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Preoperative Interventions for the Prevention of Hypothermia

Trish Haley, MS(N), CRNA
Yejin Min, MS(N), CRNA
Shawn Collins, PhD, DNP, CRNA
Vallire Hooper, PhD, RN, CPAN, FAAN

Affiliation:

Trish Haley MS(N) CRNA was a graduate student in the Nurse Anesthesia Program at Western Carolina University, Asheville, North Carolina, at the time this paper was written.

Yejin Min MS(N) CRNA was a graduate student in the Nurse Anesthesia Program at Western Carolina University, Asheville, North Carolina, at the time this paper was written.

Shawn Collins, PhD, DNP, CRNA is a program director of the Nurse Anesthesia Program at Western Carolina University School of Nursing, Asheville, North Carolina. Email: shawncollins@email.wcu.edu.

Vallire Hooper, RN, PhD, CPAN, FAAN is the nursing research manager at Mission Healths, Asheville, North Carolina.

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Abstract

Perioperative hypothermia can be a significant issue for surgical patients. Active warming methods initiated in the preoperative period may assist in the prevention of perioperative hypothermia. A literature review was conducted to provide a summary and resource for clinicians based on an evidence-based, practical, bedside approach to prewarming adult surgical populations and to highlight the further need for research. The literature review addressed preoperative warming recommendations, including warming methods and desired length of warming time. The literature supports the practice of preoperative warming for adult surgical patients to prevent or decrease the incidence of perioperative hypothermia.

INTRODUCTION

Perioperative hypothermia, defined by the American Society of PeriAnesthesia Nurses (ASPAN), is a core temperature below 36 degrees Celsius, and is known to increase the risk of surgical wound infections, poor wound healing, blood loss, prolonged and altered drug effects, increased duration of hospital stay, cardiac events, and morbidity and mortality.[1,2] Under normal physiologic conditions, the body can detect subtle drops in temperature. In response to a detected decrease in temperature, the hypothalamus will induce vasoconstriction and shivering mechanisms to maintain a core body temperature around 37 degrees Celsius. The induction of anesthesia blunts this response from the hypothalamus and contributes to perioperative hypothermia by inhibiting the body's natural mechanisms for heat regulation and redistribution of core body temperature to the periphery from the resulting vasodilation.[1-3] Anesthesia-induced redistribution of body heat is the process by which heat travels down a temperature gradient from warmer core tissues to cooler peripheral tissues. Patients undergoing surgery are at high risk of hypothermia due to thermoregulatory mechanisms becoming dysfunctional after the induction of anesthesia and exposure to surgical procedures, cold fluids, and low ambient room temperatures.[3]

The current standard of care for avoiding perioperative hypothermia consists of intraoperative and postoperative warming interventions, both active and passive, yet the incidence of perioperative hypothermia remains a significant risk.[2] One of the primary interventions used to prevent perioperative hypothermia is prewarming before the induction of anesthesia. Hooper et al defined prewarming as the "warming of peripheral tissues or surface skin before induction of anesthesia."[1(p348)]
The literature suggests that preoperative warming with forced air reduces post-induction redistribution hypothermia, allows for faster rewarming after an initial post-induction drop in temperature intraoperatively, results in a higher average intraoperative temperature than non-prewarmed counterparts, and results in greater patient satisfaction.[2,3] Additional benefits patients may experience include decreased blood loss, reduced total anesthesia costs, decreased incidence of intensive care unit (ICU) admission, reduction in myocardial infarctions, proper clotting, stable serum potassium levels, reduced need for postoperative mechanical ventilation, reduced incidence of surgical site infection, and an overall decrease in mortality.[3]

