A Review of the Evidence for Active Preoperative Warming of Adults Undergoing General Anesthesia

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Inadvertent perioperative hypothermia, a common occurrence in the operating suite, is associated with many adverse outcomes. It is the nurse anesthetist's goal to attenuate the incidence of this problem. Although active intraoperative warming is a widely accepted practice, active preoperative warming may be a less explored option for temperature maintenance. A search strategy to identify systematic reviews and investigations in peer-reviewed journals was undertaken to identify evidence examining the efficacy of preoperative warming.

Evidence sources meeting the search criteria were randomized controlled trials and a cohort study using historical controls. Most of the studies support the implementation of active preoperative warming by demonstrating that subjects were warmer during the perioperative period. Overall, these differences were statistically significant and likely clinically significant. Future clinical trials should examine shorter warming times and lower warming unit settings, should include appropriate sample sizes, and should consistently employ trained staff using calibrated biometric instruments to measure temperature.

Keywords: Adult, anesthesia, body temperature, heating, prewarming.

Patients undergoing general anesthesia are vulnerable to a perioperative decrease in core temperature leading to inadvertent perioperative hypothermia (IPH). Contributing factors include a cold environment, use of cold intravenous fluids and blood products, inhibition of thermoregulation by anesthetics,[1] redistribution of heat to the periphery,[2] and cold, dry anesthetic gases. Less than optimum body temperatures and even hypothermia (a core body temperature < 36ºC[3]) are common occurrences in the surgical suite.[4] Data suggest that 50% to 70% of all surgical patients experience IPH.[5-7]

Hypothermia is associated with many detrimental physiologic alterations and increased morbidity. These derangements include decreased metabolic rate, decreased cardiac output, metabolic acidosis, prolongation of muscle relaxants, altered clotting functions, and an increased incidence of postoperative infection.[7] Postoperative shivering may also lead to increased oxygen consumption, norepinephrine release, and myocardial ischemia.[8] Efforts to attenuate the incidence of IPH will greatly benefit the patient's surgical and anesthetic outcomes. Maintenance of normothermia can result in a reduction of patient costs by an estimated $2,500 to $7,000 per patient.[8]

History and Review of the Literature

• ***History***. In 2001, a practice guideline from the American Society of PeriAnesthesia Nurses provided "perioperative practitioners practical approaches for preventing and managing the patient at risk for developing unplanned hypothermia. It covers the entire perioperative period from preoperative care to phase II postoperative recovery."[9] Temperature monitoring existed as a standard[10] many years before 2001, but this guideline was the first to formally address IPH. US Congress also addressed IPH in the 2006 Tax Relief and Health Care Act.

This act established the Physician Quality Reporting Initiative, now called the Physician Quality Reporting System. Its mission is to establish a "physician quality reporting system, including an incentive payment for eligible professionals who satisfactorily report data on quality measures."[11] One quality measure encourages the reporting of the

> [p]ercentage of patients, regardless of age, undergoing surgical or therapeutic procedures under general or neuraxial anesthesia of 60 minutes duration or longer, except patients undergoing cardiopulmonary bypass, for whom either active warming was used intraoperatively for the purpose of maintaining normothermia, OR at least one body temperature equal to or greater than 36 degrees Centigrade (or 96.8 degrees Fahrenheit) was recorded within the 30 minutes immediately before or the 15 minutes immediately after anesthesia end time.[3]

Despite the widespread use of warmed intravenous fluids, intraoperative forced-air warming, and warmer ambient room temperatures, anesthesia providers contin-

ue to seek methods to prevent IPH. One possible method is prewarming the patient before entry into the operating room. An important step in examining the effectiveness of prewarming is the formation of a PICO question.

• ***The PICO Question.*** The "PICO" approach is helpful in identifying the essential 4 elements of a good clinical question.[12] The components of a PICO question are patient or population (P), intervention (I), comparison (C), and outcome (O).

Using this format, the clinical question guiding the search for the best current evidence was as follows: "In adults undergoing general anesthesia (P), does the addition of preoperative forced-air warming to intraoperative warming methods (I), compared with intraoperative warming methods alone (C), result in a decreased incidence of IPH (O)?"

