Original Article

Postoperative Hypothermia after Cardiac Surgery: A Retrospective Cohort Study of Incidence and Risk Factors

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Background: Postoperative hypothermia (PH) may result in perioperative complications such as adverse cardiovascular events, coagulopathy with consecutive blood loss, and wound infection. Patients undergoing cardiac surgery with cardiopulmonary bypass (CPB) are at risk for hypothermia throughout the postoperative period.

Objective: To determine the incidence and risk factors of PH in patients after open cardiac surgery.

Materials and Methods: The present study was a retrospective cohort study of patients that underwent open cardiac or thoracic aortic surgery using CPB between January and December 2013. Patient characteristics, clinical data, and perioperative outcomes were abstracted and analyzed. PH was defined as body temperatures of less than 36°C upon arrival at the cardiac surgical intensive care unit (CSICU). Postoperative outcomes including bleeding from the chest tube, postoperative inotropic support, ventilator days, CSICU length of stay, and mortality were reviewed.

Results: Seven hundred sixty patients were included in the present study with 60.4% male, a mean age of 61.7 years, and 92.4% elective surgery with 96.3% first time surgery. The incidence of PH was 43.4%. Multiple logistic regression analysis demonstrated that factors associated with PH were increasing age (odds ratio 1.013 per year, 95% CI 1.002 to 1.023, p=0.020), female patients (odds ratio 1.40, 95% CI 1.03 to 1.89, p=0.032), deep hypothermia during CPB (odds ratio 2.33, 95% CI 1.26 to 4.30, p=0.007), and administration of more than 3L of intravenous fluid including crystalloids, colloids, and blood products, after separation of CPB until discharge from the operating room (OR) (odds ratio 1.52, 95% CI 1.09 to 2.12, p=0.014).

Conclusion: Approximately 43.4% of the cardiac surgical patients develop hypothermia following open cardiac or thoracic aortic surgeries. Factors associated with PH were increasing age, female patients, deep hypothermia during CPB, and administration of more than 3L of intravenous fluid after separation of CPB until discharge from the OR.

Keywords: Hypothermia; Postoperative; Cardiac surgical procedures; Cardiopulmonary bypass

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During cardiac and thoracic aortic surgery, hypothermia is induced with cardiopulmonary bypass (CPB) to protect organs against ischemia. Although patients' body temperature is raised to normal before separation from CPB, between 28.0% and 66.0% of the patients experienced postoperative hypothermia (PH) after cardiac surgery[1-3]. Mechanisms linked to PH after separation from CPB are 1) redistribution of body heat referred to as "afterdrop"[4], 2) exposure of chest cavity and thighs to the temperature in the operating room (OR), routinely set at 18°C to 24°C[5], 3) the prolonged duration between separation from CPB and discharge from the OR, and 4) administration of large volume of intravenous infusion[6]. PH can be followed by adverse events, such as cardiac arrhythmias, coagulopathy, delay emergence, and infection[7,8].

Factors associated with inadvertent PH have been extensively investigated in non-cardiac surgical procedures. Identified risk factors included older age[9,10], female gender[9], longer duration of surgery[11], combined general anesthesia and regional anesthesia[12], and a larger volume of intraoperative intravenous fluid administration[13]. However, few studies have focused on PH after open cardiac surgery. In the present study, the authors aimed to determine the incidence and risk factors associated with PH

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following open cardiac and open thoracic aortic surgery using CPB.

Materials and Methods

The present study was a single-center retrospective cohort study conducted at Siriraj Hospital, a tertiary care facility with over a thousand cardiac surgical procedures per year. The present study was approved by the Institutional Review Board (Si393/2014). Trial registration was made at the ClinicalTrials.gov (NCT02244034). Patients 18 years or older that underwent cardiac surgery with CPB between January 2013 and December 2013 were enrolled. Patients with missing data were excluded.

Temperature management during and after cardiac surgery

All procedures were conducted by the same group of surgeons, anesthesiologists, and perfusionists. Several degrees of hypothermia were induced during CPB. The target temperatures for CPB were determined by agreement among the team. Blood cardioplegic solution and topical hypothermia with cold saline were routinely given for myocardial protection. Temperature management was ensured by nasopharyngeal temperature monitoring throughout surgery and CPB. If deep hypothermic circulatory arrest (DHCA) was anticipated, the rectal temperature was also monitored. The present study protocol for rewarming was to constantly keep the temperature gradient between the arterial outlet and venous inflow at less than 10°C. In deep hypothermia cases, the authors kept the rectal and nasopharyngeal temperature gradient at 2°C or less.

