

Preventing Inadvertent Hypothermia in Patients Undergoing Major Spinal Surgery: A Nonrandomized Controlled Study of Two Different Methods of Preoperative and Intraoperative Warming

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Purpose: To evaluate if a Full Access Underbody (FAU) blanket used preoperatively and intraoperatively in patients undergoing major spinal surgery prevents hypothermia compared with current practice and to explore patients' experiences of comfort.

Design: A nonrandomized controlled trial.

Methods: Sixty patients were included, 30 in each group. Temperature was assessed on arrival, after connecting to the bladder catheter, and at the start and end of surgery. In the FAU group, comfort was evaluated at arrival and after 10 minutes of prewarming.

Findings: The incidence of hypothermia at the start of surgery was significantly lower (relative risk [95% confidence interval], 0.28 [0.13 to 0.59]). Before prewarming, 77% felt comfortable, 20% cold, and 3% hot. After prewarming 60% felt comfortable, 37% hot, and 3% very hot.

Conclusions: Patients using the FAU blanket had a 72% lower incidence of hypothermia at the start of the operation. Attention to thermal comfort during surgery is important.

Keywords: inadvertent hypothermia, prewarming, forced air warming (FAW), thermal comfort.

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HYPOTHERMIA IS DEFINED as a core temperature of $< 36^{\circ}\text{C}$.¹ Inadvertent hypothermia of only 1°C increases intraoperative blood loss and the

need for blood transfusions because of a reduced formation of a platelet plug and clot, leading to a combination of platelet and enzyme impairment,

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increasing blood loss by about 20%.^{2,3} Vasoconstriction occurs when the patient is mildly hypothermic, resulting in reduced oxygen perfusion, reduced systemic immune activation, and reduced tissue healing, thus tripling the infection rate.²⁻⁴ Mild hypothermia is defined as a core body temperature between 34°C and 36°C.^{5,6} Previous research has indicated that intraoperative hypothermia influences the risk of myocardial ischemia and triples the risk of morbid cardiac output.² Anesthetics inhibit thermoregulatory control and affect vasoconstriction, potentially causing inadvertent hypothermia and shivering.⁷ Although hypothermia is used deliberately in some surgical procedures to preserve cells, it is associated with several adverse effects ranging from thermal discomfort to increased morbidity and mortality.¹

Major spinal surgery tends to be lengthy with an increased risk of hypothermia. Patients operated on for spinal deformities have an increased risk of hypothermia due to the length of operation, degree of exposed skin surface, and positioning.⁸ This emphasizes that length of operation, exposed skin surface, positioning, incision length, and theater temperature are considered predictors of hypothermia.⁹⁻¹¹ Postoperatively, patients can experience physical discomfort because of hypothermia during surgery.^{2,3} Years after their operation, patients identify the feeling of being cold as their worst hospital experience.^{2,3} Being warm is a substantial factor that influences the patient's experience of care during surgery. A survey among nurse anesthetists on patients' major concerns showed that 71% of the nurses found that being cold was a comfort problem.¹² Physical comfort needs include physiologic mechanisms that are disrupted such as thermoregulation. Preemptive warming is one technical comfort measure that has shown effectiveness in reducing inadvertent hypothermia,¹³ and at the same time, increasing the patient's thermal comfort.¹⁴

Prewarming is defined as warming of peripheral tissues or skin surface before anesthetic induction.^{1,15} Forced air warming (FAW) prevents intraoperative hypothermia effectively, and thermal comfort provided by FAW is superior to that provided by other warming methods.^{9,11} Prewarming is effective in preventing redistribution hypothermia, especially

1 hour after induction of anesthesia.^{2,3,12} It is not known whether the use of a Full Access Underbody (FAU) blanket can prevent hypothermia during major spinal surgery. For that reason, the aims of this study were to evaluate if an FAU blanket used preoperatively and intraoperatively can reduce the number of patients having inadvertent hypothermia when undergoing major spinal surgery, as compared with current practice, and to evaluate the thermal comfort of patients using the FAU blanket. The hypothesis is that the FAU blanket will decrease the risk of hypothermia and increase the patient's experience of thermal comfort.

