Effectiveness of a Hypothermia Prevention Guideline in Adult Patients Undergoing General Anesthesia at Srinagarind Hospital

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Abstract

Background: Perioperative hypothermia (POH), associated with various complications, has a reported incidence ranging from 30% to 70%. A previous incidence of 31% at Srinagarind Hospital prompted the development and implementation of a copyrighted clinical practice guideline (CPG) for the prevention and management of hypothermia in adults.

Objective: To assess the effectiveness and user satisfaction of this CPG.

Methods: This retrospective descriptive study included adult patients undergoing general anesthesia, with or without regional anesthesia, at Srinagarind Hospital between 1 January 2023, and 30 April 2023. POH was defined as a core temperature below 36 °C. Following induction, all patients received forced-air warming using either upper-body warming (UBW) or lower-body warming (LBW) blankets, depending on the surgical procedure and patient position. Body temperature was recorded every 15 minutes for up to 120 minutes. Postoperative satisfaction with the CPG was assessed among patients and anesthesia nurses.

Results: A total of 356 patients, predominantly male with the American Society of Anesthesiologists (ASA) classifications I-II, were enrolled. Sixty-seven patients (18.8%) developed POH. Patients receiving LBW tended to experience POH more frequently than those receiving UBW, although the difference was not statistically significant (P = .444). No patient's temperature fell below 35.5 °C. High satisfaction with CPG implementation was reported by both patients (99.4%) and anesthesia nurses (100%).

Conclusions: Implementation of a CPG emphasizing forced-air warming effectively reduced the incidence of POH in adult patients. The CPG demonstrated high satisfaction among both patients and anesthesia nursing staff.

Keywords: Hypothermia, Perioperative, Clinical practice guideline, Forced-air warming, Satisfaction

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Introduction

Perioperative hypothermia (POH), defined as a core temperature below 36 °C, represents a significant challenge in surgical patient care, affecting approximately 30%-70% of patients undergoing surgery without active warming measures.[1-4] This condition has been recognized as a critical perioperative complication since the early 1990s, with extensive research documenting its adverse effects on patient outcomes.[5] The consequences of POH extend beyond patient discomfort and include increased risk of surgical site infections, impaired wound healing, platelet dysfunction, coagulopathy, cardiac events, prolonged drug metabolism, delayed emergence from anesthesia, increased postoperative shivering, extended post-anesthesia care unit stays, and prolonged hospitalization.[6-9]

The pathophysiology of POH is multifactorial and involves several mechanisms. General anesthesia disrupts the body's thermoregulatory mechanisms by lowering the threshold for vasoconstriction and inhibiting shivering responses.[10] Inhalational anesthetics impair central thermoregulation in a dose- dependent manner, while the sympathetic blockade from neuraxial anesthesia causes peripheral vasodilation and heat redistribution from core to periphery.[6, 10, 11] Additionally, the operating room environment, with temperatures typically maintained between 20 °C and 24 °C, contributes to heat loss through radiation, convection, conduction, and evaporation. Surgical exposure, irrigation with room-temperature solutions, and administration of unwarmed intravenous fluids further exacerbate heat loss during procedures.[11]

Risk factors for developing POH include extremes of age, low body mass index (BMI), preexisting conditions (eg, hypothyroidism, severe trauma, burns), procedures involving large body cavities, lengthy surgical durations, and significant fluid shifts or blood loss.[1, 3, 5, 7] Recognizing these risk factors is essential for implementing appropriate preventive measures.