METHODS

We used the PICO question model to guide our search for current literature. The PICO question is used to define the desired population (P), intervention (I), comparison (C), and outcome (O). The PICO question used to guide this review was as follows: "In adults undergoing general anesthesia, does the addition of preoperative warming devices for a specific length of time compared to no preoperative warming methods result in a decreased incidence of perioperative hypothermia?"
The authors independently performed electronic searches for published literature in the Cumulative Index to Nursing and Allied Health Literature (CINAHL; EBSCO), MEDLINE (National Library of Medicine), and Cochrane Central Register of Controlled Trials (CENTRAL; Cochrane Collaboration) databases using the EBSCO search engine. The following keywords were used in varying combinations: "perioperative," "peri-operative," "preoperative," "pre-operative," "preoperative warming," "hypothermia," "warming methods," "body temperature," "forced-air warming," "anesthesia," "surgical," and "active warming." Boolean operators were used in the search engine to filter and combine terms.
Included articles consisted of adult (18 years or older) surgical populations receiving general anesthesia for nonemergent surgery in which preoperative warming methods were studied. Other inclusion criteria were the availability of the full text of the article, articles that underwent peer review, and articles that were written in or translated into English. Articles published before January 2008 or after October 2015 were excluded. Studies that included induced hypothermia were also excluded.
The initial search resulted in 945 papers. After application of the inclusion and exclusion criteria previously defined and the removal of duplicate papers, 12 articles were identified for review. Study quality was determined based on the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system of review.[4]

REVIEW OF LITERATURE

Table 1 is a concise presentation of the studies reviewed and presents authors, study design, journal publication and date, sample size, warming device used, and conclusions.[5-16] Table 2 lists study quality and limitations.
Three studies[5-7] produced results showing a significant effect of preoperative warming with forced-air warming gowns (Bair Paws) compared to a control group. Andrzejowski et al[5] tested 68 adult surgical patients with 31 patients receiving 60 minutes of prewarming with the warming gown system prior to induction of anesthesia compared to the control group of 37 patients. The study was not blinded but this is unlikely to have affected the results. The sample size was small and the type of general anesthetic (sevoflurane or propofol) was not controlled. The study concluded that 60 minutes of prewarming with the forced-air warming gown resulted in a decrease in both intraoperative hypothermia and perioperative hypothermia. Hooven[6] reported that 11.7% of prewarmed patients were hypothermic on arrival to the post-anesthesia care unit compared to 48.6% of non-prewarmed patients (P=0.026). The study failed to record intraoperative patient temperatures or to control ambient surgical suite temperatures and also noted a significant (P=0.048) difference in mean surgical durations between the prewarmed group and the non-prewarmed group. Kramer[7] concluded that prewarming patients with a forced-air warming device was effective in reducing the amount of heat redistribution after the induction of anesthesia. Unfortunately, this study was quite limited and lacked sufficient literature review. The sample size was small (n=24) and there were many limitations and lack of controls, including failure to control both the prewarming device temperature setting and the ambient temperature of the operating suite. Different types of temperature devices were also used with no consistent timing of measurement.
Two studies used Bair Hugger forced-air warming blankets to provide preoperative warming. Erdling and Johansson[8] studied 43 adult surgical patients and found that at 210 minutes after induction of anesthesia, esophageal temperatures in the prewarmed group increased by 0.65 degrees Celsius with a standard deviation of 0.63 (P=0.001). The group that did not receive prewarming had esophageal temperature increases of 0.27 degrees Celsius with a standard deviation of 0.62, but the increase was not statistically significant (P=0.052). It was concluded that 42 minutes of prewarming had a statistically significant effect (P=0.001) on preventing perioperative hypothermia. The authors noted the small sample size as a significant limitation. Shin et al[9] studied 72 adult surgical patients. The prewarmed group had significantly (P<0.001) higher core temperatures than did the non-prewarmed group at 20, 40, 60, 80, 100, and 120 minutes after induction and intubation. The incidence of perioperative hypothermia was significantly lower in the prewarmed group than in the non-prewarmed group at all time periods previously mentioned (P=0.007 at 20 minutes and P=0.001 at all other times). The study noted a limitation in the inconsistency of measurement devices used (tympanic or esophageal) and possible inaccuracy of the tympanic measurements due to interference with the warming device.

The Mistral-Air premium warming suit (passive warming) and Mistral-Air forced-air warming unit were studied by Perl et al.[10] A sample size of 90 adult surgical patients was divided into 3 groups. Thirty-two patients received only standard preoperative insulation (cotton blankets). Twenty-seven patients were warmed with the passive warming suit and 31 received the same passive preoperative warming combined with the forced-air warming device. A forced-air warming device with a reflective prewarming suit was significantly ($P<0.05$) effective in achieving higher core temperatures both intraoperatively and postoperatively compared to passive warming, which was shown to be ineffective at preventing perioperative hypothermia. Intraoperative warming alone was ineffective in the prevention of perioperative hypothermia. Prewarming durations varied greatly but all patients were warmed for at least 10 minutes.

