Preoperative Forced-Air Warming Combined With Intraoperative Warming Versus Intraoperative Warming Alone in the Prevention of Hypothermia During Gynecologic Surgery

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Hypothermia in the perioperative setting can have serious consequences, including increased risk of infection or adverse cardiac events. Forced-air warming units commonly are used to prevent hypothermia. This study examined the impact of adding preoperative warming (Bair Paws, 3M) to conventional intraoperative forced-air warming modalities. Thirty patients received both preoperative and intraoperative forced-air warming, and 30 patients received intraoperative warming alone. Temperature readings were recorded across 3 time periods: preoperative, intraoperative, and postoperative. Data were analyzed using descriptive statistics, analysis of variance (ANOVA), and repeated-measures ANOVA.

Demographics were similar in both groups with respect to age, body mass index, total intravenous fluids, and estimated blood loss. Statistically significant differences in temperature were seen over time (df = 2, P < .001), and for each intervention across all 3 time periods (P = .042). However, no statistically significant differences in temperature were demonstrated between groups over time. ASA status and type of procedure (laparoscopic vs open) also had no impact on results. These results suggest that preoperative warming with the Bair Paws gown offers no benefit over conventional therapy in maintaining normothermia in the perioperative period.

Keywords: Forced-air warmer, hypothermia, perioperative warming, temperature.
Literature Review

The literature identified hypothermia as a common problem in the operating room, with complications ranging from mild to severe. Several randomized controlled trials noted that hypothermia increases the rate of infection. Kurz et al.\(^5\) found that a mean intraoperative core temperature (± standard deviation [SD]) of 35.7°C ± 0.6°C had a 13% increased risk of infection compared with a normothermic body temperature. Likewise, Wenisch and colleagues\(^8\) examined the relationship between hypothermia and neutrophil activity and noted that the production of reactive oxygen species by neutrophils was linearly related to core temperature. In other words, because oxidative killing molecules are needed to fight infection, a decrease in production of reactive oxygen species may increase the risk of infection.

The effects of hypothermia on the cardiovascular and neuroendocrine systems have also been reviewed by several studies in the literature. Findings suggest a relationship between cardiac morbidity and hypothermia. Frank et al.\(^1\) studied the effects of hypothermia on the neuroendocrine response. Cortisol, norepinephrine, and blood pressure measurements were obtained in the normothermic and hypothermic groups. Although the researchers found that cortisol level differences were insignificant between the groups, norepinephrine concentrations were higher in the hypothermic patients. In addition, the hypothermic group was found to have higher arterial blood pressures in the early postoperative period compared with the normothermic group. Another study conducted by Frank et al.\(^9\) observed that ventricular tachycardia occurred less frequently in normothermic patients. Increased electrocardiographic changes have also been reported in hypothermic surgical patients compared with normothermic patients.

Additionally, hypothermia has been found to affect the pharmacokinetics of anesthetic medications and blood loss during surgery, and to alter hospital dynamics. Leslie et al.\(^10\) found that propofol concentrations averaged 28% more at 34°C than at 37°C. The duration of action of muscle relaxants such as atracurium and vecuronium have been noted to be significantly prolonged in the hypothermic groups.\(^10\) A meta-analysis completed by Rajagopalan and colleagues\(^12\) concluded that hypothermia significantly increases blood loss by approximately 16% and increases the risk of a blood transfusion by approximately 22%. Hypothermia has also been noted to increase hospital costs.\(^3\) Because normothermic patients were found to have less adverse outcomes compared with hypothermic patients, hospital-associated costs were less.\(^3\) Increased PACU length of stay and increased hospital stay were also associated with hypothermia in the perioperative setting.\(^13\)