All patients were warm until nasopharyngeal temperature reached 36.8°C to 37.5°C, and rectal temperature reached 36°C in deep hypothermia cases before separation from CPB. After the completion of CPB, warmed blood products were administered if there were indications for transfusion. Other types of fluid including crystalloids and colloids were not routinely warmed. There was no institutional protocol for setting up the OR temperature. Upon arrival at the cardiac surgical intensive care unit (CSICU), body temperature was measured using an infrared tympanic membrane thermometer. If the patients developed hypothermia, the forced-air warming blankets would be used to warm the patients.

In the present study, the primary outcome was incidence of PH, which was defined as body temperatures of less than 36°C upon arrival at the CSICU. Demographic and clinical characteristics of patients were recorded: age, gender, body weight, body surface area, the American Society of Anesthesiologists physical status (ASA-PS), condition of surgery such as elective or emergency, type of surgical procedure such as single valve surgery, coronary artery bypass graft surgery (CABGs), CABGs with valve surgery or multiple valve surgery, or aortic surgery with or without CABGs, degree of hypothermia during CPB as mild for 32°C or less or moderate for 28°C to less than 32°C or deep hypothermia for less than 28°C, DHCA technique, operative time, CPB time, duration after separation from CPB until transfer from the OR, total volume of intravenous infusion including crystalloids, colloids, and blood products after separation from CPB until discharge from the OR, and postoperative vasoactive drugs requirement. Patient outcomes as well as complications were also reviewed such as reoperation due to bleeding, bleeding from chest tube, cardiac arrhythmias, neurological complications as stroke or transient ischemic attack, length of CSICU stay, surgical site infection, and in-hospital death.

Statistical analysis

Sample size was calculated based on the incidence of hypothermia after cardiac surgery, which was about 50% from the previous studies(1,2). With an acceptable error of 3.5% and a type I error of 0.05, a sample size of 784 patients was required. Continuous data such as age, weight, operative time, and post-CPB time were presented as mean±standard deviation (SD) or median (IQR) as appropriate. Categorical data such as gender and ASA-PS were presented as numbers and percentages. Univariable analysis of factors associated with PH was performed using chi-square test and unpaired t-test. Variables with p-value less than 0.1 were entered into for multiple logistic regression analyses to determine factors associated with PH. The authors excluded DHCA technique, type of surgical procedure, and CPB time from the model due to the collinearity between these predictor variables. A p-value of less than 0.05 was considered statistically significant. Data were analyzed using SPSS Statistics, version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Demographics and baseline characteristics

Seven hundred sixty patients were enrolled in the present study. Most of the patients were male (60.4%), ASA-PS 3 (87.1%), and underwent CABGs