• ***Search Strategy.*** The identification of pertinent evidence involved an online search of the following databases: The Cochrane Library, National Guideline Clearinghouse, MEDLINE, Google, Google Scholar, EBSCOhost,[13] and SUMSearch.[14] The period searched was January 2001 to August 2012. Once relevant sources were selected, an ancestry approach was used.[15]

The following keywords and word strings were used alone and in combination: *preoperative, forced-air, warming blankets, hypothermia, temperature,* and *surgery*. Studies including pediatric subjects were excluded owing to their difference in thermoregulation during anesthesia[16] and the common practice of instituting a warmer ambient operating room temperature during surgery involving children.

In an effort to locate all available evidence, evidence sources were included if they examined the use of any active preoperative warming[17] regardless of the use of intraoperative warming. Use of warming methods other than forced-air and intraoperative warming was noted.

• ***Critical Appraisal of the Literature.*** The search yielded 35 potential sources, with a total of 11 evidence sources meeting inclusion criteria on initial review.[18-28] Of these 11 evidence sources,[18-28] further analysis revealed that 3 sources[26-28] did not meet the inclusion criteria.

These 8 evidence sources[18-25] were appraised and leveled using the method proposed by Melnyk and Fineout-Overholt,[29] where evidence levels range from level I (systematic reviews) to level VII (expert opinion). Seven studies were randomized controlled trials.[18-24] One source was a cohort study and used historical controls.[25] An evaluation of the evidence is presented in the Table.

These level II and level IV evidence sources[29] had a total sample size of 665 subjects. The evidence included men and women with the exception of 1 study[19] in which the subjects were women only. These investigators offered no rationale for the subject selection. Study participants had ASA physical status classifications of 1, 2, or 3, with 2 studies[24,25] not including these data. Mean ages ranged from 39[19] to 63.9[25] years, with 1 study[24] not specifying mean age or providing the data to calculate the mean age. Surgery types included gynecologic, orthopedic, urologic, abdominal, spinal, colorectal, laparoscopic colorectal, nondescriptive outpatient surgery, and laparoscopic cholecystectomy procedures. Most studies were conducted at large tertiary medical centers.[18-20,22-25] Only 1 trial[21] failed to provide the study setting. All but 2 sources[21,24] used exclusion criteria. These criteria included central nervous system impairment,[18] obesity,[19] immunosuppressive drugs,[20] cannabinoid use,[22] and active infection.[25]

Sample sizes were selected using a power analysis in 4 studies (α = .05, β = .8).[20-23] The remaining sources[18,19,24,25] provided no information regarding methods used in determining sample sizes. Based on a priori power analysis, 2 studies[20,21] failed to have a sufficient number of subjects in the treatment arm. Another trial[23] was underpowered to examine postoperative temperatures, but the investigators found a statistically significant difference in comfort scores between the treatment and control groups 30 minutes post warming.

Seven[18-24] of the 8[18-25] studies randomly assigned subjects to control and treatment groups. The lone cohort study[25] used data from 2 sequential years. First-year subjects received no prewarming, and second-year subjects received preoperative warming gowns. There were no differences between control and treatment groups with respect to demographic and setting variables in 7[18-23,25] of the 8[18-25] trials. These variables included age, gender, body mass index, ASA physical status, and preoperative temperature. One trial[24] failed to address group comparisons.

Preoperative and intraoperative blinding was not possible because it was evident to both subject and investigator as to who was being warmed. Some investigators did not mention postoperative blinding.[18,20,23,24]

One study[19] instituted active warming on all patients in a postanesthesia care unit (PACU). A blinded, independent observer was used in the assessment of shivering in PACU subjects, but there was no indication if this same investigator recorded postoperative temperatures. Two studies[21,22] did not comment on blinding or warming in the PACU.

Three studies[18,21,22] disclosed gifting by outside healthcare sources. Arizant Healthcare Inc provided forced-air warming blankets for 2 trials[21,22] and provided supplies and funding for the remaining source.[18] One evidence source[22] received carbon fiber blankets from NWS BVDA. All sources receiving these products reported decreased IPH.