De Witte et al[11] looked at 27 adult surgical patients and prewarmed one group (n=9) with a forced-air warming device for 30 minutes and another group (n=9) with a carbon fiber warming device, also for 30 minutes. The control group consisted of 8 patients. After 30 minutes of prewarming with the carbon fiber device, patients had a core temperature that was significantly higher ($P=0.05$) than in the control group. There was no statistically significant difference between the forced-air and control groups. As seen with many of the available studies, the use of 2 methods to measure temperature (tympanic and esophageal) was noted as a limitation, as was the small population studied and inconsistent warmed body surface area.

One study[12] (n=200) focused on the duration of warming. Preoperative patients undergoing general anesthesia with an expected surgical duration of 30 to 90 minutes compared a control group to 3 other groups receiving varying durations of active prewarming. Fifty-two patients received 10 minutes of active warming. Forty-three received 20 minutes of active warming. Fifty received 30 minutes of active warming and 55 were considered the control group and received no active preoperative warming. The authors concluded that the risk of perioperative hypothermia was considerably reduced after prewarming with forced air for 10, 20, or 30 minutes in comparison to no preoperative active warming.[12] No significant difference ($P=0.54$) was found between the 3 groups that received active warming, which suggested that at least 10 minutes of preoperative active warming is enough to affect the incidence of perioperative hypothermia.[12]

The search produced several studies with varying limitations. Table 2 addresses the most significant recognized limitations and the quality of the studies based on the GRADE system of review. In contrast to other results, 4 trials found no statistical significance in relation to the addition of preoperative warming. Rowley[13] reported a sample size of 220 patients divided into 4 groups, each consisting of 55 individuals. The results showed no benefit of preoperative interventions compared to routine care (control group) in preventing perioperative hypothermia. The study compared forced-air warming in combination with routine care (cotton blanket) to routine care only. Routine care, forced-air warming, and adjustment of the surgical suite temperature were combined as a study group as well as routine care and adjustment of surgical room temperature only. The study lacked randomization and failed to report P values clearly. The authors also noted a failure to achieve a temperature of 21.1 degrees Celsius in some of the surgical suites during the cases studied.[13]

Another study[14] consisted of 128 subjects undergoing general anesthesia for a variety of surgical cases with no mention of case duration. The study compared only prewarmed patients to non-prewarmed patients. Ambient surgical suite temperatures were not controlled for and the investigators failed to regulate the timing of temperature measurements. Intraoperative temperature measurements were also not evaluated. The findings were not significant ($P=0.314$) for any difference in mean temperatures between the 2 groups.[14]

Adriani et al[15] is yet another study that found no significant difference with the addition of preoperative warming in preventing or lessening the incidence of perioperative hypothermia. Adriani et al[15] reported no significant difference ($P=0.755$) of body temperature over time between groups. Study quality was low and had extensive limitations such as failure to control for operating room mattress temperature, ambient temperature, and the device used to measure patient's temperature. No consistency was found in devices used for measurement (esophageal or oral), and many issues regarding intraoperative warming existed, including no criteria for initiation of intraoperative warming, failure to control ambient temperature, and surgical table underbody mattress that may or may not have been warmed.[15]

One additional study listed an inability to produce a lower rate of perioperative hypothermia with the addition of preoperative warming. The study had many flaws and limitations. The study was unable to effectively evaluate prewarming compared to non-prewarming interventions, which was its stated purpose.[16] Three of the 4 studies were of low quality due to varying levels of inconsistency, numerous limitations, small sample sizes, and inability to draw reliable conclusions. These studies were not considered for final recommendations concerning prewarming for the prevention of perioperative hypothermia.

