Association of Immediate Postoperative Temperature in the Surgical Intensive Care Unit with 1-Year Mortality: Retrospective Analysis Using Digital Axillary Thermometers

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Background: Postoperative body temperature is closely associated with prognosis although there is limited research regarding this association at postoperative intensive care unit (ICU) admission. Furthermore, no studies have used digital axillary thermometers to measure postoperative body temperature. This study investigated the association between mortality and postoperative temperature measured using a digital axillary thermometer within 10 minutes after ICU admission.

Methods: This retrospective observational study evaluated data from adult patients admitted to an ICU after elective or emergency surgery. The primary outcome was 1-year mortality after ICU admission. Multivariable logistic regression analysis with restricted cubic splines was used to evaluate the association between temperature and outcomes.

Results: We evaluated data from 5,868 patients admitted between January 1, 2013 and May 31, 2016, including 5,311 patients (90.5%) who underwent noncardiovascular surgery and 557 patients (9.5%) who underwent cardiovascular surgery. Deviation from the median temperature (36.6°C) was associated with increases in 1-year mortality (≤36.6°C: linear coefficient, −0.531; P<0.001 and ≥36.6°C: spline coefficient, 0.756; P<0.001). Similar statistically significant results were observed in the noncardiovascular surgery group, but not in the cardiovascular surgery group.

Conclusions: An increase or decrease in body temperature (vs. 36.6°C) measured using digital axillary thermometers within 10 minutes of postoperative ICU admission was associated with increased 1-year mortality. However, no significant association was observed after cardiovascular surgery. These results suggest that postoperative temperature is associated with long-term mortality in patients admitted to the surgical ICU in the postoperative period.

Key Words: critical care; intensive care units; temperature

Original Article

INTRODUCTION

Body temperature is routinely measured during the postoperative period [1], as postoperative hypothermia is a common complication associated with poor outcomes [2-4]. A 1°C–3°C

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decrease in tympanic temperature is associated with an increased complication rate, which can be reduced through active rewarming [5,6]. Postoperative hyperthermia may also be associated with adverse postoperative outcomes [7] and infection [1]. Patients admitted to the intensive care unit (ICU) after surgery have relatively severe conditions and it is critical to control their body temperature. Of the patients entering the ICU after surgery, 57.1% are exposed to core hypothermia [8] and, in this setting, hypothermia (mean temperature <36°C for 24 hours) is associated with in-hospital mortality [9].

Furthermore, body temperature changes continuously within a broad range (30°C–40°C), which can influence outcomes based on the specific definitions of hypothermia and hyperthermia [8,10]. This study evaluated the association between mortality and postoperative body temperature measured using a digital axillary thermometer immediately after ICU admission. To evaluate general trends, we did not specifically define hypothermia/hyperthermia, and instead evaluated associations based on the distribution of body temperatures.

MATERIALS AND METHODS

The protocol for this retrospective observational study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (SNUBH; IRB No. B-1806/474-105). Medical records were obtained for adult patients (≥19 years old) who were admitted to an ICU after undergoing elective or emergency surgery at SNUBH between January 1, 2013 and May 31, 2016. Only the last ICU admission was counted for patients who underwent multiple surgeries and ICU admissions. The exclusion criteria were: (1) inaccurate medical records, (2) death within 1 hour of ICU admission, (3) body temperature not measured using an axillary thermometer, and (4) interval between operating room discharge and ICU admission >15 minutes (e.g., patients who underwent computed tomography before ICU admission). SNUBH is a 1,360-bed tertiary care hospital with 102 beds in four ICUs (a medical ICU, a surgical ICU, and two emergency ICUs); approximately 150 surgeries per day are performed in 36 operating rooms. All patient records have been managed since 2003 using an electronic medical record system.

Measurements and Outcomes

The following data were collected: type of surgery, age (years), body mass index (kg/m²), cancer status, history of emergency surgery, American Society of Anaesthesiologists classification,

KEY MESSAGES

- One-year mortality increases when body temperature increases or decreases (vs. 36.6°C) among postoperative patients after intensive care unit (ICU) admission.
- This trend was not observed among patients who underwent cardiovascular surgery.
- The results suggest that postoperative temperature is associated with long-term mortality among patients admitted to the surgical ICU in the postoperative period.