Table 1. Demographic and perioperative data

Variables	No hypothermia (n=430)	Hypothermia (n=330)	Total (n=760)	p-value
Age (years); mean±SD	60.7±15.2	63.0±13.7	61.7±14.6	0.034
Sex; n (%)				
Male	273 (63.5)	186 (56.4)	459 (60.4)	0.047
Female	157 (36.5)	144 (43.6)	301 (39.6)	
BSA (m^2); mean±SD	1.66±0.19	1.65±0.19	1.66±0.19	0.307
ASA-PS; n (%)				
3	394 (91.6)	268 (81.2)	662 (87.1)	<0.01
4	36 (8.4)	62 (18.8)	98 (12.9)	
Previous cardiac surgery; n (%)	14 (3.2)	14 (4.2)	28 (3.7)	0.470
Condition of surgery; n (%)				
Elective	412 (95.8)	290 (87.9)	702 (92.4)	<0.01
Emergency	18 (4.2)	40 (12.1)	58 (7.6)	
Types of surgical procedures; n (%)				
Single valve surgery	129 (30.0)	61 (18.5)	190 (25.0)	<0.01
CABGs	185 (43.0)	129 (39.0)	314 (41.3)	
CABGs with valve surgery or multiple valve surgery	74 (17.2)	70 (21.2)	144 (18.9)	
Aortic surgery with or without CABGs	42 (9.8)	70 (21.2)	112 (14.8)	
Degree of hypothermia during CPB (°C); n (%)				
Mild hypothermia (≥32)	305 (70.9)	190 (57.6)	495 (65.1)	<0.01
Moderate hypothermia (28 to <32)	99 (23.0)	82 (24.8)	181 (23.8)	
Deep hypothermia (<28)	26 (6.1)	58 (17.6)	84 (11.1)	
DHCA technique; n (%)	16 (3.7)	49 (14.8)	65 (8.6)	<0.01
Operative time (minutes); mean±SD	216.9±99.7	235.2±118.1	224.8±108.4	0.021
Operative time (hours); n (%)				
≤5	367 (85.3)	260 (78.8)	627 (82.5)	0.019
>5	63 (14.7)	70 (21.2)	133 (17.5)	
CPB time (minutes); mean±SD	109.5±54.9	116.0±60.9	112.3±57.6	0.123
CPB time group (hours); n (%)				
<3	383 (89.1)	289 (87.6)	672 (88.4)	0.523
≥3	47 (10.9)	41 (12.4)	88 (11.6)	
Time between separation from CPB to out of OR (minutes); mean±SD	60.3±26.0	66.0±31.2	62.8±28.5	0.007
Time between separation from CPB to out of OR (hour); n (%)				
≤1	276 (64.2)	190 (57.6)	466 (61.3)	0.064
>1	154 (35.8)	140 (42.4)	294 (38.7)	
Intravenous fluid administration after separation from CPB until discharge from the OR (L); mean±SD	2.9±1.4	3.4±1.4	3.1±1.5	<0.01
Intravenous fluid administration after separation from CPB until discharge from the OR (L); n (%)				
≤3	275 (64.0)	154 (46.7)	429 (56.4)	<0.01
>3	155 (36.0)	176 (53.3)	331 (43.6)	

BSA=body surface area; ASA-PS=American Society of Anesthesiologist physical status; CABGs=coronary bypass graft surgery; DHCA=deep hypothermic circulatory arrest technique; CPB=cardiopulmonary bypass; OR=operating room; SD=standard deviation

(41.3%) (Table 1). The incidence of PH was 43.4% (95% CI 39.8 to 47.0). The average temperature upon arrival at the CSICU in the hypothermia group was 35.3±0.4°C, which was significantly lower than the normothermia group, which was 36.4±0.4°C (p<0.01). Median time until body temperature returned to 36°C or warmer was 60 minutes (IQR 30, 90).

From the univariable analysis, factors associated with PH were increasing age (odds ratio 1.01 per year, 95% CI 1.00 to 1.02, p=0.032), female patients (odds ratio 1.35, 95% CI 1.00 to 1.81, p=0.047), ASA-PS 4 (odds ratio 2.53, 95% CI 1.63 to 3.93, p<0.01), emergency surgery (odds ratio 3.16, 95% CI 1.77 to 5.62, p<0.01), CABGs (odds ratio 1.48; 95% CI

Table 2. Univariable analysis of risk factors associated with postoperative hypothermia upon cardiac surgical intensive care unit arrival

Risk factors	Crude odds ratio	95% CI	p-value
Age (year)	1.01	1.00 to 1.02	0.032
Sex: female	1.35	1.00 to 1.81	0.047
ASA-PS 4[A]	2.53	1.63 to 3.93	<0.01
Previous cardiac surgery	1.32	0.62 to 2.80	0.475
Emergency surgery	3.16	1.77 to 5.62	<0.01
Types of surgical procedures[B]			
CABGs	1.48	1.01 to 2.15	0.044
CABGs with valve surgery or multiple valve surgery	2.00	1.28 to 3.13	0.002
Aortic surgery with or without CABGs	3.53	2.16 to 5.75	<0.01
Degree of hypothermia during CPB (°C)[C]			
Moderate hypothermia (28 to <32)	1.33	0.94 to 1.88	0.105
Deep hypothermia (<28)	3.58	2.18 to 5.89	<0.01
DHCA technique	4.51	2.52 to 8.09	<0.01
Operative time >5 hours	1.57	1.08 to 2.28	0.019
CPB time ≥3 hours	1.16	0.74 to 1.81	0.524
Time between separation from CPB to out of OR >1 hour	1.32	0.98 to 1.77	0.064
Administration of >3L of intravenous fluid after separation of CPB until discharge from the OR	2.03	1.52 to 2.72	<0.01