DISCUSSION

Under normal physiologic states, the body can maintain core temperatures between 36 and 37 degrees Celsius. The 2 main areas of the brain responsible for regulating body temperature are the preoptic area and the anterior hypothalamus. These areas can trigger thermoregulatory responses when an increase or decrease in core temperature is detected by afferent sensing. Vasodilation and sweating are induced to prevent hyperthermia, whereas vasoconstriction and shivering are induced to prevent hypothermia.[17]

The induction of general anesthesia creates a redistribution of body heat from core to periphery due to vasodilation and also blunts the response of the hypothalamus. Without diligent warming, hypothermia is near unavoidable depending on numerous factors including room temperature, equipment used, type of procedure, length of procedure, and intravenous fluid temperature. Over time, the anesthetized patient continues to lose heat and achieve a lower core body temperature. Because anesthetic drugs hinder proper hypothalamic responses to

hypothermia, the body is unable to induce vasoconstriction and shivering mechanisms for warming.[17] Once a patient's core temperature becomes hypothermic, intraoperative active warming with forced-air devices likely will not be sufficient to restore normothermia due to the considerable amount of time it takes for the heat to reach the core tissues.[1] Because of this, it is important to incorporate interventions necessary to prevent or lessen the degree of hypothermia experienced after induction of anesthesia.
Of the studies reviewed, 8 of 12 reported prewarming to be effective in decreasing or preventing perioperative hypothermia. Because 2 of the studies[15,16] that found prewarming to be ineffective and 2 of the studies[7,11] that found it to be effective were of poor quality, recommendations will be drawn from the remaining 8 studies.
Six of the remaining 8 studies concluded that preoperative warming was effective in varying durations ranging from 10 minutes to more than 60 minutes. Forced-air warming devices, specifically Bair Paws gowns, were most consistently studied and shown to be effective with very minimal associated risks.

CONCLUSION

The findings of this review suggest that adult surgical patients benefit from as little as 10 to 60 minutes of active prewarming to reduce perioperative hypothermia and that intraoperative warming alone is likely not adequate. Because there are few risks involved in the addition of prewarming and the available literature suggests that it is effective, it is recommended as a standard of care for all adult surgical patients prior to the induction of general anesthesia. While 10 minutes of forced-air warming is an effective option that may reduce hypothermia in the perioperative period, it is likely that additional time may be more beneficial.
There are an inadequate number of quality studies available to answer all of the questions surrounding preoperative warming interventions to prevent perioperative hypothermia. A need exists for randomized controlled trials testing current warming methods as well as newer technology. New studies should be consistent between groups and only use the most proven method of temperature measurement and reduce limitations. Specific populations should also be further studied to identify those that may benefit from these interventions.