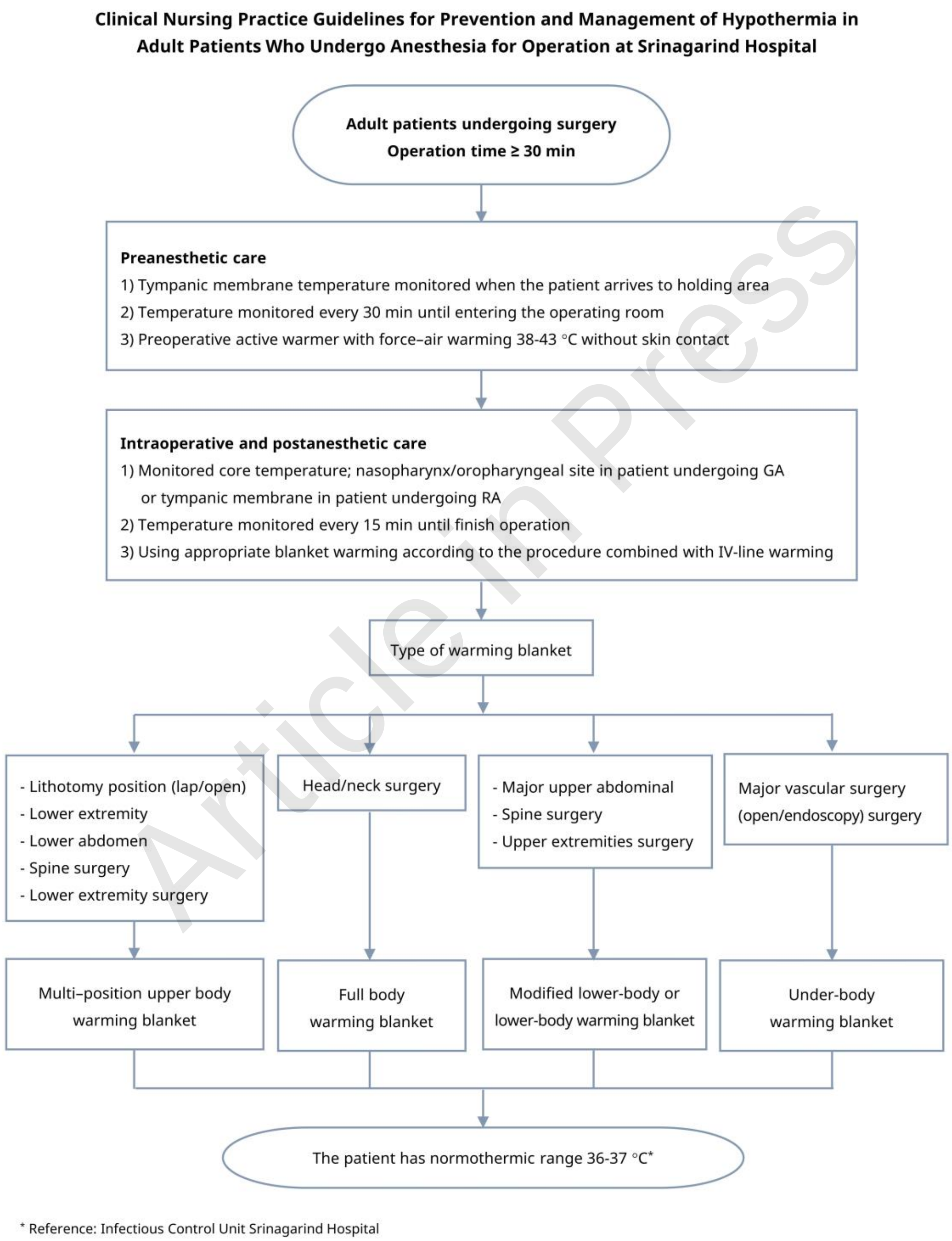
Interventions for POH prevention are categorized as passive or active. Passive interventions include increasing ambient temperature, applying warm blankets, removing wet clothing, protecting patients against wind, and using heat and moisture exchangers. While these measures help reduce heat loss, they are generally insufficient to maintain normothermia during longer procedures.[7] Active warming methods encompass infrared light, electric blankets, circulating-water mattresses or blankets, forced-air warming (convective air warming), heated intravenous and irrigation fluids, and humidified anesthetic gases.[12, 13] Among these, forced-air warming has emerged as the most widely recommended active intervention due to its effectiveness, safety profile, and cost-efficiency.[4, 14, 15]

Multiple professional organizations, including the American Society of PeriAnesthesia Nurses (ASPAN), the Association of periOperative Registered Nurses (AORN), the National Institute for Health and Care Excellence (NICE), and the Royal College of Anesthesiologists of Thailand, have published guidelines recommending routine temperature monitoring and active warming strategies for surgical patients.[16-20] These guidelines emphasize the importance of prewarming patients before anesthesia induction, maintaining appropriate operating room temperatures, and implementing active warming measures throughout the perioperative period.