ASA-PS=American Society of Anesthesiologist physical status; CABGs=coronary bypass graft surgery; DHCA=deep hypothermic circulatory arrest technique; CPB=cardiopulmonary bypass; OR=operating room; CI=confidence interval

[A] Reference group is ASA-PS 3, [B] Reference group is single valve surgery, [C] Reference group is mild hypothermia (≥32°C)

Table 3. Multivariable analysis of risk factors associated with postoperative hypothermia upon cardiac surgical intensive care unit arrival

Risk factors	Adjusted odds ratio	95% CI	p-value
Age (year)	1.013	1.002 to 1.023	0.020
Sex: female	1.40	1.03 to 1.89	0.032
ASA-PS 4[A]	1.13	0.60 to 2.13	0.708
Emergency basis	1.85	0.84 to 4.00	0.120
Degree of hypothermia during CPB (°C)[B]			
Moderate hypothermia (28 to <32)	1.23	0.86 to 1.75	0.250
Deep hypothermia (<28)	2.33	1.26 to 4.30	0.007
Time between separation from CPB to out of OR >1 hour	0.89	0.63 to 1.25	0.498
Administration of >3L of intravenous fluid after separation of CPB until discharge from the OR	1.52	1.09 to 2.12	0.014

ASA-PS=American Society of Anesthesiologist physical status; CPB=cardiopulmonary bypass; OR=operating room; CI=confidence interval

Multiple logistic regression model with the following covariates: age, sex, ASA-PS, condition of surgery, degree of hypothermia during CPB, time between separation from CPB to out of OR >1 hour, administration of >3L of intravenous fluid after separation of CPB until discharge from the OR

[A] Reference group is ASA-PS 3, [B] Reference group is mild hypothermia (lowest temperature during CPB ≥32°C)

1.01 to 2.15, p=0.044), CABGs with valve surgery or multiple valve surgery (odds ratio 2.00, 95% CI 1.28 to 3.13, p=0.002), aortic surgery (odds ratio 3.53, 95% CI 2.16 to 5.75, p<0.01), deep hypothermia during CPB (odds ratio 3.58, 95% CI 2.18 to 5.89, p<0.01), DHCA technique (odds ratio 4.51, 95% CI 2.52 to 8.09, p<0.01), operative time of more than five hours (odds ratio 1.57, 95% CI 1.08 to 2.28, p=0.019), and administration of more than 3L of intravenous fluid including crystalloids, colloids, and blood products after separation of CPB until discharge from the OR (odds ratio 2.03; 95% CI, 1.52 to 2.72, p<0.01), (Table 2).

Factors associated with PH

Table 3 describes factors associated with the development of PH. From the multivariable analyses, factors associated with increased odds of inadvertent PH development were increasing age (odds ratio 1.013 per year, 95% CI 1.002 to 1.023, p=0.020), female patients (odds ratio 1.40, 95% CI 1.03 to 1.89, p=0.032), deep hypothermia with body temperature

Table 4. Patients' outcomes related to hypothermia

Outcomes	Hypothermia; n (%)		Crude OR (95% CI)	p-value
	No	Yes		
No. of patients	430 (56.6)	330 (43.4)		
Resternotomy due to medical bleeding	8 (1.9)	11 (3.4)	1.84 (0.73 to 4.62)	0.196
Bleeding from the chest tube ≥1L	65 (15.4)	75 (23.4)	1.68 (1.16 to 2.43)	0.006
Required inotropic support >24 hours	83 (19.7)	84 (26.3)	1.45 (1.03 to 2.05)	0.035
CSICU stay >24 hours	199 (47.3)	182 (56.7)	1.47 (1.10 to 1.97)	0.010
Cardiac arrhythmias	66 (15.7)	61 (19.1)	1.27 (0.86 to 1.86)	0.226
Neurological complications[A]	4 (10.0)	7 (2.2)	2.33 (0.68 to 8.03)	0.180
Wound infection	0 (0.0)	3 (0.9)	-	-
Hospital death	9 (2.1)	10 (3.0)	1.21 (0.77 to 1.91)	0.415

CSICU=cardiac surgical intensive care unit; OR=odds ratio; CI=confidence interval

[A] Neurological complications (stroke or transient ischemic attack)

of less than 28°C during CPB (odds ratio 2.33, 95% CI 1.26 to 4.30, p=0.007), and administration of more than 3L of intravenous fluid including crystalloids, colloids, and blood products after separation of CPB until discharge from the OR (odds ratio 1.52, 95% CI 1.09 to 2.12, p=0.014).