Methods

Study Design

The study was a nonrandomized controlled trial conforming to the TREND statement (Transparent Reporting of Evaluations with Nonrandomized Designs)¹⁶ for reporting nonrandomized studies.

Patients and Recruitment

The study included 60 patients undergoing major spinal surgery, defined as spine deformity surgery. The study included patients who were Danish speaking to ensure they understood questions related to their thermal comfort, aged ≥ 14 years to match the included patients in the former quality improvement project, and with a tympanic temperature $< 38^\circ\text{C}$ or $> 36^\circ\text{C}$. Patients were excluded if they weighed more than 115 kg (FAU has a 115 kg limit), had a preoperative temperature $> 38^\circ\text{C}$ or $\leq 36^\circ\text{C}$ (normothermia is defined as a core temperature range of 36 to 38°C),¹ or had cognitive impairment to such an extent that they were not capable of cooperating.

Patients were included consecutively at the Clinic for Anesthesiology, Child Diseases, Circulation and Women, Aalborg University Hospital and divided into two groups of 30 patients depending on time of inclusion. Patients for the control group were included as part of a quality improvement project in the period from September 2012 to February 2013. Patients for the intervention group were included from November 2015 to

October 2016. The time span between the two data collection periods was caused by lack of options of how we could prevent inadvertent hypothermia effectively in this group of patients. The acquisition of the FAU blanket challenged the current warming practice and gave ideas as to how the number of patients with inadvertent hypothermia might be reduced.

Study Treatments

In the control group, patients were covered with a lint-free quilt and a reflective blanket before entering the operating theater. When the patient was placed on the operating table, the quilt and reflective blanket were placed on top of the patients' legs and arms so as not to interfere with the preoperative preparations consisting of positioning the patient, x-rays, marking of the patients' back position, and ending with the sterile draping. A Full Body Blanket with surgical access (FBBSA; Bair Hugger blanket Model 570—warming unit [3M, Maplewood, MN]) and cotton blankets on the upper limbs were applied, and FBBSA was activated shortly before the start of the operation.

In the intervention group, the FAU blanket (Bair Hugger blanket Model 635—warming unit 775 [3M]) was placed on the patient under a lint-free quilt before entering the operating theater. In the operating theater, the patient was asked to assess his or her thermal comfort. The FAU blanket was then connected to the warming unit and started at 43°C. Before induction of anesthesia, patients once again were asked to assess their thermal comfort. The FAU blanket was switched off and placed on the operating table before placing the patient on top of it in prone position. The FAU blanket was turned on and kept running throughout the remaining preoperative preparations only to be switched off momentarily while the sterile drapings were placed. In both the intervention and control groups, the temperature of the warming unit was adjusted either in accordance with the patient's statements of thermal comfort or alterations in bladder temperature. In both groups, the temperature of the operating theater was set at 20°C. This temperature was controlled and monitored by a central heating system and was digitally visible in the operating theater.

Data Collection Procedure

The patients' tympanic temperature was measured. Anesthesia was induced and maintained with fentanyl, propofol, and remifentanyl and in some cases supplemented by a volatile anesthetic. The patient was intubated and ventilated mechanically. The patients in the control group continued with nonactive warming because the FBBSA interfered with the preoperative procedures due to its placement on top of the patient. The patients in the intervention group had the FAU blanket placed beneath them, thus resuming active warming during the continuous preoperative procedures. According to current practice, all patients received a bladder catheter after the induction of anesthesia. Bladder temperature was measured and documented when the bladder catheter was connected to the monitor, and at the start and end of the operation. To be able to alternate the temperature of the blankets, the bladder temperature was observed on the monitor and reacted upon, yet not documented with 15-minute intervals throughout the operation and on arrival to the PACU. Furthermore, the patient's thermal comfort was assessed when using the FAU blanket as active prewarming.