A systematic review and meta-analysis demonstrated that active body surface warming, particularly forced-air warming, significantly reduces the risk of surgical site infections and postoperative complications compared to passive insulation.[21] Similarly, Nieh et al's[22] meta-analysis found that forced-air warming was more effective than passive insulation and circulating-water mattresses for maintaining normothermia and provided superior thermal comfort compared to other warming methods.

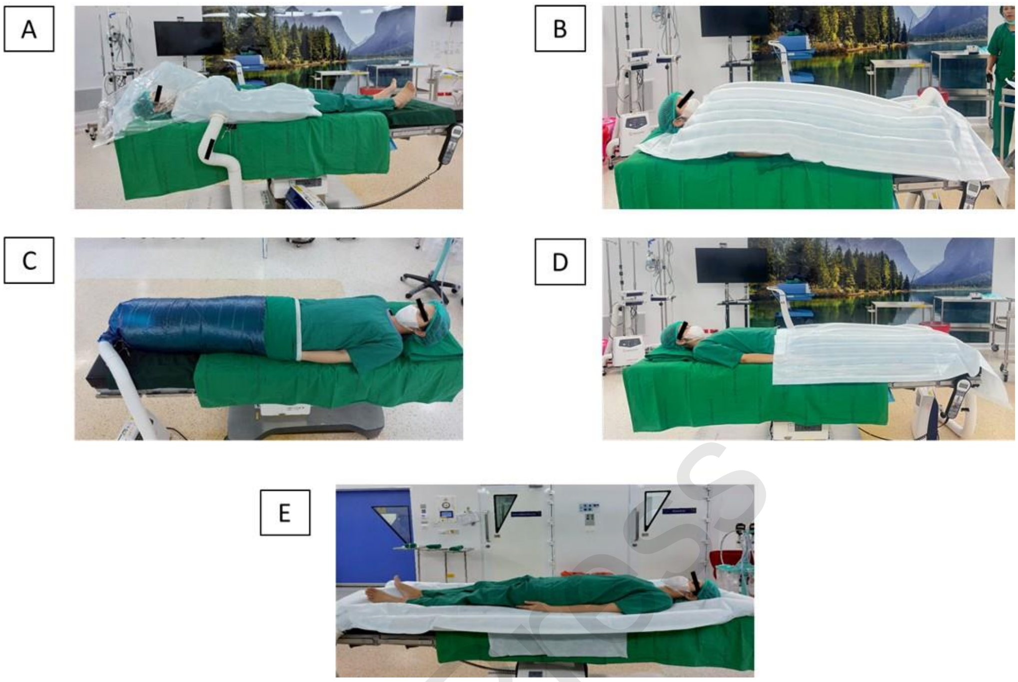
Despite substantial evidence supporting perioperative warming, implementation of comprehensive hypothermia prevention protocols remains inconsistent across healthcare facilities. Forced-air warming was not part of the routine perioperative care for patients undergoing surgeries exceeding 30 minutes at this study's institution. A 2014 survey at Srinagarind Hospital indicated a 31% incidence of POH, highlighting the need for standardized prevention protocols. In response to this challenge, this study's department developed and implemented a clinical practice guideline (CPG) emphasizing forced-air warming, copyrighted by Khon Kaen University and implemented in August 2022 (Figure 1). The CPG recommends specific warming blanket positions (multi-position upper body, full body, modified lower-body or lower-body, and under-body) (Figure 2) based on the surgical procedure and patient position. The CPG has been in effect since that time.

Figure 1. Clinical Practice Guideline for Prevention and Management of Hypothermia in Adults at Srinagarind Hospital



Abbreviations: GA, general anesthesia; IV, intravenous; RA, regional anesthesia.

Figure 2. Types of Warming Blankets



A, Multi-position upper-body warming blanket.

