Original Article/*Özgün Araştırma*
doi: 10.54875/jarss.2023.29964

Perioperative Hypothermia and Associated Factors: A Prospective Cohort Study

Perioperatif Hipotermi ve İlişkili Faktörler: Prospektif Kohort Çalışma

Yavuz Kelleci[1], Ruslan Abdullayev[1], Gul Cakmak[1], Haluk Ozdemir[1], Tumay Umuroglu[1], Ayten Saracoglu[2]

[1]Marmara University Training and Research Hospital, Department of Anesthesiology and Reanimation, Istanbul, Türkiye
[2]Qatar University College of Medicine, Department of Anesthesiology, Doha, Qatar

ABSTRACT

Objective: Perioperative hypothermia is deleterious with many consequences, including coagulopathy, decreased immune functions, prolonged drug clearance, and cardiovascular complications. In this study we aimed to demonstrate the incidence of perioperative hypothermia during general anesthesia, its associated risk factors, and outcomes.

Methods: For this prospective cohort study patients aged 18-75 years with American Society of Anesthesiologists physical status I-III scheduled for any elective operation under general anesthesia in a one-month period were recruited. The patients' body temperatures were measured in the preoperative unit, in the operating theatre before induction, at the second hour of the operation, at the end of the operation, at the postoperative recovery unit admission, and discharge using a medical infrared thermometer. The patients' demographic and hemodynamic characteristics, magnitudes of surgery, surgery and anesthesia durations, warming methods, hospital and Intensive Care Unit (ICU) length of stays were recorded.

Results: Sixty five out of 290 enrolled patients (22.4%) developed perioperative hypothermia. Anesthesia and surgery time was longer in patients with hypothermia (p<0.001). Hospital length of stay of the patients was also longer in the patients with hypothermia (p<0.001). Intensive care unit admission of the patients with hypothermia was significantly higher compared with those with normothermia (2.7 vs 9.2%, p=0.030).

Conclusion: Perioperative hypothermia continues to be a challenge despite many published clinical application guidelines in this context. Intermediate and major type surgeries resulted in more perioperative hypothermia. Perioperative hypothermia was significantly associated with longer operation and anesthesia durations, hospital length of stays, and higher ICU admissions as well. Routine monitoring and active warming should be performed throughout the perioperative period to prevent hypothermia and current practice guidelines should be followed.

Keywords: Hypothermia, incidence, length of stay, risk factor, rewarming

ÖZ

Amaç: Perioperatif hipotermi, koagülopati, azalmış bağışıklık fonksiyonları, uzamış ilaç klirensi ve kardiyovasküler komplikasyonlar dahil olmak üzere birçok sonucu olan zararlı bir durumdur. Bu çalışmada genel anestezi sırasında perioperatif hipotermi insidansını, ilişkili risk faktörlerini ve sonuçlarını göstermeyi amaçladık.

Yöntem: Bu prospektif kohort çalışma için, bir aylık bir süre içinde genel anestezi altında herhangi bir elektif operasyon planlanan Amerikan Anesteziyologlar Derneği fiziksel durumu I-III olan 18-75 yaş arası hastalar alındı. Hastaların vücut sıcaklıkları preoperatif ünitede, ameliyat salonunda indüksiyondan önce, operasyonun ikinci saatinde, operasyon sonunda; ameliyat sonrası derlenme ünitesinin girişinde ve çıkışında tıbbi kızılötesi termometre kullanılarak ölçüldü. Hastaların demografik ve hemodinamik özellikleri, cerrahi büyüklükleri, ameliyat ve anestezi süreleri, ısıtma yöntemleri, hastane ve yoğun bakım ünitesin (YBÜ) yatış süreleri kaydedildi.

Bulgular: Kayıtlı 290 hastanın altmış beşinde (%22,4) perioperatif hipotermi gelişti. Anestezi ve cerrahi süresi hipotermili hastalarda daha uzundu (p<0,001). Hastaların hastanede kalış süreleri de hipotermisi olan hastalarda daha uzundu (p<0,001). Hipotermili hastaların yoğun bakıma yatışları normotermili hastalara göre anlamlı olarak daha yüksekti (%2,7'ye karşı %9,2, p=0,030).

Sonuç: Perioperatif hipotermi, bu bağlamda yayınlanan birçok klinik uygulama kılavuzuna rağmen sorun olmaya devam etmektedir. Orta büyüklükte ve majör tip ameliyatlar daha fazla perioperatif hipotermi ile sonuçlandı. Perioperatif hipotermi, daha uzun operasyon ve anestezi süreleri, hastanede kalış süreleri ve daha yüksek YBÜ yatışları ile de anlamlı şekilde ilişkiliydi. Hipotermiyi önlemek için perioperatif dönem boyunca rutin monitörizasyon ve aktif ısıtma yapılmalı, bu konuda güncel uygulama kılavuzları takip edilmelidir.

Anahtar sözcükler: Hipotermi, insidans, yatış süresi, risk faktörü, ısıtma

Received/Geliş tarihi : 26.03.2023
Accepted/Kabul tarihi : 05.10.2023
Publication date : 27.10.2023

***Corresponding author:** Yavuz Kelleci • dryavuzk@gmail.com
Yavuz Kelleci 0000-0002-0629-9272 / Ruslan Abdullayev 0000-0002-1025-4026
Gul Cakmak 0000-0001-6900-0293 / Haluk Ozdemir 0000-0001-6587-9990
Tumay Umuroglu 0000-0001-6887-1740 / Ayten Saracoglu 0000-0002-1186-0933

Cite as: Kelleci Y, Abdullayev R, Cakmak G, Ozdemir H, Umuroglu T, Saracoglu A. Perioperative hypothermia and associated factors: A prospective cohort study. JARSS 2023;31(4):339-348.

