients who died tended to be colder but also sicker and older than patients who survived. On multivariate analysis, however, hypothermia was associated with mortality independent of age. Our multivariate logistic regression analysis indicated that hypothermia in ICU had an odds ratio of 1.8 for in-hospital mortality for each degree Celsius decrease. Insler et al. [15] also found a strong association of inadvertent hypothermia with mortality in cardiac surgical patients however previous smaller studies by Konsayreepong and Abelha failed to show an association between hypothermia and mortality in general surgical patients [15–17].

This is a large study of inadvertent hypothermia in a mixed surgical population of ICU patients that is one of few to examine the association between hypothermia and mortality [1]. The limitations of our study include that is a single centre, retrospective study, that did not include some surgical groups, particularly patients with severe trauma. These factors may limit the generalisability of our results. Another possible limitation of this study, as well as of previous studies by Karalapillai et al., Abelha et al. and Kongsayreepong et al. [5, 16, 17] is that all four studies used infrared tympanic thermometers to measure patients temperatures. Using Bland–Altman analyses to compare the 'gold standard' of a thermistor in a pulmonary artery catheter [22] to infrared tympanic, the tympanic thermometers have a bias (mean difference) of 0.1–0.4% less than thermistors.

Therefore when compared to a pulmonary artery catheter thermistor, infrared tympanic thermometers may overestimate the frequency of hypothermia. Furthermore, based on the limits of agreement (precision) estimates of Bland–Altman analyses, the tympanic thermometers are thought to be less precise than thermistors [23]. One limitation of these comparisons however is that the proportion of the bias and imprecision due to either tympanic thermometers or thermistors cannot be separated. It is likely however that the contribution of bias and imprecision from thermistors will be less than that from infrared thermometers. If the greatest reported bias is applied to our data the incidence of hypothermia would still be about 25% of patients. At present, however, the balance between accuracy, safety, and cost between non-invasive tympanic thermometers and thermistors in pulmonary artery catheters or urinary catheters is unclear.

Other limitations of our study relate to deficiencies in our collected data. The available data base did not include factors that may alter the risk for intra-operative hypothermia including elective or emergency surgery, duration of surgery, intra-operative temperature measurement, and intaoperative and postoperative warming. The database recorded only the lowest temperature in the first 24 h after admission to the ICU but not the time point during the 24 h that the lowest teperature occured.

Conclusions

Inadvertent hypothermia in postoperative ICU patients is common and is more likely after non-cardiac surgery. Tympanic temperature < 36 °C in the early postoperative period is associated with in-hospital mortality. Given the nature and limitations of this study we cannot, however, make any conclusions about causation. Further study is required to determine the most appropriate way to measure a patient's temperature in ICU and whether active warming of ICU patients decreases complications and mortality. This timing of the lowest temperature may be an important variable in these studies. In the interim, however, given the available evidence of adverse outcome associated with peri-operative hypothermia [1] we suggest that ICU staff should routinely expect to actively warm all postoperative patients admitted to the intensive care unit and have the appropriate resources to do so. Anaesthetists should remain vigilant in warming the patient and minimising heat loss both during and after surgery en route to ICU.

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