Prevention of perioperative hypothermia with the use of forced-air warming devices has been proved effective. Several studies have demonstrated that the use of forced-air warming before the induction of anesthesia ("prewarming") minimizes intraoperative hypothermia. Andrzejowski et al.\(^14\) indicated that 68% of patients prewarmed with a Bair Paws warming system before anesthesia maintained an intraoperative temperature above 36°C compared with 43% in the control group. A smaller decrease in core temperature was seen between 40 and 80 minutes after induction in the prewarmed group. Similarly, Camus et al.\(^15\) noted that after 1 hour of anesthesia, 6 of 8 prewarmed patients had core temperatures of at least 36.5°C, whereas only 1 of the 8 control patients did. In another study, patients receiving a combination of preoperative warming and intraoperative skin surface warming had core temperatures significantly more elevated than those of other patients during the first 2 hours of anesthesia.\(^16\) The minimum warming duration and optimal heating temperature to decrease redistribution hypothermia have been reviewed by Sessler et al.\(^17\)

Forced-air warming with the Bair Hugger for 30 minutes increased peripheral tissue heat content by more than the amount normally redistributed during the first hour of anesthesia.

Anesthesia and surgery commonly cause disruptions of the thermoregulatory process. During surgery, a patient can lose heat through convection, radiation, and conduction.\(^18\) Conductive heat transfer has the greatest effect of heat loss through the direct transfer of body heat to the operating room table, cold irrigation fluids, and cold blood and intravenous fluids. Insensible loss from the skin, cold skin preparation solution, and cold dry anesthetic gases can result in convective cooling. Radiational heat transfer can occur from the patient to the operating room walls. Besides heat loss mechanisms, anesthesia itself can result in core hypothermia. When muscle relaxants are used, protective mechanisms for hypothermia such as shivering are absent.\(^13\) Sessler\(^18\) explains that anesthesia distributes body heat, leading to core hypothermia. In addition, much more core hypothermia results from the altered distribution of body heat than from heat production and heat loss mechanisms. The anesthetics used at induction produce vasodilation. With vasodilation, central core heat flows down the temperature gradient to the peripheral tissues. This redistribution of body heat decreases core temperature. A study on heat flow and distribution during induction of general anesthesia was completed by Matsukawa et al.\(^19\) Results concluded that the redistribution of body heat from the core to the periphery decreases the core temperature 1°C to 1.5°C during the first hour of general anesthesia. Redistribution continued to be the major cause of core hypothermia after 3 hours of anesthesia. The loss of heat from the environment contributed little to this initial decrease.\(^2\)

Limitations in methods and design were also noted in some studies. Some indicated that their small sample
size, sample type, or short sampling period may have been a limitation in their study. For example, Frank et al.\textsuperscript{19} mentioned that the sample size used to study the relationship between unintentional hypothermia and myocardial infarction may have been too small to evaluate major morbidity. Likewise, Matsukawa and colleagues\textsuperscript{19} studied the heat distribution in only young male subjects. Other studies indicated that the measuring tool used may have not accurately reflected core temperatures. Another study noted that a few patients received antibiotics before the surgical wound was cultured in both the experimental and control groups.\textsuperscript{7} External variables also subject the study to limitations. When hypothermia and its association with PACU delays were described, the author mentions other reasons for PACU delays that may have affected outcomes. These include the availability of the floor bed, the type of surgical procedure performed, or the discharging physician.\textsuperscript{13}

**Materials and Methods**

- **Participants.** The target population included women who were undergoing gynecologic surgery at Bridgeport Hospital, Bridgeport, Connecticut. Inclusion criteria consisted of ASA classes 1 through 3, age between 18 and 85 years, general anesthesia with an endotracheal tube, and use of intraoperative forced-air warming. Exclusion criteria consisted of ASA class 4, age less than 18 years and greater than 85 years, emergency or trauma patients, and robotic-assisted procedures. Procedures included both laparoscopic and open gynecologic surgeries. Types of surgeries consisted of total abdominal hysterectomies, ovarian cystectomies, oophorectomies, vaginal hysterectomies, and myomectomies. This population was readily accessible because gynecologic procedures are performed regularly at Bridgeport Hospital.