This work is licensed by "Creative Commons Attribution-NonCommercial-4.0 International (CC)".

INTRODUCTION

Hypothermia is defined as body temperature <36 °C, and this value is recognized in many international guidelines as a threshold. Behavioral responses to hypothermia include clothing, sheltering, using warmers. Body temperature regulation is provided by behavioral and autonomic responses. Autonomic responses to hypothermia are arteriovenous shunt vasoconstriction, shivering, and non-shivering thermogenesis in infants (1-4).

General anesthesia naturally eliminates behavioral responses, and moreover it has substantial effects on autonomic thermoregulatory control. Volatile anesthetics, including nitrous oxide; intravenous anesthetics, and opioids impair thermoregulatory control (1). Vasoconstriction and shivering thresholds are both decreased with these agents in a concentration or dose-dependent manner. A typical combination of drugs during general anesthesia decreases the vasoconstriction threshold to about 34.5 °C. Shivering pattern and intensity is also obscured by general anesthesia and neuromuscular blockade further impairs this response (5).

Cool operating room and anesthesia-induced impairment of the thermoregulation results in perioperative hypothermia in unwarmed patients. There are four major routes of heat loss, which are radiation, convection, evaporation, and conduction, with the first two accounting for more than 80% of the total perioperative loss (6).

Perioperative hypothermia, which is reported in 25-90% of surgical patients under general anesthesia is deleterious with many consequences, including coagulopathy; decreased host defense and susceptibility to infections; prolonged action of many drugs; thermal discomfort and shivering; cardiovascular complications like hypertension, tachycardia, and myocardial injury (6-15).

Patients can normally maintain normothermia in hospital environments, but cold operating rooms and the effect of general anesthesia disrupt the balance between heat production and loss. So, perioperative thermal management is challenging, and many unwarmed patients become hypothermic. This has resulted in development of many warming devices, including warming blankets; forced air warming devices; heated intravenous fluids; and warmed inspired and peritoneal gases as well.

Because of well-known complications of hypothermia described above, maintaining intraoperative normothermia has become a standard-of-care. Indeed, many guidelines have included recommendations about intraoperative temperature monitoring and active warming of the patients.

In this prospective cohort study, we aimed to demonstrate the incidence of hypothermia, its associated risk factors and outcomes in patients undergoing elective operations under general anesthesia. Our primary outcome measure was operation magnitude. Secondary outcome measures were hospital, and intensive care unit (ICU) length of stays. Our hypothesis was that the patients with longer operations would have more perioperative hypothermia, and that perioperative hypothermia would result in prolonged hospital and/or ICU length of stay.

MATERIAL and METHODS

This prospective cohort observational study was conducted in Marmara University Training and Research Hospital. Investigational Review Board approval (No: 09.2021.296) was obtained for the study and Declaration of Helsinki about the ethical principles for medical research involving human subjects were followed. Patients aged 18-85 years with American Society of Anesthesiologists (ASA) physical status I-III scheduled for any elective operation under general anesthesia expected to last 1-8 hours in a one-month period were recruited for the study. A written informed consent was obtained from the participants or their legal representatives in case of poor communication. Patients with neurological or psychiatric disorder; uncontrolled cardiovascular, respiratory, hepatic, renal or metabolic disorder with constant threat to life; those with alcohol or substance abuse; mentally retarded patients; and those having open heart surgeries were excluded from the study. Clinical trial registration was also made for the study (No: NCT05151237).

The patients' body temperatures were measured in certain time points through the perioperative period using a medical infrared thermometer (Harbin Xiande GP-300, China). This thermometer works with the principle of infrared radiation from the body. It is a revolver like device with a button that when you push measures the patient's body temperature using infrared radiation principle, Figure 1. It is capable of measuring body temperature within the range of 32-42.9 °C with measurement accuracy of ± 0.2 °C within 35-42 °C. Measuring distance from the body is 3-5 cm, and the measuring time is 1 sec. Three thermometers of the same model were used for the study to provide thermal conditioning of the device, where the thermometer should be kept for a minimum of 30 minutes in the specified area before the measurement performed. These thermometers were in the preoperative unit, in the operating room and postoperative recovery unit. Measurements were performed by a single investigator from the middle of the patient's forehead from a four cm distance. Four measurements were performed for each time specified measurement, of which an arithmetic mean of the middle two values was recorded as a data. A total of six measure-

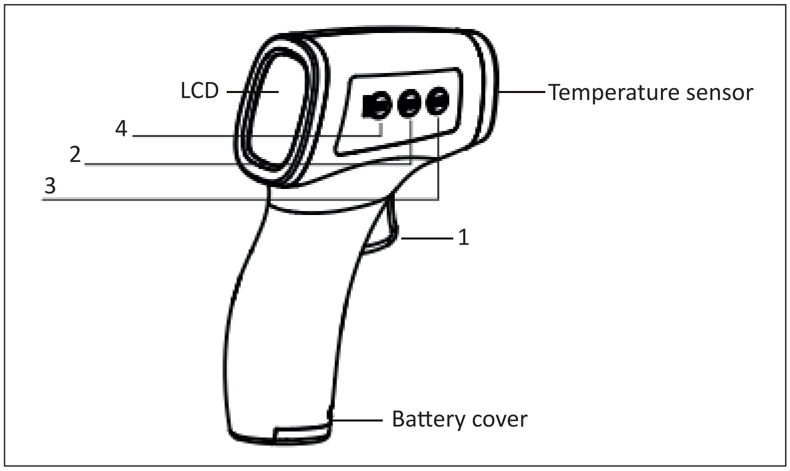

Figure 1: Schematic representation of the infrared thermometer (Harbin Xiande GP-300) used in the study. 1, Measure button; 2 and 3, temperature memory values; 4, Set key for body/surface temperature switch; or Celsius/Fahrenheit switch (with long press).

ments were performed, that were in the preoperative unit, in the operating theatre before induction, at the second hour of the operation (for the operations lasting more than two hours), at the end of the operation, at the postoperative recovery unit admission, and discharge.