operation time (minute), body temperature (°C), albumin level (g/dl), creatinine level (mg/dl), hemoglobin concentration (g/dl), platelet count (/μl), prothrombin time–international normalized ratio, and white blood cell count (/μl). The patients' temperatures were measured within 10 minutes of ICU admission using a digital axillary thermometer (ET*C205S; Terumo Corporation, Tokyo, Japan). Body temperature was measured in a single axilla by trained ICU nurses in accordance with a set protocol, and the measurement was repeated in the other axilla if the initial measurement was inaccurate. The mean temperature was recorded if measurements were performed more than twice based on suspicion of abnormal body temperature. The minimum values of the laboratory test results after ICU admission were recorded. Cardiac or major vascular surgeries using cardiopulmonary bypass were classified as cardiovascular surgeries; all other procedures were classified as noncardiovascular surgeries. The primary outcome was 1-year mortality after ICU admission. We also examined this association according to whether the patients underwent cardiovascular or noncardiovascular surgery.

Statistical Analysis

Continuous variables were reported as mean and standard deviation or median (range), and categorical variables were reported as number and percentage. Intergroup comparisons of 1-year mortality were performed using Student t-test and the chi-square test. The relationship between body temperature and 1-year mortality was analyzed after dividing the body temperatures using three knots (10%, median, and 90%). We then performed univariable logistic regression analyses with restricted cubic splines (RCS) at each of the continuous intervals between the knots (10% to median and median to 90%). Multivariable logistic regression analysis was performed using an RCS model that was fit with covariates that had P-values <0.1, and the analysis was adjusted for covariates that were fit in the univariable analysis [11]. Statistical significance was set

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at P<0.05, and analyses were performed using IBM SPSS ver. 23.0 (IBM Corp., Armonk, NY, USA) and R software ver. 3.3.2 with R packages (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Patients

A total of 8,198 cases were admitted to the ICUs after surgical procedures between January 1, 2013 and May 31, 2016. Among

Table 1. Baseline and demographic characteristics of postoperative patients in the ICU

Variable	Value	Median (range)
Operation		
Noncardiovascular surgery	90.5	
Cardiovascular surgery	9.5	
Age (yr)	61.51±15.50	63.0 (19.0–97.0)
Height (cm)	162.13±9.13	162.5 (123.0–195.3)
Weight (kg)	62.68±12.64	61.7 (24.3–160.0)
BMI (kg/m²)	23.76±3.80	23.6 (12.2–55.4)
Cancer		
No	65.9	
Yes	34.1	
Emergency operation		
No	82.6	
Yes	17.4	
ASA class		
1	12.8	
2	52.7	
3	32.6	
4+5+6	1.9	
Operation time (min)	235.57±140.81	220.0 (5.0–1,050.0)
Body temperature (°C)[a]	36.62±0.78	36.6 (28.9–39.8)
Albumin (g/dl)	3.14±0.69	3.1 (1.4–5.0)
Creatinine (mg/dl)	1.16±1.58	0.80 (0.15–18.46)
Hemoglobin (g/dl)	11.10±2.02	11.0 (5.0–17.4)
Platelet count (×10³/μl)	182.87±91.61	168.5 (7.0–821.0)
Prothrombin time (INR)	1.30±0.38	1.20 (0.84–5.27)
White blood cell count (×10³/μl)	10.99±6.02	10.06 (0.30–70.30)

Values are presented as percent (total number=5,868) or mean±standard deviation.
ICU: intensive care unit; BMI: body mass index; ASA: American Society of Anaesthesiologists; INR: international normalized ratio.
[a]Body temperature was defined as the first temperature measured using a digital axillary thermometer within 10 minutes of entry into the intensive care unit.

them, 1,028 cases were omitted because of two or more postoperative ICU admissions for single patients; only the last postoperative ICU admission was considered in the analysis. An additional 1,302 cases were also excluded because of patient age ≤18 years (477 patients), inaccurate data regarding operation time or ICU admission timing (91 patients), axillary temperature not measured within 10 minutes of ICU admission (617 patients), non-axillary temperature measurements (94 patients), death within 1 hour of ICU admission (six patients), and not being immediately admitted to the ICU (17 patients). Thus, 5,868 patients were included in the final analysis.

Table 1 summarizes the patients' characteristics. Noncardiovascular surgery was performed for 5,311 patients (90.5%) and cardiovascular surgery was performed for 557 patients (9.5%). Table 2 summarizes the patients' characteristics according to surgery type and mortality 1 year after ICU admission. No significant differences were observed in the axillary temperatures of patients who died within 1 year or survived to 1 year (survival, 36.62°C±0.52°C vs. death, 36.61°C±0.88°C; P=0.683). The same results were observed for the noncardiovascular surgery (P=0.661), and cardiovascular surgery (P=0.061) groups.