Association between PH and postoperative outcomes

Table 4 shows the association between PH and postoperative outcomes. The overall in-hospital mortality was 2.5%. There was no difference in mortality rate in the patients developed PH (3.0%) and in the normothermia group (2.1%) (p=0.415). Among patients who survived until discharge, the development of PH was associated with requirement of inotropic support of more than 24 hours (odds ratio 1.45, 95% CI 1.03 to 2.05, p=0.035), bleeding from chest tube of more than 1L (odds ratio 1.68, 95% CI 1.16 to 2.43, p=0.006), and CSICU stay longer than 24 hours (odds ratio 1.47, 95% CI 1.10 to 1.97, p=0.010).

Discussion

Despite attempts to rewarm the patients to normothermia prior to discontinuation from CPB, 43.4% of the patients developed PH following cardiac surgery. The incidence of PH in the present study was between those reported by the other two studies, 66% reported by Karalapillai et al[2] and 28% reported by Insler et al[1]. In the study by Karalapillai et al[2], different types of open-heart surgery were included and their primary endpoint was the lowest temperature in the first 24 hour of ICU admission. Therefore, the incidence of PH in Karalapillai et al's study was higher than the present study and the report from Insler et al[1]. However, the results from a large public clinical database (MIMIC III) demonstrated that only 7.3% of the patients had a mean body temperature during the first 24 hours of less than 36°C[14], therefore, suggested that immediate PH after cardiac surgery was transient.

Interestingly, the incidences of PH following cardiac surgery with CPB was close to that reported after surgical procedures without CPB, such as off-pump coronary artery bypass graft surgery (OPCAB) (46.7%)[15], assorted non-cardiac surgical procedures (56.7%)[16], and orthopedic surgeries under brachial plexus block (40.6%)[17]. Patients undergoing anesthesia and surgery are subject to heat loss from different mechanisms[18] such as 1) redistribution of core circulation to peripheries because it is more pronounced in general anesthesia than regional anesthesia, 2) loss of body heat by radiation, convection, evaporation and conduction, and 3) ineffective response of the body to heat loss. Hence, despite being actively warmed to ensure normothermia before discontinuation from CPB, the patients are still susceptible to the same heat loss mechanisms as other surgical patients while in the OR.

Factors associated with PH

Hypothermia and age: In the present study, a per-year increase in age was one of the risk factors for PH after cardiac surgery. Each year of increasing age was associated with the risk of hypothermia by 1.013%. The result is consistent with the previous studies in patients after CABGs[1] and assorted types of cardiac surgery[2]. Advancing age is also a known risk factor for PH in patients after different procedures, including OPCAB[15]. The incidence of PH among elderly patients after general surgery were between 33% to 93.1%[10,16,19]. Elderly patients are prone to PH as they have less subcutaneous fat, lower resting muscle tone, together with reduced ability to effectively regulate and maintain a normal body temperature[19]. Therefore, advancing age was associated with PH in the present study, as well as others.

Hypothermia and gender: Similar to other studies[1,2], female gender was also one of the significant risk factors for PH in the present study. Female gender was also identified as a risk factor for PH in patients after orthopedic surgery under different anesthesia techniques, mostly general anesthesia (73.4%)[9]. However, in a more recent study by Liu et al[20] in patients after total arch replacement with DHCA, female gender was not associated with PH. Different body characteristics between the two genders may influence thermoregulation during cardiac surgery. For instant, compared to males at the same age, females have lower body surface area, higher fat percentage, and different area of fat distribution. These characteristics may be associated with the cooling and rewarming difficulty during CPB, which can result in hypothermia after surgery. Additionally, from the mathematics model, Tindall et al[21] demonstrated that excess fat on the peripheral and rectal regions resulted in a larger core temperature drop at the end of rewarming. The other possible mechanism may be related to the hormone levels. Lee et al[22] had shown that the patients with intraoperative hypothermia had significantly lower estrogen and progesterone levels than the non-hypothermia group. Therefore, compared to male gender, female gender had a higher risk for the development of PH.