The patients' demographic and morphometric characteristics, ASA physical statuses, pre- and postoperative heart rate (HR) and mean arterial pressure (MAP), intravenous (IV) fluids or blood products administered, surgical disciplines were recorded. The patients were grouped as those with normothermia (body temperature ≥ 36.0 °C, Group N) and those who developed hypothermia (body temperature < 36.0 °C, Group H) at any time during the perioperative period. Surgical procedure was grouped as minor, intermediate, or major in a subjective manner depending on the duration of the operation, extent of the procedure, expected fluid and heat loss. Superficial eye or skin operations lasting less than 2 hours were considered as minor operations. Laparoscopic operations, superficial abdominal operations, orthopedic operations without significant blood loss were considered intermediate. Operations involving opening of the body cavities, like laparotomy or thoracotomy; those associated with considerable loss of blood (>25 mL kg^{-1} body weight) or loss of insensible body fluid (>6 mL kg^{-1} h^{-1}) were considered as major surgeries. Perioperative warming method of the patient if present was noted. Operating theatre temperature at the start of the surgery, operation and anesthesia durations were noted as well. The patients' hospital and if present ICU length of stays were noted.

Statistical analysis was performed by Statistical Package for the Social Sciences (SPSS) 20.0 software (IBM Corp., Chicago, IL, USA). Incidence of perioperative hypothermia was estimated in this study. Categorical variables such as sex, ASA physical status, active warming method were presented as numbers and percentages. Continuous variables such as age, Body Mass Index (BMI), duration of anesthesia and surgery were presented as means and standard deviation (SD). Student's t test and Mann Whitney u test were used in the comparison of quantitative data with and without normal distribution, respectively. Kolmogorov-Smirnov test was used in the normality analysis. Chi-square test and Fisher exact test were used in the comparison of qualitative data. To identify the risk factors for hypothermia, a multivariate logistic regression analysis was performed for potential variables. A p<0.05 was considered statistically significant.

RESULTS

A total of 290 patients were recruited for the study in a one-month period, of which 146 (50.3%) were males, and the mean age of the patients was 46 ± 17 years (range between 18-82). Demographic, morphometric, and other baseline characteristics of the patients are presented in the Table I.

Hypothermia at any time during the perioperative period was observed in 65 (22.4%) patients (Table II). None of the patients had preoperative and only one had preinduction hypothermia. Temperature changes in the groups N and H throughout the perioperative period are presented in Figure 2. Throughout all perioperative period patients in the Group H had lower body temperatures compared with Group N (p=0.002 for preoperative values, p<0.001 for other time points).

The patient characteristics are presented in Table III. The patients' demographic, morphometric characteristics, ASA physical statuses were comparable between the two groups. Pre- and postoperative mean arterial pressure values, as well as preoperative heart rate of the patients were comparable between the two groups. However, postoperative heart rate was significantly higher in the Group H, compared with the Group N (p=0.032). Operating theatre temperatures were comparable between the groups. Anesthesia and surgery time was longer in the Group H (p<0.001). Hospital length of stay of the patients was longer in the Group H as well (p<0.001).

Intensive Care Unit length of stay in the Groups N and H were 3.2 ± 2.1 and 6.5 ± 7.6 days, respectively, but the difference was not statistically significant (p=0.589). Patients in Group H received significantly higher amount of IV crystalloid fluids, compared with Group N. There was significantly higher number of the patients receiving IV colloid fluids and packed red blood cells (PRBC) in Group H, compared with Group N (p=0.021 and 0.011 for colloids and PRBC, respectively). No significant difference between the groups was observed for Fresh Frozen Plasma (FFP) transfusion. About one tenth of the patients with minor operations had hypothermia, while about 30% of the patients with intermediate and major surgery had hypothermia, and this difference was statistically significant (p<0.001). One fifth of the patients not receiving any warming had hypothermia, while about one third of the patients with forced air warming developed hypothermia, and no patients with IV fluid warming had hypothermia (p= 0.006). Intensive Care Unit admission of the patients was 2.7 and 9.2% in the Groups N and H, respectively, and the difference was statistically significant (p=0.030).

Table I: Baseline Characteristics of the Patients

		n=290
Age (years)		46 ± 17 (18-82)
Gender	Male	146 (50.3)
	Female	144 (49.7)
ASA	I	109 (37.6)
	II	135 (46.6)
	III	46 (15.9)
Magnitude of surgery	Minor	117 (40.3)
	Intermediate	67 (23.1)
	Major	106 (36.6)
Surgical discipline		
Cardiovascular surgery		1 (0.3)
Ear nose throat		39 (13.4)
General surgery		76 (26.2)
Gynecology		16 (5.5)
Neurosurgery		40 (13.8)
Ophthalmology		15 (5.2)
Orthopedics		23 (7.9)
Plastic surgery		24 (8.3)
Thoracic surgery		39 (13.4)
Urology		17 (5.9)
Warming method		
None		217 (74.8)
Forced air warming device		67 (23.1)
IV fluid warming		6 (2.1)

Data are given as mean ± standard deviation (minimum-maximum) for quantitative, and number (percentage) for quantitative variables. **ASA:** American Society of Anesthesiologists physical status, **IV:** Intravenous.