- **Study Design.** A quasi-experimental design was used for data collection. The study was approved by the institutional review board at Bridgeport Hospital, and a waiver of patient consent was met. A power analysis was conducted with a medium sample effect of 0.5, $\alpha = 0.05$, power of 0.8, and allowing for a possible attrition rate of 90%. The sample size for each group was calculated to be 30 subjects. Nonrandomized or convenience sampling was completed. All subjects were recruited in the preoperative department at Bridgeport Hospital. Individual instruction regarding data collection and placement of the Bair Paws gown was given to the preoperative nursing aides before initiation of the study. The data collection sheet was placed in the patient's chart by the principal investigator on the morning of the patient's scheduled surgery. If the patient was part of the intervention group, the preoperative nursing aides were instructed to provide the patient with at least 30 minutes of preoperative forced-air warming with the Bair Paws. The patient's baseline temperature, minutes of preoperative warming, and start and finish time of the Bair Paws warming were collected on the data sheet provided. Forced air warming was then continued once the patient arrived in the operating room. The preoperative staff was notified if the patient was in the control group and then instructed to not place the Bair Paws gown on the patient. The control group received only intraoperative forced-air warming with the Bair Hugger blanket, which was placed on the patient by the anesthesia staff. An oral thermometer was used for baseline temperature readings in the preoperative area.

The second half of the data sheet was completed by the anesthesia staff. Instruction regarding data collection was again reviewed by the lead investigator on an individual basis. Certified Registered Nurse Anesthetists and student registered nurse anesthetists completed the intraoperative data collection. Anesthesia providers varied according to the daily staff schedule. The anesthesia provider who was assigned to the gynecologic case on any scheduled day received instruction. Recorded patient information included height, weight, age, ASA class, type of surgical procedure, the first temperature reading in the operating room with the esophageal thermometer, amount of intravenous fluids or blood products given, blood loss, and whether the Bair Hugger and fluid warmer were used intraoperatively. After the final PACU temperature was documented on the data sheet, the anesthesia personnel were instructed to return the data sheet to a designated folder that was placed in a secure area in the PACU.

- **Measures.** Both oral and esophageal thermometers were used to collect patient temperatures. The Level 1 Acoustoscope esophageal stethoscope (Smiths Medical) was used to measure core temperatures intraoperatively. Oral temperatures in the preoperative and PACU settings were obtained using the SureTemp Plus electronic thermometer (Welch Allyn). The oral thermometer and esophageal probe are regarded as valid instruments for temperature measurements. Oral thermometry is accepted as the most accurate means of noncore temperature assessment with the probe properly placed in the posterior sublingual pocket.\textsuperscript{21} Likewise, an esophageal thermometer has been identified as an accurate reflection of core temperature. The optimal position for the sensor is approximately 45 cm from the nose or in the lower third of the esophagus in adults. This allows the sensor to be close to the heart and aorta.\textsuperscript{22} Calonder et al.\textsuperscript{23} investigated intraoperative core temperatures measured by the esophageal probe and compared them with temperatures taken by an oral thermometer for adult patients undergoing colorectal or gynecologic surgery. It was found that oral temperatures were biased high relative to esophageal temperature by 0.12°C on average ($P = .0008$). Although this difference was found to be statistically significant, it can be regarded as clinically acceptable.

- **Data Analysis.** The statistical analyses for this
study were performed using the Statistical Package for the Social Sciences (IBM SPSS) 20.0 for Mac. A t test was completed to determine if patient characteristics, including age, body mass index (BMI), total intravenous fluids, estimated blood loss, preoperative temperature, and first recorded temperature in the operating room, differed between the 2 groups. Because temperature readings were recorded across 3 time periods (preoperative, intraoperative, and PACU) a repeated-measures analysis of variance (ANOVA) was used to determine if temperature changes were significant over time both within and between the 2 study groups. In addition, a repeated-measures ANOVA was conducted to determine if body temperature was affected over time by ASA status and open vs laparoscopic procedures.