B, Full body warming blanket.

C, Modified lower-body blanket.

D, Lower-body warming blanket.

E, Under-body warming blanket.

This study aimed to evaluate the effectiveness of the CPG in reducing the incidence of POH and to assess user satisfaction with the guideline. The findings of this study may contribute to the optimization of perioperative care protocols and the prevention of POH-related complications in surgical patients.

Methods

Study Design and Participants

This retrospective descriptive study was approved by the Khon Kaen University Ethics Committee in Human Research (HE661371, approved on 9 August 2023). The requirement for individual patient consent was waived due to the retrospective nature of the study and the use of anonymized data. For the photographs showing warming blanket positions (Figure 2), informed consent was obtained from the individuals shown, and all identifiable features were obscured to protect privacy.

This study included adult patients who underwent general anesthesia, with or without regional anesthesia, at Srinagarind Hospital between 1 January 2023, and 30 April 2023. Inclusion criteria were age of at least 18 years, elective surgical procedures, surgical duration exceeding 120 minutes, and ASA physical status classification I-IV. Exclusion criteria encompassed patients undergoing total intravenous anesthesia for endoscopic procedures, lung or heart surgery (due to different temperature management protocols), incomplete medical records that lacked essential temperature measurements, and emergency surgeries.

Based on previous literature reporting POH incidence rates between 30% and 70% and this study hospital's baseline incidence of 31%, this study calculated that a sample size of 340 patients would provide 80% power to detect a reduction in POH incidence to 20% with a significance level of .05. Accounting for potential incomplete data, this study aimed to include at least 350 patients in the study.

Temperature Measurement Protocol

Body temperature was measured using 3 different methods at various perioperative stages: 1) preoperatively, a calibrated tympanic membrane thermometer (Braun ThermoScan® PRO 6000, Welch Allyn, USA) was used to measure body temperature during the preanesthetic evaluation; 2) intraoperatively, a nasopharyngeal temperature probe (General Purpose Temperature Probe, Smith Medical, USA) connected to the anesthesia monitoring system (Philips IntelliVue MP70, Philips Healthcare, Netherlands) was inserted to a depth of 10 to 15 cm from the nostril after anesthesia induction. The probe placement was verified by resistance at the nasopharynx and the absence of a fluctuating temperature reading that would indicate placement near the endotracheal tube; 3) postoperatively, the same tympanic membrane thermometer used preoperatively measured body temperature upon arrival at the postanesthesia care unit (PACU). Hypothermia was defined as a core temperature below 36 °C, consistent with the definition used by ASPAN and NICE.[16]

Implementation of the Hypothermia Prevention Guideline

All patients received standard monitoring according to ASA guidelines, including electrocardiography, noninvasive blood pressure measurement, pulse oximetry, capnography, and temperature monitoring. Anesthetic management followed standard protocols for the respective surgical procedures.

After anesthesia induction, patients were positioned according to surgical requirements. The appropriate warming blanket was selected based on the CPG recommendations: 1) upper-body warming (UBW) blanket, used for surgeries where the lower body was the surgical site or required exposure (eg, urological procedures, lower limb orthopedic surgeries); 2) lower-body warming (LBW) blanket, used for surgeries involving the head, neck, thorax, or upper extremities (eg, thyroidectomy, breast surgery, upper limb orthopedic procedures).

Forced-air warming devices (Bair Hugger™ Model 775, 3M, USA) were activated immediately after blanket placement and set to 38 to 43 °C according to the manufacturer's recommendations. The operating room temperature was maintained between 20 °C and 24 °C as per institutional protocol.

Intravenous fluids were administered at room temperature for volumes less than 1 L. For procedures anticipated to require larger fluid volumes (> 1 L) or blood transfusions, fluid warming devices (Ranger™ Blood/Fluid Warming System, 3M, USA) were employed.