Table 1. Overview of the Articles Included in the Literature Review			
Author, Date, Journal, Design	**Population, Sample Size (n)**	**Type of Preoperative Warming Device, Duration**	**Conclusions**
Adriani & Moriber (2013) *AANA Journal* Quasi-experimental Nonrandomized Trial	n=60 Women undergoing general anesthesia for a variety of surgical types ASA class I-III	Bair Paws, forced-air warming gown Minimum of 30 minutes with a mean time of 51 minutes Temperature controlled by patient	Active prewarming with Bair Paws gown demonstrated no significant effect on preventing perioperative hypothermia. Body temperature over time showed no statistically significant difference between groups.
Andrzejowski et al (2008) *British Journal of Anaesthesia* Randomized Controlled Trial	n=68 Adults undergoing general anesthesia for spinal surgery ASA class I & II	Bair Paws, forced-air warming gown 60 minutes	60 minutes of prewarming with Bair Paws gown yielded a decrease in both intraoperative hypothermia and perioperative hypothermia.
De Witte et al (2010) *Anesthesia and Analgesia* Randomized Controlled Trial	n=27 Adults undergoing general anesthesia for laparoscopic colorectal surgery	Forced-air warming Carbon fiber warming 30 minutes	30 minutes of prewarming with resistive heating produced significantly higher core temperatures than in the control group. No significant difference between the forced-air and control group.
Erdling & Johansson (2015) *AANA Journal* Experimental Randomized Controlled Trial	n=43 Adults undergoing general anesthesia in combination with regional analgesia for colorectal surgery ASA class I&II	Pre-warmed group: Forced-air warming device Warm Touch, Nellcor, or Gaymar, Smiths Medic 32-52 minutes	Prewarming for 42 minutes had a positive effect in preventing perioperative hypothermia and even shorter prewarming times may be of benefit for hypothermia prevention.
Fettes et al (2013) *AORN Journal* Experimental Randomized Controlled Trial	n=128 Adults undergoing general anesthesia for a variety of surgical cases ASA class I-III	Forced-air warming blanket Approximately 60 minutes	Prewarming did not significantly affect patient temperature on arrival to the PACU or the length of time spent in the PACU.
Hooven (2011) *Journal of Peri-Anesthesia Nursing* Quasi-experimental Nonrandomized Trial	n=148 Adults undergoing general anesthesia for colorectal surgery	Bair Paws forced-air warming gown 60 minutes	11.7% of prewarmed patients were hypothermic compared with 48.6% of non-prewarmed patients (*P*=0.026). Prewarming with the Bair Paws forced-air warming blanket decreased the incidence of perioperative hypothermia in patients undergoing colorectal surgery.
Horn et al (2012) *Anaesthesia* Experimental Randomized Controlled Trial	n=200 Adults undergoing general anesthesia with a variety of surgical cases with expected durations of 30-90 minutes ASA class I-II	Snuggle Warm Upper Body Blanket, forced-air warming blanket covered by cotton blanket, connected to Level 1 Equator warmer 10, 20, or 30 minutes	Forced-air prewarming of 10, 20, or 30 minutes considerably decreased the incidence of perioperative hypothermia. There was no significant difference (*P*=0.540) between the 3 prewarmed groups.
Kramer (2013) *Journal of Peri-Anesthesia Nursing* Quasi-experimental Nonrandomized Trial	n=24 Women undergoing general anesthesia for breast reconstruction	Forced-air warming gown Minimum of 30 minutes	Forced-air prewarming gown was effective in decreasing post-induction redistribution hypothermia.
Nicholson (2013) *AORN Journal* Experimental Randomized Controlled Trial	n=66 Adults undergoing general anesthesia for colorectal surgery ASA class I-IV	Forced-air warming gown Minimum 30 minutes	Prewarming with a forced-air warming gown was unable to decrease the number of patients who had perioperative hypothermia.
Perl et al (2014) *Minerva Anestesiologica* Experimental Prospective, randomized, multi-center, controlled study	n=90 Adults undergoing general anesthesia for a variety of surgical cases scheduled for 30-120 minutes ASA class I-III	Mistral-Air premium warming suit (passive warming) Mistral-Air premium warming suit and Mistral-Air forced-air warming unit 30-60 minutes	A forced-air warming device with a reflective prewarming suit was effective in achieving higher core temperatures both intraoperatively and postoperatively compared to passive warming, which was ineffective at preventing perioperative hypothermia. Intraoperative warming alone was ineffective in preventing perioperative hypothermia.
Rowley et al (2015) *Clinical Nursing Research* Quasi-experimental Nonrandomized Trial	n=220 Adults undergoing general anesthesia for a variety of surgical procedures lasting a minimum of 60 minutes.	Forced-air warming blanket Approximately 20-30 minutes	No significant difference was found between preoperative to postoperative core body temperatures for each group. Prewarming interventions were not more effective in preventing perioperative hypothermia.
Shin et al (2015) *BMC Anesthesiology* Experimental Randomized Controlled Trial	n=72 Adults undergoing general anesthesia for endovascular coiling to treat cerebral aneurysm	Bair Hugger, forced-air warming full-body blanket connected to warm-air-blower 30 minutes	The prewarmed group had significantly higher core temperatures than those of the non-prewarmed group at 20, 40, 60, 80, 100, and 120 minutes post intubation (*P*<0.001). Incidence of perioperative hypothermia was significantly lower in the prewarmed group than in the non-prewarmed group at 20, 40, 60, 80, 100, and 120 minutes after intubation (*P*=0.002 at 20 min, *P*<0.001 at other times). Conclusion: prewarming should be considered as part of the anesthetic management for patients undergoing coiling of aneurysm at risk of hypothermia in a cold environment.
Abbreviations: ASA, American Society of Anesthesiologists; PACU, post-anesthesia care unit.			