Multivariable Regression Model with RCS for 1-Year Mortality

The RCS between 1-year mortality and the initial postoperative axillary temperature in the ICU is shown according to surgical type in Figure 1. The three temperature knots were 36.0°C for 10%, 36.6°C for the median, and 37.2°C for 90%. The 1-year mortality rate tended to increase in both noncardiovascular and cardiovascular surgery groups as the postoperative body temperature decreased from 36.6°C. However, when the postoperative body temperature increased to more than 36.6°C, the 1-year mortality tended to increase in the noncardiovascular surgery group, but not in the cardiovascular surgery group.

Supplementary Table 1 shows the results of univariable logistic regression analysis with RCS for 1-year mortality, and Table 3 shows the results of the multivariable logistic regression analysis with RCS for 1-year mortality after adjusting for covariates. Overall, increases or decreases in temperature relative to the median (36.6°C) were associated with increased 1-year mortality (≤36.6°C: linear coefficient, −0.531, P<0.001; ≥36.6°C: spline coefficient, 0.756, P<0.001). A similar trend with larger coefficients was observed in the noncardiovascular surgery group (≤36.6°C: linear coefficient, −0.701, P<0.001;

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Table 2. One-year mortality after postoperative admission to the intensive care unit

Variable	All patients (n=5,868)			Noncardiovascular surgery (n=5,311)			Cardiovascular surgery (n=557)		
	1-Year survival	1-Year death	P-value	1-Year survival	1-Year death	P-value	1-Year survival	1-Year death	P-value
Age (yr)	60.54±15.45	68.27±14.11	<0.001	60.27±15.58	68.04±14.43	<0.001	63.08±13.92	70.75±9.96	<0.001
BMI (kg/m²)	23.99±3.79	22.06±3.47	<0.001	23.97 (3.80)	22.00 (3.51)	<0.001	24.19±3.69	22.77±2.96	0.001
Cancer	30.6	58.7	<0.001	33.5	64.1	<0.001	2.8	1.6	1.000
Emergency surgery	15.8	28.2	<0.001	16.2	28.0	<0.001	11.8	31.3	<0.001
ASA class			<0.001			<0.001			0.002
1	14.0	4.5		15.6	5.0		0.7	0	
2	53.4	47.5		56.5	51.3		28.0	9.4	
3	31.0	44.0		26.6	40.6		66.9	77.4	
4+5+6	1.6	4.0		1.2	3.1		4.4	13.2	
Body temperature (°C)[a]	36.62±0.52	36.61±0.88	0.683	36.63±0.50	36.65±0.81	0.661	36.50±0.65	36.18±1.31	0.061
Albumin <3 g/dl	31.8	57.1	<0.001	33.4	58.0	<0.001	18.8	48.2	<0.001
Creatinine >1.3 mg/dl	10.5	23.4	<0.001	10.0	21.2	<0.001	14.7	45.6	<0.001
Hb (g/dl)	11.24±1.94	10.49±1.97	<0.001	11.05±1.54	10.62±1.72	<0.001	10.94±1.75	10.01±1.94	<0.001
Platelet <100,000/μl	9.0	16.8	<0.001	7.5	15.6	<0.001	21.7	29.3	0.252
PT >1.3 INR	23.5	43.7	<0.001	18.8	40.1	<0.001	59.9	76.4	0.026
White blood cell count >10,000/μl	48.3	54.1	0.006	47.1	53.6	0.003	58.6	58.6	1.000