Data Collection

Demographic and clinical data were extracted from electronic medical records, including: 1) patient characteristics (age, sex, weight, height, BMI, ASA classification, and comorbidities);

2) surgical details (type of surgery, surgical position, and duration of anesthesia and surgery); 3) anesthetic management (anesthetic technique, fluid administration, and blood transfusion); 4) temperature measurements (preoperative, intraoperative [every 15 minutes for up to 120 minutes], and postoperative temperatures); and 5) complications (presence and grade of shivering, cardiovascular events, and wound complications).

The primary outcome was the incidence of POH, defined as a core temperature below 36 °C at any point during the perioperative period. Secondary outcomes included temperature trends over the 120-minute observation period, and the incidence and severity of postoperative shivering, graded on a 5-point scale (grade 0: no shivering; grade 1: piloerection or peripheral vasoconstriction without visible shivering; grade 2: muscular activity in only one muscle group; grade 3: muscular activity in more than one muscle group, but not generalized; grade 4: whole body shivering).

Satisfaction Assessment

Postoperative satisfaction with the CPG implementation was evaluated among patients with a simple binary question (satisfied/unsatisfied) which was asked during the routine postoperative visit, focusing on thermal comfort during the perioperative period, and anesthesia nurses with a survey which was conducted among the anesthesia nursing staff responsible for implementing the CPG, assessing satisfaction with the guideline's clarity, feasibility, and perceived effectiveness.

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp; 2019). Continuous data were presented as mean (SD) or median (interquartile range [IQR]) based on the normality of distribution as assessed by the Shapiro-Wilk test. Categorical data are presented as counts and percentages. Temperature measurements collected at multiple time points were analyzed using repeated measures analysis of variance (ANOVA). The incidence of POH between warming techniques was compared using the chi-square test or Fisher exact test as appropriate. A *P* value less than .05 was considered statistically significant for all analyses.

Results

Patient Characteristics

All recruited patients demonstrated full compliance with the CPG. Of the 356 enrolled patients, the majority were female (59.3%) and had an ASA classification of I-II (85.1%). The mean (SD) age was 51.6 (17.1) years, and the mean (SD) BMI was 24.0 (5.8) kg/m^2. The most common surgical procedures were general surgery (39.6%) and orthopedic surgery (23.3%) (Table 1).

Incidence of Perioperative Hypothermia

The overall incidence of POH in this study population was 18.8% (67/356 patients), representing a significant reduction from the previously reported 31% incidence at this study’s institution prior to CPG implementation. Analysis by warming technique revealed that patients receiving LBW experienced POH more frequently (41/203, 20.2%) than those receiving UBW (26/153, 17.0%), although this difference did not reach statistical significance (*P* = .444) (Table 2).

Table 1. Demographic and Clinical Data of the Patients

Data	No. (%)
Age, mean (SD), y	51.6 (17.1)
Sex (male/female)	145 (40.7)/211 (59.3)
ASA	
I	95 (26.7)
II	208 (58.4)
III	52 (14.6)
IV	1 (0.3)
BMI, mean (SD), kg/m^2	24.0 (5.8)
MAP, mean (SD), mmHg	77.3 (9.7)
HR, mean (SD), beat/min	66.0 (10.9)
Types of surgery	
Dental	3 (0.8)
Ear, nose, and throat	47 (13.2)
Eye	6 (1.7)
Gynecology	42 (11.8)
Orthopedic	83 (23.3)
General surgery	141 (39.6)
Neurosurgery	12 (3.4)
Plastic surgery	14 (3.9)
Urology	5 (1.4)
Vascular	3 (0.8)
Blood transfusion, unit	
0	434 (96.9)
PRC 1	10 (2.2)
PRC 2	1 (0.2)
PRC 2 + FFP 1	1 (0.2)
PRC 5	2 (0.5)
Anesthetic technique	
GA	330 (92.7)
GA + PNB	6 (1.7)
GA + EPB	10 (2.8)
GA + SB	10 (2.8)
Preoperative body temperature, mean (SD), °C	36.4 (2.0)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; EPB, epidural block; FFP, fresh frozen plasma; GA, general anesthesia; HR, heart rate; MAP, mean arterial pressure; PNB, peripheral nerve block; PRC, packed red cell; SB, spinal block.