Table 2. Article Limitations		
Author, Date, Journal, Design	**Quality**	**Limitations**
Adriani & Moriber (2013) *AANA Journal* Quasi-experimental Nonrandomized Trial	Strength: Level 2 Quality: Low	Oral and esophageal probe was used to obtain temperature readings Extraneous variables not controlled: ambient temperature, OR mattress temperature, and staff taking temperature readings Non-blinded, nonrandomized, small sample size
Andrzejowski et al (2008) *British Journal of Anaesthesia* Randomized Controlled Trial	Strength: Level 1 Quality: Moderate	Not all patients had same method of anesthesia maintenance Non-blinded Actual mean duration of prewarming longer than the target of 60 minutes
De Witte et al (2010) *Anesthesia and Analgesia* Randomized Controlled Trial	Strength: Level 2 Quality: Low	Small population studied Warmed body surface area inconsistent between forced-air group and carbon fiber group Duration of anesthesia 90-260 minutes 2 methods were used to measure core temperature: tympanic and esophageal probe Clinical setting was inappropriate to study heat balance and the quantification of redistribution of heat
Erdling & Johansson (2015) *AANA Journal* Experimental Randomized Controlled Trial	Strength: Level 1 Quality: High	Limitations in sample size, type of surgery, and anesthesia technique limiting generalizability Beta-blockers and vasopressor medications were used in both prewarmed and non-prewarmed group during anesthesia Patient conditions such as perfusion and tissue disorders may have affected results Varied placement of temperature probes in patients Outflow temperature in the warming device varied from -1°C to +5°C from the preset value of 43°C
Fettes et al (2013) *AORN Journal* Experimental Randomized Controlled Trial	Strength: Level 1 Quality: Moderate	Small sample size Both groups received warmed cotton blankets preoperatively Lack of patients with hypothermia in both groups throughout the study Intraoperative temperature measurements were not evaluated Imprecise time intervals for temperature measurements
Hooven (2011) *Journal of Peri-Anesthesia Nursing* Quasi-experimental Nonrandomized Trial	Strength: Level 2 Quality: Moderate	Temperature measurements only obtained for preoperative and postoperative periods Mean surgical duration time differed significantly between the 2 groups (P=0.048) Significant difference in preoperative temperatures in both groups (P=0.008) Temperature measurement intervals unclear and staff training on correct equipment use unclear
Horn et al (2012) *Anaesthesia* Experimental Randomized Controlled Trial	Strength: Level 1 Quality: High	Distribution of surgery types was not equal among groups 4% of patients were already hypothermic on arrival to preoperative unit Patients not blinded
Kramer (2013) *Journal of Peri-Anesthesia Nursing* Quasi-experimental Nonrandomized Trial	Strength: Level 2 Quality: Low	Nonrandomized Oral and esophageal temperature measurement instruments used in the study Not clear on prewarming device set temperature, ambient OR room temperature, correct use of temperature measurement instruments and other equipment
Nicholson (2013) *AORN Journal* Experimental Randomized Controlled Trial	Strength: Level 1 Quality: Low	Both study groups received prewarming before induction of general anesthesia Few participants were hypothermic on arrival to preoperative area; no mention of distribution in the study groups No mention of prewarming device temperature and staff training on equipment use Various temperature measurement instruments used throughout the study: oral, nasal, esophageal, or rectal temperature probe or temperature-sensing urinary catheter Lack of dedicated research assistants or co-investigators, the facility policy to warm patients intraoperatively before induction, and difficulty obtaining oral temperatures in the immediate postoperative period
Perl et al (2014) *Minerva Anestesiologica* Experimental Prospective, randomized, multi-center, controlled study	Strength: Level 1 Quality: Moderate	22 patients had to be excluded due to protocol violations A wide range of prewarming durations (but all patients received greater than 10 minutes of prewarming) A relevant number of patients were hypothermic on arrival to the OR No mention of prewarming device temperature or staff training on equipment use Oral and esophageal probe used for temperature measurement in the study
Rowley et al (2014) *Clinical Nursing Research* Quasi-experimental Nonrandomized Trial	Strength: Level 2 Quality: High	No randomization (convenience sample) Unable to achieve desired ambient surgical room temperature of 21.1°C/70°F for some study cases in samples III and IV EBL not included in the data collection Many surgical candidates excluded from the study due to obesity and comorbidities
Shin et al (2015) *BMC Anesthesiology* Experimental Randomized Controlled Trial	Strength: Level 1 Quality: High	Oral and esophageal probe used for temperature measurement in the study Warming device indirectly affected tympanic membrane temperature and caused inaccuracy of core temperature measurement with the infrared tympanic thermometer, so the highest value of 3 consecutive measurements were recorded to decrease error and the study relied more heavily on the esophageal temperature as the accurate measurement of core temperature No mention of prewarming device temperature and staff training on equipment use

Abbreviations: EBL, estimated blood loss; OR, operating room.

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