Table II: Perioperative Hypothermia of the Patients

	n=290
At any time	65 (22.4)
Preoperative	0
Preinduction	1 (0.3)
Intraoperative 2nd hour	32/200* (16.0)
Postoperative	54 (18.6)
Recovery room admission	19 (6.6)
Recovery room discharge	6 (2.1)

Data are given as number of the patients with the percentage in parentheses. ***Intraoperative 2nd hour hypothermia data are only provided for the operations lasting more than 2 hours.

Multivariate logistic regression analysis indicated that IV crystalloid fluid amount received (OR=2.954, 95% CI: 1.283-6.802, p=0.011), administration of IV colloid fluid (OR=3.805, 95% CI: 1.480-9.781, p=0.006), intermediate (OR=4.345, 95% CI: 1.731-10.902, p=0.002) and major (OR=2.896, 95% CI: 1.181-7.102, p=0.020) type of surgery were the most significant indicators for the development of perioperative hypothermia (Table IV). Receiver operating characteristics (ROC) analysis revealed that cut-off point for IV crystalloid fluid amount in the development of perioperative hypothermia was 2000 mL (Chi-square 31.31, p<0.001).

There was no perioperative major morbidity or mortality in the patients recruited for the study.

DISCUSSION

In this prospective cohort study, we investigated the incidence of perioperative hypothermia in adult patients, its associated risk factors, patient outcomes, including length of hospital and ICU stay. We have also investigated the perioperative active warming rates and techniques in the operating room. The main results of the study were that 22.4% of the patients developed hypothermia at any time of the perioperative period. Perioperative hypothermia was significantly associated with operation and anesthesia duration, and with hospital length of stay as well.

Risk factors associated with perioperative hypothermia are older age, poor nutritional status, comorbidities impairing thermoregulation (polyneuropathy, hypothyroidism, etc.), ASA physical status higher than I, preexisting hypothermia, combination of neuraxial and general anesthesia, duration of anesthesia more than 2 hours, nature, and extent of surgery, use of large amounts of unwarmed irrigation fluids, temperature of the operating theater (6). Age and BMI have been associated with the development of hypothermia (16,17). In

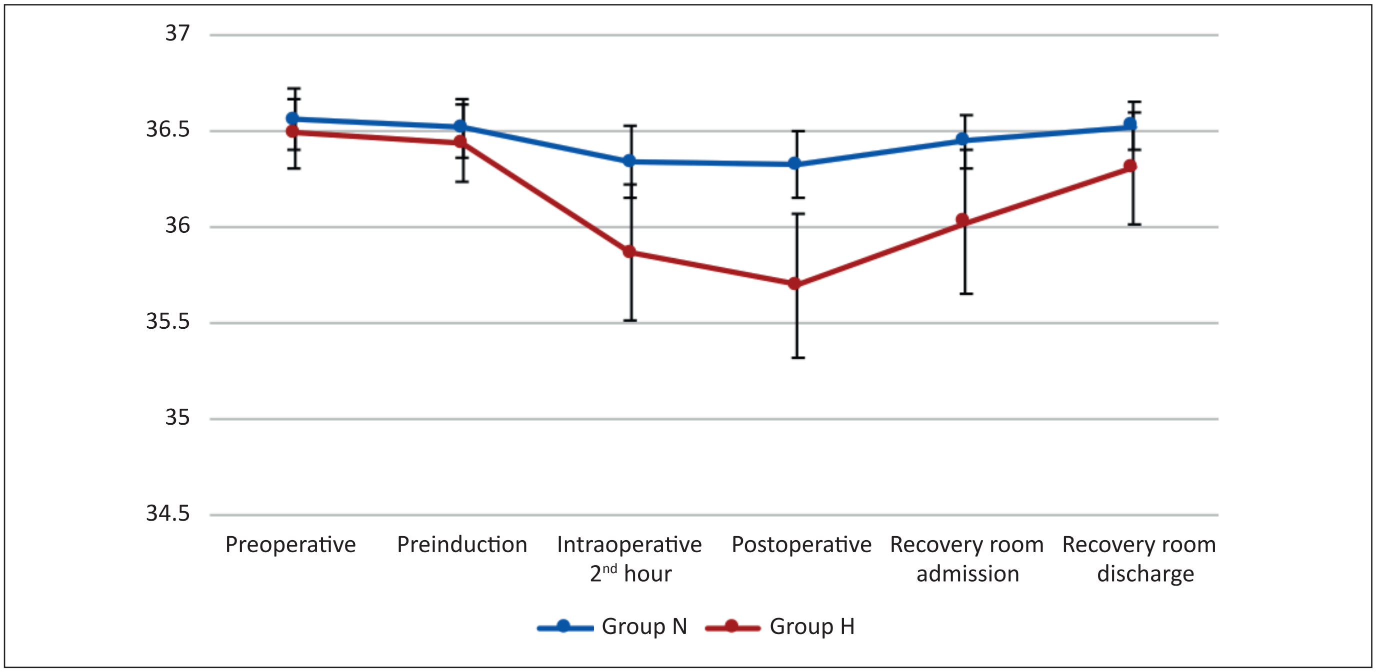

Figure 2: Temperature changes of the patients throughout the perioperative period.