Discussion of State of the Art

Appraised studies were level II and level IV evidence sources.[29] Subject demographics varied among the trials

Evidence source	Design/ surgery type	Sample size	Subjects' mean age (y)	Findings	Comments
Fossum et al,[18] 2001	RCT; gynecologic, orthopedic, urologic	100	45.2	Postoperative forced-air warming group was significantly warmer than control group (36.0°C vs 35.5°C, $P = .001$), ↓ IPH, ↑ thermal comfort, ↑ PONV	Probably clinically significant, various surgery types studied, lower warming unit setting, calibration of biometric instruments regularly checked and staff instructed on use, surgery durations unknown, no power analysis
Vanni et al,[19] 2003	RCT; abdominal	30	39.0	Postoperative forced-air warming group was significantly warmer (> 36.0°C vs < 36.0°C, $P < .05$), ↓ IPH, ↓ shivering, earlier extubation	Probably clinically significant, young sample age, female-only sample, no power analysis, widely varying warming unit settings
Wong et al,[20] 2007	RCT; abdominal	103	61.6	Group receiving preoperative conductive carbon polymer mattress warming was significantly warmer (36.9°C vs 36.3°C, *P* not calculated), ↓ IPH, ↓ blood loss, ↓ transfusions, longer hospital stay	Probably clinically significant, underpowered treatment arm, longer preoperative warming period, greatly varying surgery durations
Andrzejowski et al,[21] 2008	RCT; spinal	68	55.6	Postoperative forced-air warming group was significantly warmer (36.3°C vs 36.0°C, $P < .005$), ↓ IPH, ↑ PONV	Probably clinically significant, longer preoperative warming period, lower warming unit setting, questionable biometric instrument, underpowered treatment arm, unknown surgical setting
De Witte et al,[22] 2010	RCT; laparoscopic colorectal	26	63.2	Group receiving preoperative carbon fiber blanket warming was significantly warmer (36.5°C vs 35.9°C, $P < .05$), postoperative forced-air warming group was not significantly warmer (36.2°C vs 35.9°C, $P > .05$), ↓ IPH, ↑ risk for subject-to-subject infection transmission	Probably clinically significant, 2 methods for preoperative warming examined, shorter warming period, greatly varying surgery durations
Leeth et al,[23] 2010	RCT; outpatient	105	43.5	Postoperative forced-air warming group was not significantly warmer (36.6°C vs 36.5°C, $P = .487$), ↓ cost, ↑ thermal comfort	Probably not clinically significant, underpowered, calibration of biometric instruments regularly checked and staff instructed on use, no preoperative warming duration
Lynch et al,[24] 2010	RCT; laparoscopic cholecystectomy	84	Not given	No inferential statistics, postoperative forced-air warming group had fewer hypothermic (< 36°C) subjects (25% vs 46%)	Unable to determine statistical or clinical significance, no actual endpoint temperatures reported, no surgical duration, no warming unit settings, no power analysis
Hooven,[25] 2011	Cohort study; colorectal	149	63.9	Postoperative forced-air warming group was significantly warmer (36.4°C vs 36.0°C, $P = .026$)	Probably clinically significant, vague temperature endpoint, staff instructed on use of biometric instruments, no power analysis

Table. Summary of Evidence Sources Examining Addition of Active Preoperative Warming and Its Effect on Inadvertent Perioperative Hypothermia in Subjects Undergoing General Anesthesia

Abbreviations: IPH, inadvertent perioperative hypothermia; PONV, postoperative nausea and vomiting; RCT, randomized controlled trial; ↑, increased; ↓, decreased.

and represented wide ranges of subject age, gender, ASA physical status, procedure duration, and surgery type.

Average endpoint temperature differences between control and treatment groups from all appraised studies ranged from about 0.06°C[23] to 0.6°C.[20,22] In 6[18-22,25] of the 8[18-25] evidence sources, the difference in endpoint temperatures between subjects receiving preoperative warming and those not receiving preoperative warming attained statistical significance. This was true for a wide range of settings, regardless of age, surgery type, surgery

duration, type of active warming instituted, warming unit settings, instrument used for temperature measurement, or the concomitant use of active intraoperative warming. One study[23] showed no significant difference between subject temperature in the treatment and control groups, but the sample size was not based on a power analysis. The remaining source[24] provided no inferential statistics other than to point out that, of the subjects receiving active preoperative warming, a smaller percentage of them were hypothermic.

Treatment groups from 7[18-23,25] of the 8 trials reported average endpoint temperatures above 36.0ºC; thus, the subjects did not experience IPH. The remaining trial[24] did not provide this information. However, it should be noted that 4 of the sources[20,21,23,25] also had control groups with average endpoint temperatures above 36.0ºC. Although there is overall statistical significance, the clinical significance must be examined.