Values are presented as mean±standard deviation or percent.
BMI: body mass index; ASA: American Society of Anaesthesiologists; Hb: hemoglobin; PT: prothrombin time; INR: international normalized ratio.
[a]Body temperature was defined as the first temperature measured using a digital axillary thermometer within 10 minutes of entry into the intensive care unit.
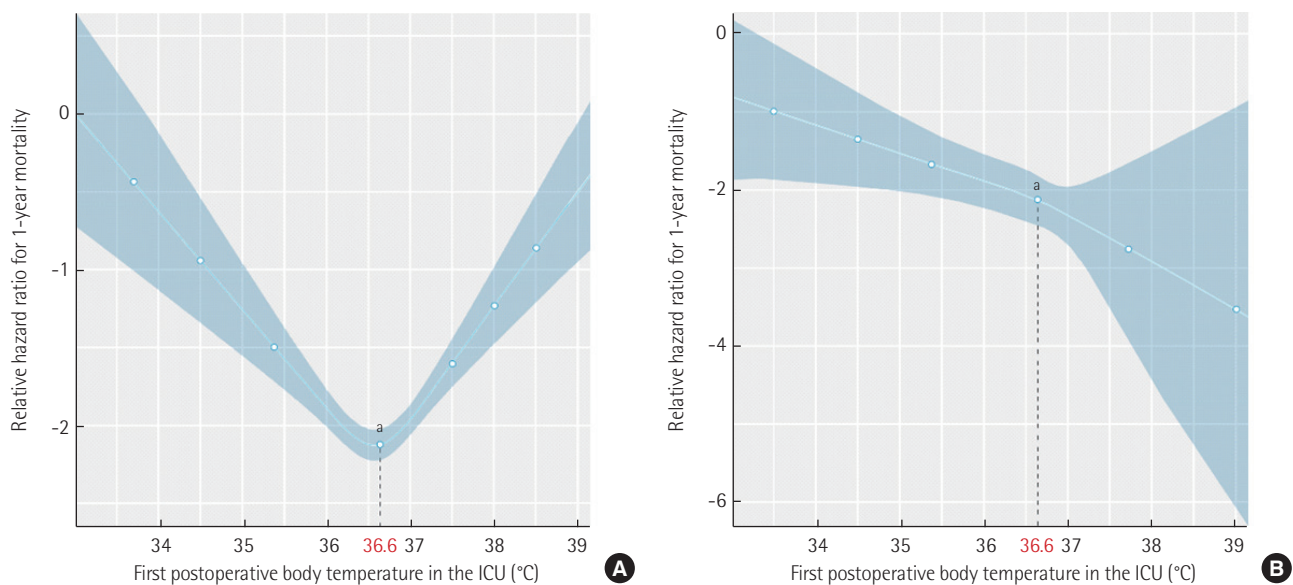

Figure 1. Restricted cubic splines between initial postoperative axillary temperature in the intensive care unit (ICU) and postoperative 1-year mortality. The results are shown for (A) noncardiovascular surgery and (B) cardiovascular surgery. Body temperature was defined as the first temperature measured using a digital axillary thermometer within 10 minutes of entry into the ICU. [a]The median value of the distribution of first postoperative body temperature in the ICU.

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Table 3. Multivariable regression model with restricted cubic splines for 1-year mortality after postoperative admission to the intensive care unit

Variable	All patients			Noncardiovascular surgery			Cardiovascular surgery		
	Coefficient	SE	P-value	Coefficient	SE	P-value	Coefficient	SE	P-value
Age (yr)	0.032	0.004	<0.001	0.030	0.004	<0.001	0.053	0.015	<0.001
BMI (kg/m²)	–0.119	0.015	<0.001	–0.121	0.016	<0.001	–0.107	0.054	0.049
Cancer (yes)	1.353	0.109	<0.001	1.425	0.116	<0.001	-	-	-
Emergency surgery (yes)	0.646	0.125	<0.001	0.606	0.134	<0.001	0.990	0.403	0.014
Body temperature: linear (≤36.6℃)[a]	–0.531	0.114	<0.001	–0.701	0.138	<0.001	–0.230	0.191	0.229
Body temperature: spline (≥36.6℃)[a]	0.756	0.140	<0.001	0.974	0.158	<0.001	-	-	-
Albumin (<3 g/dl)	0.494	0.117	<0.001	0.456	0.128	<0.001	0.902	0.359	0.012
Creatinine (>1.3 mg/dl)	0.857	0.134	<0.001	0.765	0.147	<0.001	1.390	0.358	<0.001
Hemoglobin (g/dl)	–0.045	0.029	0.120	–0.040	0.031	0.196	–0.042	0.099	0.674
Platelet count (<100 ×10³/μl)	0.429	0.150	0.004	0.518	0.165	0.002	-	-	-
PT >1.3 INR	0.563	0.118	<0.001	0.586	0.129	<0.001	0.248	0.376	0.510
White blood cell (>10×10³/μl)	0.228	0.106	0.031	0.245	0.112	0.029	-	-	-

SE: standard error; BMI: body mass index; PT: prothrombin time; INR: international normalized ratio.
[a]Body temperature was defined as the first temperature measured using a digital axillary thermometer within 10 minutes of entry into the intensive care unit.

≥36.6℃: spline coefficient, 0.974, P<0.001). However, no significant trend was observed in the cardiovascular surgery group (≤36.6℃: linear coefficient, –0.230, P=0.229; ≥36.6℃: spline coefficient, –0.157, P=0.710) (Supplementary Table 1).