Intraoperative 2nd hour hypothermia data are only provided for the operations lasting more than 2 hours. Group N, patients with normothermia (n=225). Group H, patients with hypothermia (n = 65). p=0.002 for preoperative values, p<0.001 for the rest.

Table III: Characteristics of the Patients with and without Perioperative Hypothermia

		Group N (n=225)	Group H (n=65)	p
Age (years)		46.2 ± 17.4	45.6 ± 16.6	0.791
Age (years)	<40	85 (79.4)	22 (20.6)	0.422
	40-64	98 (74.2)	34 (25.8)	
	≥65	42 (82.4)	9 (17.6)	
Gender	Male	115 (78.8)	31 (21.2)	0.627
	Female	110 (76.4)	34 (23.6)	
Height (cm)		168.3 ± 8.0	168.2 ± 8.9	0.931
Weight (kg)		76.0 ± 11.8	76.9 ± 13.1	0.614
BMI (kg m^{-2})		27.0 ± 4.7	27.3 ± 5.0	0.626
BMI	<25	77 (79.4)	20 (20.6)	0.818
	25-30	91 (75.8)	29 (24.2)	
	≥30	57 (78.1)	16 (21.9)	
ASA	I	87 (79.8)	22 (20.2)	0.544
	II	105 (77.8)	30 (22.2)	
	III	33 (71.7)	13 (28.3)	
MAP_0 (mmHg)		93.0 ± 13.6	93.5 ± 15.9	0.804
HR_0 (beat min^{-1})		87.8 ± 13.3	88.9 ± 13.3	0.577
MAP_{postop} (mmHg)		85.2 ± 11.7	86.4 ± 12.0	0.477
HR_{postop} (beat min^{-1})		78.2 ± 12.8	82.02 ± 11.6	0.032*
Operating theatre temperature (°C)		22.8 ± 1.8	22.7 ± 1.9	0.522
Operation duration (min)		130 ± 77	208 ± 105	<0.001*

Table III: Cont.

	Group N (n=225)	Group H (n=65)	p
Anesthesia duration (min)	155 ± 84	237 ± 109	<0.001*
Hospital length of stay (days)	3.6 ± 3.0	5.4 ± 4.5	<0.001*
ICU length of stay (days)	3.2 ± 2.1	6.5 ± 7.6	0.589
IV crystalloid fluid (mL)	1306 ± 710	2142 ± 1267	<0.001*
IV colloid fluid	63 (28.0)	28 (43.1)	0.021*
PRBC tx	15 (6.7)	11 (16.9)	0.011*
FFP tx	2 (0.9)	2 (3.1)	0.183
Magnitude of surgery			
Minor	104 (88.9)	13 (11.1)	
Intermediate	45 (67.2)	22 (32.8)	< 0.001*
Major	76 (71.7)	30 (28.3)	
Warming method			
None	176 (81.1)	41 (18.9)	
Forced air warming device	43 (64.2)	24 (35.8)	0.006*
IV fluid warming	6 (100)	0	
ICU stay	6 (2.7)	6 (9.2)	0.030*

Data are given as mean ± standard deviation (minimum-maximum) for quantitative, and number (percentage) for quantitative variables. *P <0.05. Group N, patients with normothermia; Group H, patients with hypothermia; **BMI:** Body mass index; **ASA:** American Society of Anesthesiologists physical status; **MAP_0, MAP_{postop}:** Baseline and postoperative mean arterial pressures; **HR_0, HR_{postop}:** Baseline and postoperative heart rates; **ICU:** Intensive care unit; **IV:** Intravenous; **PRBC tx:** Packed red blood cell transfusion; **FFP tx:** Fresh frozen plasma transfusion.

Table IV: Regression Analysis of Risk Factors for The Development of Perioperative Hypothermia

Variable	OR	95% CI	p
Anesthesia duration	0.994	0.970-1.018	0.611
Operation duration	1.020	0.994-1.047	0.141
IV crystalloid fluid amount**	2.954	1.283-6.802	0.011*
IV colloid fluid administration	3.805	1.480-9.781	0.006*
PRBC tx units	2.574	0.740-8.956	0.137
Intermediate type surgery	4.345	1.731-10.902	0.002*
Major type surgery	2.896	1.181-7.102	0.020*
Warming method	1.121	0.519-2.421	0.771

IV: Intravenous; **PRBC tx:** Packed red blood cell transfusion; **OR:** Odds ration; **CI:** Confidence interval. *p<0.05. **Threshold of 2000 mL was determined for IV crystalloid amount.

our study we did not observe higher rates of hypothermia in patients of 65 years or over. Nor there was difference regarding different BMI and ASA physical status groups. Although these have been considered as risk factors for the development of hypothermia in the literature, the results of our study could not demonstrate this. As perioperative warming was not a standard care for all the patients and this was left to the discretion of the primary anesthesiologist, who may have selected the patients to receive active warming. This selection based on the patient's age, BMI, ASA physical status, and comorbidities may have caused these results. Pre-existing hypothermia is an independent risk factor for hypothermia (6). Interestingly, in our study we did not observe preoperative hypothermia, and only one patient suffered from preinduction hypothermia. In our hospital we do not use active warming in patients preoperatively, but we have strict protocols for appropriate dressing and covering of the patients with a blanket to preserve their body heat. We linked these findings with our strict adherence to these local protocols. Anesthesia durations more than 2 hours have also been associated with hypothermia (6). In our study groups, mean anesthesia duration for patients with hypothermia was about 4 hours, whereas this was 2.5 hours for the patients who did not have hypothermia. It was not surprising that longer surgeries have resulted in more hypothermia. Infusion of large amounts of unwarmed solutions are also associated with the development of perioperative hypothermia. In our study patients in the hypothermia group had higher amount of crystalloid infusions, however this could only be attributed to the long durations of surgery. Transfusion of cold red blood cells have been associated with hypothermia (6). In our study patients with hypothermia had higher rates of PRBC transfusions, however it is hard to demonstrate a cause-effect relationship. Cold blood products could have resulted in hypothermia, and on the other hand hypothermia could have resulted in coagulopathy necessitation blood transfusions. Nature and extent of surgery was regarded as a risk factor for hypothermia (6). Our findings were concordant with this, as about 10% of the patients with minor, and about 30% with intermediate and major operations developed hypothermia. Operating room temperature is also decisive for perioperative hypothermia. Warmer theatres (21-24 °C) have resulted in less perioperative hypothermia than did colder ones (18-21 °C) (18). Operating theatre temperatures were comparable between normo- and hypothermia groups in our study (22.8 ± 1.8 vs 22.7 ± 1.9, p=0.522). According to our institutional protocols we routinely keep a temperature between 22-24 °C in our operating theatres for adult patients.