The use of preoperative warming for the prevention of IPH was likely clinically significant. Those studies with statistically significant results[18-22,25] had differences between control and treatment groups' endpoint temperatures ranging from 0.3ºC[21] to 0.6ºC.[20,22] Percentages of subjects in the treatment group whose temperatures were above 36.0ºC included 100%,[22] 88%,[25] 75%,[24] 68%,[21] and 56%.[18] Percentages of controls with temperatures of at least 36.0ºC included 54%,[24] 50%,[25] 43%,[21] and 28%.[18] The numbers of subjects in the control group whose temperatures remained above 36.0ºC were not reported in 4 studies.[19,20,22,23]

These findings must be considered in the context of the presence of potentially confounding variables present in the studies. These include selection of endpoint temperature times, warming devices and temperature measuring instruments, warming times, warming unit settings, surgical durations, surgical types, and use or nonuse of intraoperative warming.

• ***Endpoint Temperature Times***. Two studies[18,23] selected arrival to the PACU as endpoints. Another[24] chose 15 minutes after leaving the operating room. One source[25] failed to designate a specific endpoint time by referencing only a postoperative timeframe. The remaining trials[19-22] designated set time intervals (80 minutes,[21] 90 minutes,[22] 120 minutes,[19] and 270 minutes[20]) after subject arrival in the operating suite as endpoints. Temperature variations were significantly different at selected points, but this did not necessarily continue as surgeries progressed. Narrowed temperature gaps could be due to efficient intraoperative warming and increased intraoperative warming times.

• ***Warming Devices and Temperature Measuring Instruments.*** Seven studies[18,19,21-25] implemented active preoperative warming via forced-air units. A second treatment group in one study[22] received active warming from an alternate source—a thermostatically controlled carbon fiber blanket. The final trial[20] consisted of subjects warmed preoperatively with a "conductive carbon polymer mattress."

Location for temperature measurement and instruments used to measure temperatures also varied among the studies. Locations included the tympanic membrane,[18-20,22,24,25] oral,[23] nasopharyngeal,[20] and esophageal.[21,22] A temporal artery scanner was used in one study.[21] Concerns include the questionable accuracy of temporal artery scanners[30] and the potential for inaccuracy when using an oral probe.[31] Staff members were instructed in the correct use of thermometers in only 3 sources.[18,23,25] Another major limitation of the appraised evidence sources is the predominant lack of calibration of thermometers and no reporting of the manufacturer's accuracy and precision data. Calibration of instruments was reported in only 2 studies,[18,23] with accuracy and precision addressed in 2 of the trials.[22,23] These factors may threaten the validity and reliability of the findings.

• ***Warming Times.*** Warming times were 30 minutes,[22] 60 minutes,[19,21,25] and 120 minutes.[20] Another source[18] warmed subjects for a minimum of 45 minutes, with no final warming durations stated. Two sources[23,24] did not provide the preoperative warming duration. Regardless whether warming times were 30 or 120 minutes, all interventional groups had significantly warmer subjects. Only those studies failing to provide warming data reported no significant difference[23] or did not use inferential statistics to determine if there was a difference.[24] These longer warming times may not be practical in a busy operating room.

• ***Warming Unit Settings.*** Settings were 38ºC,[18,21] 40ºC,[20] 42ºC,[22] and 42º to 46ºC.[19] One trial[23] allowed regulation of warming units by subjects preoperatively and by staff intraoperatively. Two evidence sources[24,25] provided no data. Subjects were reported to be significantly warmer in trials with fixed settings.[18-22] Subjects in the experimental group were not significantly warmer compared with subjects in the control group in the study[23] that allowed the staff to regulate the warming unit.

• ***Surgical Durations.*** Reported mean durations ranged from 113 minutes[22] to 196 minutes.[20] Two studies[18,23] failed to provide duration data, but the inclusion criteria for both studies consisted of surgeries lasting 60 to 180 minutes. Despite the possible 136-minute difference in mean surgical length, 6 trials[18-22,25] yielded statistically significant differences between treatment and control groups. One study[23] resulted in no significant difference. One trial[24] provided no surgical length data and no inclusion criteria.

• ***Surgical Types.*** Surgical types included gynecologic, orthopedic, urologic, abdominal, spinal, colorectal, laparoscopic colorectal, nondescriptive outpatient surgery, and laparoscopic cholecystectomy procedures. Only patients undergoing nondescript outpatient surger-

ies[23] failed to have statistically significant temperature differences. One trial involving laparoscopic cholecystectomies[24] failed to determine whether significant temperature differences existed.