DISCUSSION

The present study revealed that 1-year mortality increased in a linear pattern when body temperatures decreased relative to median temperature at ICU admission and increased in a spline pattern when the temperatures increased relative to the median temperature. This trend was maintained in the non-cardiovascular surgery group but was not observed in the cardiovascular surgery group. These findings are meaningful, as the multivariable logistic regression analysis with RCS used three knots without defining hypothermia and hyperthermia using specific cutoff values.

There are many possible explanations for increased mortality at relatively high and low body temperatures. First, the temperature measurements may reflect intraoperative hypothermia because they were measured immediately after surgery, and that state is relatively common and closely associated with adverse outcomes [12]. Second, hypothermia at ICU admission is predicted by several critical conditions, such as coagulopathy, excessive blood loss, acidosis, and shock [13]. However, the fact that some patients had hyperthermia immediately after surgery, despite receiving anaesthetic agents

and undergoing surgical procedures that could induce hypothermia [14], suggests that they may have had infections [15].

Interestingly, this trend was limited to the overall group and the noncardiovascular surgery group and was not observed in the cardiovascular surgery group (with cardiopulmonary bypass). A possible explanation is that we did not exclude patients who underwent mild therapeutic hypothermia to reduce their metabolic demands and improve neurological outcomes after cardiovascular surgery [16]. In addition, patients who required sedation or depended on an extracorporeal membrane oxygenation device during the immediate postoperative period were included in the cardiovascular surgery group. Thus, the effects of complex variables make it difficult to detect a direct association between body temperatures during the immediate postoperative period and long-term outcomes in the cardiovascular surgery group. Therefore, given the relatively small sample size of the cardiovascular surgery group (n=557), additional research is needed to examine this further.

The strengths of this study are the standardized definition of hypothermia (≤36.6℃) and the use of digital axillary temperature. In contrast, previous studies have used various cutoff points to define hypothermia [10,17], which allow for precise evaluation of the association with mortality [9]. However, changes in the definition of hypothermia can eliminate noticeable changes in mortality (e.g., using 36℃ and comparing 35.9℃ vs. 36.1℃, or 35.5℃ vs. 36.5℃). Furthermore, given

that the range of normothermia is quite large [18], it may be preferable to analyze body temperature as a continuous variable. It is also possible that a digital axillary thermometer is less accurate than a tympanic thermometer for measuring core temperature [19], although a previous study indicated that the accuracies of both thermometers are similar [20]. However, digital axillary thermometers are superior in terms of ease-of-use, speed, durability, security, patient comfort, and cost [21]. Finally, tympanic thermometers can cause perforation of the tympanic membrane [22], and their use may be limited in patients who have undergone facial, ear, or brain surgery. Therefore, given patients' instability during their postoperative ICU stay, it may be more appropriate to use digital axillary thermometers.

The present study has several limitations. First, the single-centre retrospective design is associated with known risks of bias. Second, the design did not consider any changes in clinical practice that had taken place during the study period. Third, only the first temperature measurement after ICU admission was used in the analysis, and we did not consider treatment or management processes (e.g., warming and therapeutic hypothermia). Fourth, the present study only evaluated a single method for measuring temperature.

In conclusion, the present study revealed increases in 1-year mortality when body temperature increased or decreased (vs. 36.6°C) among postoperative patients who were evaluated using a digital axillary thermometer within 10 minutes of ICU admission. However, this trend was not observed among patients who underwent cardiovascular surgery. This study suggests that postoperative temperature is associated with long-term mortality among patients admitted to the surgical ICU in the postoperative period.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Conceptualization: JK, TKO, IAS. Data curation: SK. Formal analysis: JL. Methodology: JK, TKO, IAS. Writing – original draft: JK, TKO. Writing – review & editing: IAS.

SUPPLEMENTARY MATERIALS

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Supplementary Table 1. Results of univariable logistic regression with restricted cubic splines for 1-year mortality after postoperative admission to the intensive care unit

Variable	All patients			Noncardiovascular surgery			Cardiovascular surgery		
	Coefficient	SE	P-value	Coefficient	SE	P-value	Coefficient	SE	P-value
Body temperature[a]									
Linear (≤36.6℃)	−0.539	0.091	<0.001	−0.628	0.109	<0.001	−0.341	0.150	0.023
Spline (≥36.6℃)	0.799	0.106	<0.001	0.909	0.120	<0.001	−0.157	0.421	0.710

SE: standard error.

[a]Body temperature was defined as the first temperature measured using a digital axillary thermometer within 5 minutes of entry into the intensive care unit.