Volume of IV crystalloid fluid, administration of IV colloid fluid, and extent of surgery other than minor type were associated with the developing perioperative hypothermia in our study. Patients receiving high volume IV crystalloid fluids had greater chance of developing perioperative hypothermia, and 2000 mL was found to be the cut-off. Patients receiving IV crystalloid fluid volume above 2000 mL had 3 times greater chance of developing perioperative hypothermia. Patients receiving IV colloid fluids had 3.8 times more probability to develop perioperative hypothermia in our study as well. Moreover, patients undergoing intermediate and major surgeries had 4.3 and 2.9 times more probability to develop perioperative hypothermia. Chen et al. in their study have demonstrated that volume of intravenous fluids, and duration of surgery were significantly associated with perioperative hypothermia (19). Similar results regarding volume of intravenous fluids, and duration of surgery have been demonstrated by Poveda and Nascimento (20). The results of our study were concordant with their findings.

Taking all the risk factors for the development of perioperative hypothermia into consideration prediction of hypothermia can be made. Hypothermia prediction models have been tried, but they revealed high risk of bias and lack of validation, obviating their routine application in clinical practice (7). We suggest using individual risk factors in the development of perioperative hypothermia and evaluate them separately until solid and validated evidence-based risk prediction models evolve.

Perioperative hypothermia has negative effects on surgical outcomes, including impaired surgical wound healing, increased risk of infections, and increased hospital length of stay (21,22). On the other hand, there are reports in the literature which could not demonstrate differences regarding clinical outcomes in hypothermic patients compared with normothermic ones (8). A recent meta-analysis of randomized controlled trials and observational studies have demonstrated that intraoperative hypothermia did not result in longer hospital stays and mortality (23). Nevertheless, there are many studies in the literature pointing to the importance of the maintenance of body temperature in the perioperative period. Yi et al. have demonstrated beneficial effects of active warming in open thoracic and hip replacement surgeries, which resulted in less perioperative blood loss (24). Pan et al. have demonstrated similar results in total joint arthroplasty patients (25). Poveda and Nascimento did not demonstrate increased rates of blood transfusion with hypothermia (20). However, length of stay in post-anesthetic care unit was increased with hypothermia in their study. In our study patients with hypothermia had higher rates of PRBC transfusion compared with the normothermic ones. In addition, hospital length of stay of the patients with hypothermia was higher, compared with the normothermic patients.

As radiation and convection contribute to most of the heat lost perioperatively, convective heating like forced air warming blanket is very effective. Active warming is suggested to all the patients whose anesthesia is expected to last more than 30 minutes (21,22). Blankets laid on top of the body are suggested. Blankets laid under the patient should only be used as supplemental modality to other methods (26,27). Body insulation is also suggested to decrease conductive heat loss (28). Warming infusion fluids and blood products is also suggested if the rates of infusions are high (21,22). In our study we did not use active warming in 75% of the patients, while 23% were actively warmed via forced air warming device, and 2% via additional intravenous fluid in-line warming. In a study by Gabriel et al. about national guideline compliance, intraoperative forced air warming was used in 54% of the patients (29). Intraoperative active warming in our study was far less compared with these results. Moreover, Gabriel et al. have also demonstrated that active preoperative warming was used in 20% of the patients, which was in accordance with the recent guidelines used in their clinical practice (29). Indeed, preoperative warming was recommended by clinical practice guidelines, including German S3 Guideline and NICE Guideline for perioperative hypothermia (21,22). They have found 13% intraoperative hypothermia, which was 22% in our study. Another interesting finding of our study was that about 36% of the patients warmed intraoperatively with forced air warming devices developed hypothermia, while the ratio of hypothermia was 19% in the patients without any warming. This is an indication that we were selective about warming patients perioperatively. As a matter of course physician' decision together with the consideration of possible risk factors for developing hypothermia can be outlined here.