• ***Intraoperative Warming.*** Use or nonuse of intraoperative warming did not appear to affect temperature differences in the studies. This was probably due to consistent trial conditions for both the treatment and control groups with only a few exceptions.[19,24] Intraoperative warming was withheld in 1 of the 3 experimental groups in one of the trials[19] and 2 of the 3 groups in another.[24] One study[23] encouraged providers to continue preoperative conditions; however, they were allowed to deviate if subject temperature and safety warranted such changes. In a seemingly contradictory outcome, 1 trial[23] resulted in no significant difference in endpoint temperature between treatment and control groups despite application of intraoperative warming to the treatment group.

Only 1 study[23] examined the cost-effectiveness of active preoperative warming compared with passive radiant-heat blankets. The cost analysis involved the following costs: (1) blanket laundering; (2) delivery to the surgical unit; (3) warming gown; and (4) retrieval time by the registered nurse. Possible cost savings of active preoperative warming was $1,235 per year.

Although outside the PICO question, other significant benefits of preoperative warming were reported to include decreased intraoperative blood loss,[20] decreased surgical complication rates,[20] decreased time to tracheal extubation,[19] and increased thermal comfort reported by the patient using a Likert-type scale.[18,23] Active preoperative warming showed significant benefit in the prevention of shivering in 1 trial,[19] but no advantage was found in 2 other studies.[18,21] The need for postoperative pain medication was similar between treatment and control groups in the lone trial that addressed the variable.[18] Postoperative nausea and vomiting was another dependent variable examined. One study reported a larger percentage of subjects reporting nausea in the intervention group (32%) vs the control group (28%).[18] Another trial also reported increased nausea and vomiting (an incidence of 10% each) in the intervention group vs the control group (5% and 3%, $P < .05$).[21] This difference may represent clinical significance. No mechanism was proposed for these findings, and possible causes should be explored.

One study[18] reported no difference between groups in the number of subjects who complained of shivering, but participants in the treatment group were significantly more likely to report "thermal comfort." In the same trial, younger subjects (mean age ± standard deviation, 36 ± 10.6 years versus 46.6 ± 14.2 years) complained of shivering more than older subjects did (mean age ± standard deviation, 36.0 ± 10.6 years vs 46.6 ± 14.2 years, respectively) despite having higher initial postoperative temperatures.

Summary

The appraised studies contained a number of inconsistencies, including selection of endpoint temperature times, warming devices and temperature measuring instruments, warming times, warming unit settings, surgical durations, surgical types, and use or nonuse of intraoperative warming. Despite these potential problems, most of the evidence[18-22,25] supports the implementation of active preoperative warming to prevent IPH. Seven trials[18-23,25] resulted in treatment groups with study endpoints above the hypothermic threshold. One trial[23] found no statistically significant benefit to the treatment, and another study[24] failed to provide inferential statistics. Implementation of preoperative warming has few risks beyond cost. This cost can be lessened by using the same forced-air warming blanket preoperatively and intraoperatively. If there were more substantial risks of preoperative warming, a provider would likely refrain from its use pending further investigation.

Additional reported benefits of prewarming included decreased shivering,[19] blood loss,[20] and cost,[23] as well as increased thermal comfort[18,23] and earlier extubation.[19] Two sources[18,21] reported increased postoperative nausea and vomiting in the treatment groups. A shorter preoperative warming time of 30 minutes[22] and a lower warming unit setting of 38ºC[18,21] produced statistically and clinically significant results.

A 2012 systematic review also supported the implementation of active preoperative warming to prevent IPH.[28] That group also concluded that active preoperative warming may be effective in preventing IPH. However, this review used different inclusion criteria for anesthesia type.

Evidence strengths and weaknesses should be noted when considering treatment implementation. Study strengths included a diverse subject population and a variety of surgical settings, procedures, and lengths. Active preoperative warming interventions included forced-air blankets, carbon fiber blankets, and conductive carbon polymer mattress. Data were collected using varied settings for warming units. Evidence weaknesses included overall lack of biometric instrument calibration and accuracy data along with lack of staff instruction on use. Power analyses were absent in 4 studies.[18,19,24,25] Three trials[20,21,23] were underpowered, and blinding was absent for the most part.

Future trials should include shorter warming times, lower warming unit settings, appropriate sample sizes, and the consistent use of calibrated biometric instruments by trained staff.

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