### Results

Sixty patients were recruited into the study. Thirty patients received prewarming with intraoperative warming, and 30 patients received intraoperative warming alone. A Student t test was used to compare between groups with respect to age, BMI, total intravenous fluids, estimated blood loss, preoperative temperature, and first recorded temperature in the operating room. There were no statistically significant differences between the group receiving prewarming with the Bair Paws and the group receiving traditional intraoperative warming with the Bair Hugger (nonprewarmed) regarding age, BMI, total intravenous fluids, or estimated blood loss for the procedures (Table 1). There was a statistically significant difference in preoperative temperatures in the prewarmed group vs the nonprewarmed group (P = .026). The mean duration of prewarming was 51 minutes (SD, 19; range, 30-104 minutes). However, these differences disappeared once the patients entered the operating room. No significant differences were seen between the 2 groups with the first recorded temperature in the operating room (P = .341; Table 2).

A repeated-measures ANOVA analysis was used to examine the impact of the Bair Paws vs traditional Bair Hugger for management of perioperative temperatures across the 3 time periods: preoperative, intraoperative, and PACU. Repeated-measures ANOVA showed a significant effect of time on temperature (F = 193.86, df = 2, P < .001), as well as a significant effect of each intervention across all 3 time periods (F = 3.264, df = 2, P = .042). However, there was no statistically significant difference between groups with respect to body temperature over time (F = 0.98, df = 1, P = .755).

A repeated-measures ANOVA was conducted to determine if body temperature differed between patients who underwent open vs laparoscopic procedures over time. Thirty-four procedures were completed laparoscopically and 26 were open procedures. Repeated-measures ANOVA showed a significant effect of time on temperature (F = 189.66, df = 2, P < .001), but no significant effect of open vs laparoscopic procedures across all 3 time periods (F = 1.556, df = 2, P = .215). In addition, there was no statistically significant difference between groups with respect to body temperature over time (F = 0.574, df = 1, P = .452). Therefore, type of procedure did not affect body temperature over time.

A repeated-measures ANOVA was conducted to determine if body temperature differed between patients depending on ASA status. Repeated-measures ANOVA showed a significant effect of time on temperature (F = 102.771, df = 2, P < .001) and a significant interaction effect across all 3 time periods (F = 2.881, df = 2, P = .026). However, there was no statistically significant difference between ASA status groups with respect to body temperature over time (F = 0.236, df = 1, P = .790). Therefore, ASA status did not affect body temperature over time.

### Discussion

Unintended hypothermia is a common problem in the perioperative setting. A review of the literature suggested that a core body temperature of less than 36°C perioperatively might increase the risk of infection, increase length of hospital stay, increase cardiac comorbidities, increase the duration of action of muscle relaxants, and increase stress on the body. Research supports that preoperative forced-air warming can limit the redistribution of body heat that occurs after the induction of anesthesia. This

### Table 1. Patient Characteristics and Perioperative Variables

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Experimental (Bair Paws) group: prewarming + intraoperative warming (mean ± SD)</th>
<th>Traditional group: intraoperative warming alone (mean ± SD)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>49.43 ± 13.74</td>
<td>46.67 ± 15.02</td>
<td>.428</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>27.77 ± 5.59</td>
<td>29.20 ± 5.29</td>
<td>.308</td>
</tr>
<tr>
<td>IV fluids, mL</td>
<td>2,430.0 ± 1,028.52</td>
<td>2,280.0 ± 906.83</td>
<td>.551</td>
</tr>
<tr>
<td>Estimated blood loss, mL</td>
<td>193.33 ± 200.32</td>
<td>189.67 ± 174.11</td>
<td>.940</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; IV, intravenous.
study investigated 2 methods of perioperative warming in the prevention of hypothermia. Preoperative warming with the Bair Paws warming unit combined with intraoperative warming was compared with applying a Bair Hugger alone intraoperatively.