Turkish national guidelines for perioperative hypothermia prevention also recommend preoperative warming (30). In a study by Koksal et al. only 29% of the patients had routine perioperative warming (31). This study was conducted before the national guidelines were evolved, and maybe this was the incentive for the guidelines to be developed. Nevertheless, in a recent survey study by Inal et al. about the approach of anesthesiologists on perioperative hypothermia, only 26% of the participants had frequent routine use of perioperative temperature monitoring, and only 15% of them used routine perioperative warming of the patients (32). This study has demonstrated an interesting fact that although many of the specialists were aware of the complications of hypothermia and knew the guidelines regarding its prevention, still there was a problem about the implementation. Another survey study by Koh et al. comprising 6 Asia-Pacific countries, reported that routine intraoperative temperature monitoring during general anesthesia was 68% and routine intraoperative warming was 44% (33). Some factors may have contributed to the low rates of routine perioperative temperature monitoring and active warming in our country, including workload on the personnel and financial restrictions as well. Unfortunately, we do not have data about the rates of routine perioperative temperature monitoring in our institution, but we estimate it to be about 30-40% overall, being much more for pediatric patients, and probably reaching 100% for cardiac, trauma and neonatal surgeries. We had active warming, either with forced air warming device or with IV fluid warming, in about 25% of the patients in our study. This rate was close to the rates demonstrated by our national studies, and lower compared with the above-mentioned international survey studies.

The gold standard for core body temperature measurement is the measurement from the pulmonary artery via Swan-Ganz catheter. Less invasive measurement sites that are also regarded as core body temperatures are nasopharyngeal, distal esophageal, and tympanic membrane. The firs method is very rarely used, considering the invasiveness and the declining trend of the pulmonary artery catheters. Nasopharyngeal and esophageal measurements are somewhat invasive and special probes are needed obviating their routine perioperative use. Tympanic membrane measurements are based on the infrared radiation principle, and this method can give false results when the probe is misdirected to the tympanic membrane itself. Although skin temperatures are not good representatives of the core body temperatures, forehead skin temperatures generally have less variability (1,34). This was the reason for us to choose the forehead as a measurement site of temperature together with the noninvasiveness of the technique.

In our study we have taken 36 °C as a threshold for hypothermia. This value has been used in most if not all studies of hypothermia in the literature. Although it is practical to use this threshold in clinical practice, this could not always demonstrate significant differences regarding patient outcomes. In a meta-analysis performed by Xu et al. patients were subgrouped according to different hypothermia thresholds, including 35.5 and 35.0 °C, and no differences were demonstrated regarding intraoperative bleeding, hospital and ICU length of stay (23). Some other studies in the literature have also used 35.5 or 35.0 °C as a threshold for hypothermia and demonstrated no differences in surgical times, and hospital length of stays (35,36). We have used 36.0 °C as a threshold in our study and whether different thresholds, including 35.5 and 35.0 °C will change patient outcomes are beyond the scope of this paper and needs to be confirmed by future studies.

This study had some limitations. Firstly, we only measured intraoperative 2nd hour temperature of the patients, considering the workload related factors. This have resulted in lack of data of intraoperative values of the patients with operations under two hours. Considering the non-invasiveness of the measurement method, even more frequent measurements could have been made. Secondly, we did not record data of postoperative shivering, a common complication of perioperative hypothermia bringing about thermal discomfort to the patient. Even though we have treated it if this was the case, data about the shivering rates would provide valuable information about its relationship with hypothermia. Thirdly, we didn't collect the data about the regional anesthesia blocks performed on the patients. Considering the difference in the mechanisms of the heat loss, it would have been reasonable to obtain this data. Finally, we did not follow the patients regarding postoperative hemorrhage, surgical wound dehiscence, and infectious complications. These are well-known complications of perioperative hypothermia and could have resulted in prolonged hospital stays, ICU admissions, and ICU lengths of stay. Even though we have recorded the patients' hospital and ICU length of stays, reasons for prolonged stays or ICU admissions, including patient comorbidities, surgical complications, and complications of hypothermia would certainly provide more precise information.

In conclusion, 22.4% of the patients developed hypothermia at any time of the perioperative period. Perioperative hypothermia was significantly associated with longer operation and anesthesia durations, hospital length of stays, and higher

ICU admissions as well. Intermediate and major type surgeries resulted in more perioperative hypothermia. Intraoperative administration of large volumes of IV crystalloid fluid with a cut-off point of 2000 mL was associated with hypothermia, but this effect might have been only a consequence of the long operation periods. Intraoperative administration of IV colloid solutions and PRBC transfusion were associated with hypothermia, but cause-effect relationship should be validated by randomized controlled trials with homogeneous groups.