Table 2. Main Outcomes

Outcome	No. (%)
Core temperature < 36 °C	67 (18.8)
UBW (n = 153)	26 (7.3)
LBW (n = 203)	41 (11.5)
Postoperative shivering	7 (1.9)
Grade 1	3 (0.8)
Grade 2	4 (1.1)

Abbreviations: LBW, lower body warming; UBW, upper body warming.

Temperature Trends

Despite the differences in POH incidence between warming techniques, both UBW and LBW groups exhibited similar intraoperative temperature patterns over the 120-minute observation period. There was an initial gradual decrease in core temperature during the first 30 to 45 minutes after anesthesia induction, followed by a gradual increase as the active warming took effect (Figure 3).

The mean temperature nadir occurred at approximately 45 minutes after induction in both groups. The mean (SD) lowest recorded temperature was 36.1 (0.4) °C in the UBW group and 36.0 (0.5) °C in the LBW group ($P = .073$). Notably, no patient's temperature fell below 35.5 °C during the study period, indicating that while mild hypothermia occurred in some patients, moderate to severe hypothermia was effectively prevented.

Repeated measures ANOVA revealed a significant time effect on temperature changes ($P < .001$), confirming the observed pattern of initial temperature drop followed by recovery. The interaction between time and warming technique was not statistically significant ($P = .396$), suggesting that the temperature trends were similar regardless of which warming technique was used.

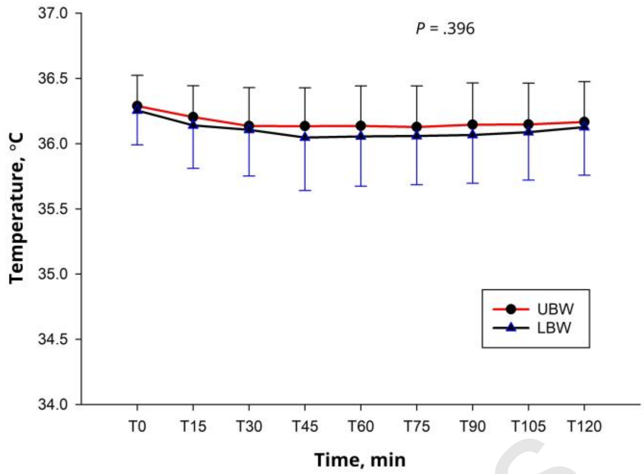
Postoperative Shivering

Postoperative shivering was observed in only 7 patients (1.9%), with mild manifestations (grade 1-2) in all cases (Table 2). No patient experienced moderate to severe shivering (grade 3-4). Among patients who developed POH, 5 (7.5%) experienced shivering, compared to 2 (0.7%) in the normothermic group ($P = .002$), indicating a significant association between hypothermia and shivering despite active warming measures.

Satisfaction With CPG Implementation

High satisfaction with CPG implementation was reported by nearly all patients (354/356, 99.4%) and all participating anesthesia nurses (85/85, 100%) (Table 3). Two patients who reported dissatisfaction both experienced mild hypothermia (core temperatures of 35.7 °C and 35.8 °C) and grade 1 shivering during the postoperative period.

Figure 2. Types of Warming Blankets



Abbreviations: LBW, lower body warming; UBW, upper body warming.

Table 3. Patients' and Anesthesia Nurses' Satisfaction

Satisfaction	No. (%)
Patients (n = 356)	
Satisfied	354 (99.4)
Unsatisfied	2 (0.6)
Anesthesia nurses (n = 85)	
Satisfied	85 (100.0)
Unsatisfied	0