Degree of hypothermia during CPB: It is established that metabolism and oxygen requirements decrease following each degree drops in the body temperature. Therefore, body temperature is regulated for organ protection, especially the heart and the brain during CPB. During circulatory arrest, deep hypothermic technique, or less than 28℃, is a commonly used protective strategy to temporarily reduce metabolic demand while blood flow is interrupted. Results from the present study suggest that deep hypothermia during CPB is associated with PH. Liu et al[20] also reported that each degree drop in bladder temperature during CPB was associated with the risk for the development of PH after aortic surgery. Despite rewarming to normal body temperature, a post-CPB core temperature afterdrop can occur as a result of 1) post-CPB heat loss, 2) reduction of blood flow during CPB to muscle and viscera, and 3) post-CPB heat transfer from the core to the periphery as redistribution of heat[4,23].

The severity of afterdrop is usually more prominent if deep hypothermia was applied. Two studies by the same group of authors Rajek et al[24,25] reported an afterdrop of 2.2±0.4℃ in patients after cooling to deep hypothermia to a temperature of 17℃, and 2.3±0.9℃, and 1.5±0.4℃ in patients cooling to 27℃ and 31℃, respectively. In addition, deep hypothermia technique is typically adopted in more complex aortic surgeries that prolonged surgical and CPB time, as well as extensive volume of fluid and blood products administered after separation from CPB. Therefore, patients frequently develop PH after deep hypothermia.

Hypothermia and volume of intravenous fluid after separation from CPB until discharge from the OR: Extensive intraoperative fluid administration is related to hypothermia as reported from many studies with or without the use of CPB. Cho et al[26] had reported that receiving a larger volume is a risk factor of PH in patients undergoing orthopedic surgery under brachial plexus block. Another multicenter survey[27], which included 830 patients undergoing general anesthesia in 24 hospitals in Beijing, also demonstrated that receiving more than 1L of intravenous fluid was a risk for inadvertent intraoperative hypothermia. Besides the volume of fluid given, the temperature of the fluid and the rate of administration also contributed to hypothermia. In the authors' institute, only blood products were routinely warmed before being given to the patients, not crystalloid. Unsurprisingly, administration of more than 3L of intravenous fluid after separation from CPB until discharge from the OR was significantly associated with PH in the present study. A meta-analysis by Campbell et al[28] demonstrated that patients receiving warmed intravenous fluids intraoperatively had a higher (0.5℃) core temperature at the end of the surgery compared to the control group. Thus, it is reasonable to warm all fluid and blood products before administration to the patients to prevent PH after separation from CPB.

Although the authors demonstrated that intravenous fluid administration post CPB was associated with the development of PH, they were unable to take surgical blood loss into account. Surgical bleeding is known to increase the risk for PH, however, retrospective estimation of intraoperative blood loss in cardiac surgery can be challenging due to the use of pump suction, CPB priming fluid, and direct cooling fluid for heart protection. Therefore, the accurate amount of intraoperative blood loss was unknown and was not examined as a risk factor for PH.

Factors not associated with PH

DHCA technique, type of surgical procedure, and an operative time of more than five hours were also significantly associated with PH from univariable analysis. However, the authors did not include these factors in the multiple logistic regression analyses because of the collinearity of these covariates with deep hypothermia during CPB. Nonetheless, several studies[11,29] had reported that prolonged operative time increased the risk of hypothermia in patients receiving general anesthesia.

There are limitations to the present study. First, due to its retrospective nature, there is incomplete data such as ambient temperature and post-bypass temperature management. Additionally, during the study period, the authors' institution did not have a strict protocol for perioperative temperature management during cardiac surgery, which may result in variations among individual management, such as CPB temperature settings, active warming devices, and OR temperature. Moreover, the actual amount of blood loss in cardiac surgery can be challenging to estimate and influenced by many factors, such as CPB fluid, swabs, drapes, and drains, therefore, the authors did not include intraoperative blood loss into the analyses in the present study. These confounding factors were not recorded in the charts and thus not included in the analyses. Finally, infrared tympanic membrane temperature measurement can be approximately 0.5°C to 0.6°C below the urinary bladder temperature measurement[30].