AUTHOR CONTRIBUTIONS

Conception or design of the work: AS
Data collection: GC, HO, YK
Data analysis and interpretation: YK, HO, RA, GC, TU
Drafting the article: YK, RA
Critical revision of the article: AS, TU
Other (study supervision, fundings, materials, etc): YK, RA, AS
The author (YK, HO, RA, GC, TU, AS) reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Sessler DI. Perioperative thermoregulation and heat balance. Lancet 2016;387(10038):2655-64.
2. Hales JR, Jessen C, Fawcett AA, King RB. Skin AVA and capillary dilatation and constriction induced by local skin heating. Pflugers Arch 1985;404(3):203-7.
3. De Witte J, Sessler DI. Perioperative shivering: Physiology and pharmacology. Anesthesiology 2002;96(2):467-84.
4. Karlberg P, Moore RE, Oliver TK Jr. Thermogenic and cardiovascular responses of the newborn baby to noradrenaline. Acta Paediatr Scand 1965;54:225-38.
5. Ikeda T, Kim JS, Sessler DI, et al. Isofl urane alters shivering patterns and reduces maximum shivering intensity. Anesthesiology 1998;88(4):866-73.
6. Torossian A, Bräuer A, Höcker J, et al. Preventing inadvertent perioperative hypothermia. Dtsch Arztebl Int 2015;112(10):166-72.
7. Yan L, Yao L, Zhao Q, et al. Risk prediction models for inadvertent intraoperative hypothermia: A systematic review. J Perianesth Nurs 2021;36(6):724-9.
8. Yi J, Lei Y, Xu S, et al. Intraoperative hypothermia and its clinical outcomes in patients undergoing general anesthesia: National study in China. PloS One 2017;12(6):e0177221.
9. Valeri CR, Khabbaz K, Khuri SF, et al. Eff ect of skin temperature on platelet function in patients undergoing extracorporeal bypass. J Thorac Cardiovasc Surg 1992;104(1):108-16.
10. Reed RL 2nd, Johnston TD, Hudson JD, Fischer RP. The disparity between hypothermic coagulopathy and clotting studies. J Trauma 1992;33(3):465-70.
11. Heier T, Caldwell JE. Impact of hypothermia on the response to neuromuscular blocking drugs. Anesthesiology 2006;10455):1070-80.
12. Leslie K, Sessler DI, Bjorksten AR, Moayeri A. Mild hypothermia alters propofol pharmacokinetics and increases the duration of action of atracurium. Anesth Analg 1995;80(5):1007-14.
13. Lenhardt R, Marker E, Goll V, et al. Mild intraoperative hypothermia prolongs postanesthetic recovery. Anesthesiology 1997;87(6):1318-23.
14. Frank SM, Higgins MS, Breslow MJ, et al. The catecholamine, cortisol, and hemodynamic responses to mild perioperative hypothermia. Anesthesiology 1995;82(1):83-93.
15. Greif R, Laciny S, Rajek A, Doufas AG, Sessler DI. Blood pressure response to thermoregulatory vasoconstriction during isofl urane and desfl urane anesthesia. Acta Anaesthesiol Scand 2003;47(7):847-52.
16. 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 Orthopaed Surg 2018;26(24):e497-503.
17. Emmert A, Gries G, Wand S, et al. Association between perioperative hypothermia and patient outcomes after thoracic surgery: A single center retrospective analysis. Medicine 2018;97(17):e0528.
18. El-Gamal N, Elkassabany N, Frank SM, et al. Age-related thermo-regulatory differences in a warm operating room environment (approximately 26 degrees C). Anesth Analg 2000;90(3):694-8.
19. 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 2016;16(9):e0257816.
20. Poveda VB, Nascimento AS. The effect of intraoperative hypothermia upon blood transfusion needs and length of stay among gastrointestinal system cancer surgery. Eur J Cancer Care 2017;26(6):e12688.
21. Torossian A, Becke K, Bein B, et al. S3 Leitlinie "Vermeidung von perioperativer hypothermie" Aktualisierung 2019. Available from: https://register.awmf.org/assets/guidelines/001-018l_S3_Vermeidung_perioperativer_Hypothermie_2019-08.pdf .
22. Hypothermia: Prevention and management in adults having surgery. National Institute for Health and Clinical Excellence (NICE) Clinical Guideline. Available from: https://www.nice.org.uk/guidance/CG65.
23. Xu H, Wang Z, Guan X, et al. Safety of intraoperative hypothermia for patients: Meta-analyses of randomized controlled trials and observational studies. BMC Anesthesiol 2020;20(1):202.
24. Yi J, Liang H, Song R, Xia H, Huang Y. Maintaining intraoperative normothermia reduces blood loss in patients undergoing major operations: A pilot randomized controlled clinical trial. BMC Anesthesiol 2018;18:126.

25. Pan P, Song K, Yao Y, Jiang T, Jiang Q. The impact of intraoperative hypothermia on blood loss and allogenic blood transfusion in total knee and hip arthroplasty: A retrospective study. BioMed Res Int 2020;3:1096743.
26. De Witte JL, Demeyer C, Vandemaele E. Resistive-heating or forced-air warming for the prevention of redistribution hypothermia. Anesth Analg 2010;110(3):829-33.
27. Galvão CM, Marck PB, Sawada NO, Clark AM. A systematic review of the effectiveness of cutaneous warming systems to prevent hypothermia. J Clin Nurs 2009;18(5):627-36.
28. Sessler DI, McGuire J, Sessler AM. Perioperative thermal insulation. Anesthesiology 1991;74(5):875-9.
29. Gabriel P, Höcker J, Steinfath M, et al. Prevention of inadvertent perioperative hypothermia - Guideline compliance in German hospitals. Ger Med Sci 2019;17:Doc07.
30. Turk Anesteziyoloji ve Reanimasyon Derneği istenmeyen perioperatif hipoterminin önlenmesi rehberi. Turk J Anaesth Reanim 2013;41(5):188-90.
31. Köksal GM, Dikmen Y, Utku T, et al. Perioperative temperature monitoring and patient warming: A survey study. Turk J Anaesth Reanim 2013;41(5):149-55.
32. İnal MA, Ural SG, Cakmak HŞ, Arslan M, Polat R. Approach to perioperative hypothermia by anaesthesiology and reanimation specialist in Turkey: A survey investigation. Turk J Anaesthesiol Reanim 2017;45(3):139-45.
33. Koh W, Chakravarthy M, Simon E, et al. Perioperative temperature management: A survey of 6 Asia-Pacific countries. BMC Anesthesiol 2021;21(1):205.
34. Barnason S, Williams J, Proehl J, et al. Emergency nursing resource: non-invasive temperature measurement in the emergency department. J Emerg Nurs 2012;38(6):523-30.
35. Walters MJ, Tanios M, Koyuncu O, et al. Intraoperative core temperature and infectious complications after colorectal surgery: A registry analysis. J Clin Anesth 2020;63:109758.
36. İwata Y, Newburger JW, Zurakowski D, Jonas RA. Postoperative hypothermia and blood loss after the neonatal arterial switch procedure. Ann Thorac Surg 2007;84(5):1627-32.