Discussion

Implementation of the CPG for prevention and management of hypothermia in adults at Srinagarind Hospital successfully reduced the incidence of POH from the previously reported 31% to 18.8% in this study population. This represents a relative reduction of 39.4%, demonstrating the effectiveness of a standardized approach to perioperative temperature management with forced-air warming as the primary intervention. Moreover, the severity of hypothermia was markedly decreased, with no patient's temperature falling below 35.5 °C, indicating effective prevention of moderate to severe hypothermia. These findings were consistent with those of previous studies evaluating active warming interventions. Yoo et al[15] conducted a randomized controlled trial comparing perioperative active forced-air warming with passive cotton blanket covering and reported that active warming significantly reduced the incidence of intraoperative and postoperative hypothermia (19.0% vs 57.1%, $P < .001$; 3.3% vs 16.9%, $P = .013$, respectively). Similarly, Horn et al[23] demonstrated that preoperative forced-air warming for just 15 minutes reduced the incidence of intraoperative hypothermia by approximately 50% in patients undergoing spinal anesthesia. A systematic review by Moola et al[4] concluded that single strategies such as forced-air warming were more effective than passive warming, although combined strategies, including preoperative commencement, use of warmed fluids plus forced-air warming as other active strategies were more effective in vulnerable groups (age or durations of surgeries).

The temperature profiles which were observed in this study, showing an initial decrease followed by a gradual increase over time, were consistent with the known pathophysiology of perioperative temperature changes. The initial drop in core temperature during the first 30 to 45 minutes after anesthesia induction primarily reflects redistribution of body heat from the core to peripheral tissues due to anesthetic-induced vasodilation. This phase is typically followed by a more gradual linear decrease in temperature due to heat loss exceeding metabolic heat production, and finally, a plateau phase as thermoregulatory vasoconstriction is activated.[7, 11, 15] The gradual increase in temperature observed in this study after the 45-minute mark likely reflects the effectiveness of the forced-air warming intervention in counteracting heat loss and eventually restoring normal body temperature.

The temperature patterns observed in both UBW and LBW groups were similar, suggesting that both warming techniques effectively prevent progressive heat loss during surgery. However, the slightly higher incidence of POH in the LBW group (20.2% vs 17.0% in UBW) warrants further investigation. This difference might be related to the larger surface area covered by upper-body blankets compared to lower-body blankets, or potential differences in the surgical procedures and body areas exposed during surgery. Previous studies have suggested that UBW might be more effective than LBW due to differences in heat transfer efficiency and the density of arteriovenous anastomoses in different body regions.[12]

The low incidence of postoperative shivering (1.9%) in this study's population is particularly noteworthy, as shivering is associated with increased oxygen consumption, carbon dioxide production, cardiac work, and patient discomfort.[24] The ASPAN guidelines recognize shivering as a significant complication of POH and recommend active warming interventions to prevent it.[16] This study's findings support the effectiveness of forced-air warming in reducing shivering, which was consistent with a systematic review and meta-analysis, which reported that active warming significantly decreased the incidence of shivering compared to passive warming (relative risk, 0.39; 95% CI, 0.28-0.55).[25]

There has been concern that the use of forced-air warming might increase the risk of surgical site infections (SSIs), particularly during orthopedic procedures involving implants. Augustine et al.[26] reported a 78% reduction in joint implant infections after switching from forced-air warming to an air-free conductive fabric electric warming system for joint replacement surgeries, suggesting a potential link between forced-air warming devices and periprosthetic joint infection. However, that study has been criticized for methodological limitations, including insufficient control of other factors influencing SSI rates.[9] More rigorous investigations have failed to establish a causal relationship between forced-air warming and increased infection risk. Haeberle et al[27] conducted a systematic review examining this issue and concluded that there is no evidence in the literature directly linking forced-air warming to increased SSI rates. These findings support the continued use of forced-air warming devices as a safe and effective method for maintaining intraoperative normothermia.

The high satisfaction rates reported by both patients (99.4%) and anesthesia nurses (100%) in this study indicate excellent acceptability of the CPG. Patient satisfaction is particularly important, as thermal comfort significantly influences overall perioperative experience and satisfaction. Madrid et al's[14] systematic review and meta-analysis demonstrated that forced-air warming provides superior thermal comfort compared to passive insulation, resistive heating blankets, and radiant warming systems. From the healthcare providers' perspective, the high satisfaction among anesthesia nurses suggests that the CPG was well-designed, practical, and easy to implement in clinical practice. Several professional organizations have emphasized the importance of implementing comprehensive hypothermia prevention protocols. The NICE guidelines recommend that patients should be kept comfortably warm preoperatively, that active warming should be used intraoperatively for procedures lasting longer than 30 minutes, and that temperature should be measured and documented regularly throughout the perioperative period.[19] Similarly, the Royal College of Anesthesiologists of Thailand has published guidelines emphasizing preoperative risk assessment, temperature monitoring, and active warming strategies.[20] This study's CPG incorporates these evidence-based recommendations and provides specific guidance for selecting appropriate warming methods based on surgical procedure and patient position.