Conclusion

In summary, PH is common following adult cardiac surgery. Increasing age, female gender, deep hypothermia during CPB, and excessive intravenous fluid administration after separation from CPB until discharge from the OR are risk factors for PH. Since PH may potentially lead to complications, the authors encourage combination of different strategies, such as, slow rewarming, the use of water circulating devices, OR temperature control, and pre-warming intravenous fluid prior to administration to prevent inadvertent PH, especially in high-risk older patients, female patients, lowest body temperature of less than 28°C, and when extensive amount of fluid administration are anticipated.

What is already known on this topic?

Inadvertent PH is common after cardiac surgery. The risk factors of PH include age, female gender, body surface area, CPB time, and low bladder temperature during CPB.

What this study adds?

There is still a need for improvement in reducing the incidence of PH after cardiac surgery in the authors hospital by increasing awareness. Implementation of a clear designed institutional guideline for managing PH is mandatory for improvement of patient outcomes. This study also shows that increasing age, female gender, deep hypothermia during CPB, and excessive intravenous fluid administration after separation from CPB until discharge from the OR are risk factors for PH.

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Conflicts of interest

The authors declare no conflict of interest.

References

1. Insler SR, O'Connor MS, Leventhal MJ, Nelson DR, Starr NJ. Association between postoperative hypothermia and adverse outcome after coronary artery bypass surgery. Ann Thorac Surg 2000;70:175-81.
2. Karalapillai D, Story D, Hart GK, Bailey M, Pilcher D, Cooper DJ, et al. Postoperative hypothermia and patient outcomes after elective cardiac surgery. Anaesthesia 2011;66:780-4.
3. Yu PJ, Cassiere HA, Kohn N, Mattia A, Hartman AR. Impact of postoperative hypothermia on outcomes in coronary artery bypass surgery patients. J Cardiothorac Vasc Anesth 2017;31:1257-61.
4. Pujol A, Fusciardi J, Ingrand P, Baudouin D, Le Guen AF, Menu P. Afterdrop after hypothermic cardiopulmonary bypass: the value of tympanic membrane temperature monitoring. J Cardiothorac Vasc Anesth 1996;10:336-41.
5. Wang CS, Chen CL, Huang CJ, Cheng KW, Chen KH, Wang CC, et al. Effects of different operating room temperatures on the body temperature undergoing live liver donor hepatectomy. Transplant Proc 2008;40:2463-5.
6. Ferraris VA, Ferraris SP. Limiting excessive