Results showed a significant effect of time on temperature, as well as a significant effect of each intervention across 3 time periods: preoperative, intraoperative, and PACU. However, there was no statistically significant difference between the 2 interventions with respect to body temperature over time. In addition, analyses indicated that type of procedure did not affect body temperature over time. No statistically significant difference with respect to body temperature over time was found between patients who underwent either laparoscopic or open gynecologic procedures. The effect of ASA class on body temperature over time showed similar results. Furthermore, none of the patients were hypothermic in the PACU. All of the subjects had a body temperature above 36°C when they arrived in the PACU.

Even though there was a statistically significant difference in preoperative temperatures in the prewarmed group vs the group that was not prewarmed, once in the operating room no significant differences were seen between the 2 groups with the first recorded operating room temperature. By the time the patients in either group entered the operating room, body temperature was cooled from baseline preoperative temperature readings. Preoperative forced-air warming was discontinued en route to the operating room. Although this study did not account for when the intraoperative warming was initiated, clinically, it is common practice to institute forced-air warming with the Bair Hugger after the patient is surgically draped. Body temperature cools during this elapsed time.

A number of threats to external and internal validity existed in this study. Two different instruments were used to obtain temperature readings. The patient’s baseline temperature in the prewarmed area was obtained with an oral thermometer. This temperature was then compared with temperature readings obtained via an esophageal probe in the operating room. Perhaps using the same type of thermometer throughout the study would produce more valid results. Patient characteristics and intraoperative variables such as BMI, age, ASA class, estimated blood loss, and total intravenous fluids were controlled for in this study and were found to be statistically insignificant between the 2 groups. Data also indicated that all patients received warmed intravenous fluids intraoperatively. Extraneous variables not controlled for included ambient temperatures and staff-persons taking temperature readings. Environmental temperatures can have an effect on core body temperatures. A cool environment can cause the body to lose heat and decrease core body temperature. This may contribute to the decrease in body temperature that was noted once the patient entered the operating room. Also, the operating room nurse may or may not have warmed the operating room bed mattress, thus affecting patient temperature readings in this study. This variable was not taken into account during data collection. However, environmental temperatures would have been difficult to control for in this study because wall thermostats in the preoperative, intraoperative, and PACU areas can be adjusted at any time by the perioperative staff. There would have been much variability in the readings. Anesthesia providers were not kept constant throughout this study. Therefore, different persons were obtaining temperatures, and the accuracy of the temperature measurements is considered. Correct positioning of the oral thermometer and esophageal probe are important for accurate readings. For example, a more proximal positioning of the esophageal probe can result in falsely decreased temperatures because of the proximity to the trachea and the impact of cold, dry gases on the site. In addition, this study investigated only gynecologic surgeries. Perhaps including other types of surgeries would increase external validity and produce results that can be more generalizable.

Several other limitations are noted in this study. Neither the researchers nor the persons collecting data were blinded. However, it would have been difficult to perform blinding in this study. In addition, patients were not randomized into the groups, and convenience sampling was completed. Perhaps a larger sample size may be needed for future studies.

Further studies on the patient's perspective or satisfaction with preoperative warming and the Bair Paws warming unit may be valuable. O'Brien et al noted that patients who used the Bair Paws system preoperatively reported a decrease in anxiety. In addition, the ability to control the temperature of a handheld device can result in overall greater patient comfort. Additional research,
however, may be needed to improve the external validity of these study findings.

Bridgeport Hospital’s cost for a single Bair Paws warming gown is more than double the cost for an upper body Bair Hugger blanket ($15.57 vs $6.11). From a cost perspective, results of this study indicate that applying the Bair Paws warming unit preoperatively offers no benefit if no difference was seen in patient temperature over time compared with performing intraoperative warming alone. Again, all patients in this study had normothermic body temperatures once they arrived in the PACU. Moreover, future investigations involving patient satisfaction, comfort, and cost outcomes with preoperative warming are warranted.

REFERENCES


AUTHORS

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