Clinical Implications

The successful implementation of this study's hypothermia prevention CPG has several important clinical implications which include 1) standardization of care: the CPG provides a structured approach to perioperative temperature management, reducing practice variations and ensuring consistent application of evidence-based interventions; 2) resource optimization: by specifying appropriate warming techniques for different surgical procedures; the CPG helps optimize the use of warming devices and minimizes unnecessary resource utilization; 3) quality improvement: the significant reduction in POH incidence demonstrates the value of quality improvement initiatives focused on addressing common perioperative complications; 4) education and awareness: the development and implementation of the CPG has increased awareness among healthcare providers about the importance of perioperative temperature management; and 5) patient-centered care: the high patient satisfaction rates reflect improved perioperative comfort, an important aspect of patient-centered care.

Future enhancements to the CPG could include the incorporation of preoperative warming for high-risk patients, implementation of closed-loop temperature control systems, and integration with electronic health records for automated documentation and decision support.

Limitations

This study has several limitations that should be acknowledged. First, its retrospective design introduces potential biases in data collection and analysis. Although this study attempted to minimize selection bias by including consecutive eligible patients within the specified timeframe, the retrospective nature of the study means that unmeasured confounders might have influenced the results. Second, the single-center setting limits the generalizability of this study's findings to other healthcare facilities with different patient populations, surgical case mixes, or available resources. Multicenter studies would be valuable to validate the effectiveness of the CPG across diverse clinical settings. Third, this study's assessment of patient satisfaction was limited to a simple binary question (satisfied/unsatisfied) without detailed exploration of specific aspects of thermal comfort or overall perioperative experience. More comprehensive satisfaction assessment tools would provide richer insights into patients' perspectives. Fourth, this study did not include a direct comparison group of patients who did not receive forced-air warming, as this would raise ethical concerns given the established benefits of active warming. Instead, this study compared this study's results to historical data from this study's institution, which may be subject to temporal biases related to other changes in perioperative care practices. Fifth, this study's observation period was limited to 120 minutes intraoperatively, which may not capture the full trajectory of temperature changes in longer procedures. However, this duration was chosen based on previous research suggesting that body temperature typically normalizes with appropriate temperature control beyond this point.[15] Sixth, the routine use of forced-air warmers increases the cost. Finally, this study did not assess long-term outcomes such as surgical site infections, length of stay, or other complications that might be influenced by perioperative temperature management. Further multicenter, prospective research with longer-term follow-up and inclusion of cost-effectiveness evaluation would provide more robust insight into these outcomes.

Conclusions

Implementation of a CPG emphasizing forced-air warming for the prevention of hypothermia in adults successfully reduced the incidence of POH from 31% to 18.8% at this study's institution. The severity of hypothermia was markedly decreased, with no patient experiencing moderate to severe hypothermia. Only a small number (1.9%) of patients experienced mild shivering. The temperature patterns observed in both the UBW and LBW groups showed similar trajectories, with an initial decrease followed by gradual recovery, consistent with the known pathophysiology of perioperative temperature changes.

The CPG was associated with high satisfaction rates among both patients and anesthesia nurses, indicating excellent acceptability and feasibility in clinical practice. These findings support the value of standardized approaches to perioperative temperature management and the effectiveness of forced-air warming as the primary intervention for preventing POH. Future research should focus on further optimizing warming protocols for high-risk populations, evaluating the impact of combined warming strategies, and assessing long-term outcomes associated with improved perioperative temperature management. Multicenter prospective studies would enhance the generalizability of this study's findings and contribute to the continued refinement of evidence-based practices for preventing perioperative hypothermia.

Additional Information

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