postoperative blood transfusion after cardiac procedures. A review. Tex Heart Inst J 1995;22:216-30.
7. Inaba K, Teixeira PG, Rhee P, Brown C, Salim A, DuBose J, et al. Mortality impact of hypothermia after cavitary explorations in trauma. World J Surg 2009;33:864-9.
8. Knaepel A. Inadvertent perioperative hypothermia: a literature review. J Perioper Pract 2012;22:86-90.
9. Kleimeyer JP, Harris AHS, Sanford J, Maloney WJ, Kadry B, Bishop JA. Incidence and risk factors for postoperative hypothermia after orthopaedic surgery. J Am Acad Orthop Surg 2018;26:e497-503.
10. Chun EH, Lee GY, Kim CH. Postoperative hypothermia in geriatric patients undergoing arthroscopic shoulder surgery. Anesth Pain Med 2019;14:112-6.
11. Chen HY, Su LJ, Wu HZ, Zou H, Yang R, Zhu YX. Risk factors for inadvertent intraoperative hypothermia in patients undergoing laparoscopic surgery: A prospective cohort study. PLoS One 2021;16:e0257816.
12. Mendonça FT, Lucena MC, Quirino RS, Govêia CS, Guimarães GMN. Risk factors for postoperative hypothermia in the post-anesthetic care unit: a prospective prognostic pilot study. Braz J Anesthesiol 2019;69:122-30.
13. Cho CK, Chang M, Sung TY, Jee YS. Incidence of postoperative hypothermia and its risk factors in adults undergoing orthopedic surgery under brachial plexus block: A retrospective cohort study. Int J Med Sci 2021;18:2197-203.
14. Xu F, Zhang C, Liu C, Bi S, Gu J. Relationship between first 24-h mean body temperature and clinical outcomes of post-cardiac surgery patients. Front Cardiovasc Med 2021;8:746228.
15. Hannan EL, Samadashvili Z, Wechsler A, Jordan D, Lahey SJ, Culliford AT, et al. The relationship between perioperative temperature and adverse outcomes after off-pump coronary artery bypass graft surgery. J Thorac Cardiovasc Surg 2010;139:1568-75.e1.
16. Mendonca FT, Ferreira JDS, Guilardi VHF, Guimaraes GMN. Prevalence of inadvertent perioperative hypothermia and associated factors: a cross-sectional study. Ther Hypothermia Temp Manag 2021;11:208-15.
17. Cho CK, Chang M, Sung TY, Jee YS. Incidence of postoperative hypothermia and its risk factors in adults undergoing orthopedic surgery under brachial plexus block: A retrospective cohort study. Int J Med Sci 2021;18:2197-203.
18. Riley C, Andrzejowski J. Inadvertent perioperative hypothermia. BJA Educ 2018;18:227-33.
19. Yang L, Huang CY, Zhou ZB, Wen ZS, Zhang GR, Liu KX, et al. Risk factors for hypothermia in patients under general anesthesia: Is there a drawback of laminar airflow operating rooms? A prospective cohort study. Int J Surg 2015;21:14-7.
20. Liu H, Wang X, Liu S, Cong S, Lu Y, Yang Y, et al. Postoperative hypothermia after total aortic arch replacement in acute type A aortic dissection-multivariate analysis and risk identification for postoperative hypothermia occurrence. J Thorac Dis 2020;12:7089-96.
21. Tindall MJ, Peletier MA, Severens NM, Veldman DJ, de Mol BA. Understanding post-operative temperature drop in cardiac surgery: a mathematical model. Math Med Biol 2008;25:323-35.
22. Lee C, Park S, Kim B, Yim H, Lee M, Lee J, et al. Effects of female reproductive hormone levels on inadvertent intraoperative hypothermia during laparoscopic gynecologic surgery: A retrospective study. Medicina (Kaunas) 2021;57:1255.
23. Engelman R, Baker RA, Likosky DS, Grigore A, Dickinson TA, Shore-Lesserson L, et al. The Society of Thoracic Surgeons, The Society of Cardiovascular Anesthesiologists, and The American Society of ExtraCorporeal Technology: Clinical practice guidelines for cardiopulmonary bypass--temperature management during cardiopulmonary bypass. Ann Thorac Surg 2015;100:748-57.
24. Rajek A, Lenhardt R, Sessler DI, Grabenwoger M, Kastner J, Mares P, et al. Tissue heat content and distribution during and after cardiopulmonary bypass at 17 degrees C. Anesth Analg 1999;88:1220-5.
25. Rajek A, Lenhardt R, Sessler DI, Kurz A, Laufer G, Christensen R, et al. Tissue heat content and distribution during and after cardiopulmonary bypass at 31 degrees C and 27 degrees C. Anesthesiology 1998;88:1511-8.
26. Cho CK, Chang M, Sung TY, Jee YS. Incidence of postoperative hypothermia and its risk factors in adults undergoing orthopedic surgery under brachial plexus block: A retrospective cohort study. Int J Med Sci 2021;18:2197-203.
27. Yi J, Xiang Z, Deng X, Fan T, Fu R, Geng W, et al. Incidence of inadvertent intraoperative hypothermia and its risk factors in patients undergoing general anesthesia in Beijing: A prospective regional survey. PLoS One 2015;10:e0136136.
28. Campbell G, Alderson P, Smith AF, Warttig S. Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia. Cochrane Database Syst Rev 2015;(4):CD009891.
29. Sari S, Aksoy SM, But A. The incidence of inadvertent perioperative hypothermia in patients undergoing general anesthesia and an examination of risk factors. Int J Clin Pract 2021;75:e14103.
30. Khan TA, Vohra HA, Paul S, Rosin MD, Patel RL. Axillary and tympanic membrane temperature measurements are unreliable early after cardiopulmonary bypass. Eur J Anaesthesiol 2006;23:551-4.