Measurements

Preoperatively, demographic and morphometric characteristics including age, gender, weight, American Society of Anesthesiologists, and tympanic temperature were documented. Ear canal temperature (Braun Welch Allyn Pro 4000 [Welch Allyn, Skaneateles Falls, NY] $\pm 0.2^\circ\text{C}$ for the thermometer at 35.5°C to 42.0°C)¹⁷ was measured upon arrival because of its unobtrusive nature and ease of management,¹⁸ although it is considered inferior compared with other temperature sites.^{3,19,20} The accuracy of this measurement was, however, of less importance because it was used to include or exclude patients in the study. A Foley bladder catheter measured the bladder temperature using a temperature sensor (Level 1 FC 400/12-14; Smiths Medical, Inc.). The bladder temperature is considered suitable for clinical use, provided there is an adequate urine flow.³ Hypothermia was defined as temperature $< 36^\circ\text{C}$. Patients' thermal comfort was assessed with a modified 5-point Likert visual scale consisting of 5 points: 1, very cold; 2, cold; 3, comfortable; 4, hot; 5, very hot. The Likert scale is a psychometric scale

of five points that allows individuals to express how much they agree or disagree with a particular statement.²¹ For the purpose of this study, the Likert scale was modified and included digits and smileys so it was easier for patients to see and grade.

Ethics and Registration

The study was registered at [ClinicalTrials.gov](https://clinicaltrials.gov) (NCT03193905) and was carried out in accordance with the Helsinki Declaration.²² The patients (and their legal guardians if younger than 18 years) were informed about the study before surgery and about their rights to withdraw from the study at any time. Confidentiality and anonymity was ensured. In accordance with Danish legislation, formal ethics approval of the study was not required because the study was an analysis of current practice and thus had no implications for the treatment of the patient. Authorization by the regional Danish Data Protection Agency Identity number 2015-135 was obtained.

Data Analysis

Potential between-group differences in demographics and treatment-related variables were compared using the two-sample t test, Pearson's χ^2 test, or Fischer's exact test depending on data type and cell numbers. Relative risk (95% confidence interval [CI]) and Pearson's χ^2 test or Fischer's exact test were used to compare hypothermia (temperature < 36°C) between groups. Thermal comfort was numerically calculated and presented in a diagram. The significance level was set at $P < .05$, and all analyses were performed using IBM SPSS Statistics, version 24 (IBM Corporation, Armonk, NY).

Findings

Table 1 presents the demographic and morphometric characteristics and treatment-related variables of the patients included. Length of stay in the operation theater ($P = .003$) and length of operation ($P = .002$) were significantly shorter in the intervention group than in the control group. There were no other statistically significant differences found between the two groups in demographic or treatment-related variables. When connecting to the bladder catheter, no significant between-group difference was found (RR [95%

CI], 0.20 [0.03 to 1.61]; **Table 2**) in the incidence of hypothermia with mean (SD) temperatures of 36.3 (0.5) °C in the control group and 36.5 (0.4) °C in the intervention group. At the start of the operation, the incidence of hypothermia (< 36°C) was significantly lower in the intervention group than in the control group (RR [95% CI], 0.28 [0.13 to 0.59]; **Table 2**) with mean (SD) temperatures of 35.8 (0.5) °C in the control group and 36.3 (0.3) °C in the intervention group. At the end of the operation, no significant between-group difference was found (RR [95% CI], 0.33 [0.04 to 3.03]; **Table 2**) in the incidence of hypothermia with mean (SD) temperatures of 36.8 (0.7) °C in the control group and 37.1 (0.4) °C in the intervention group. When asked, 23 (77%) patients in the intervention group indicated that they felt thermally comfortable, 6 (20%) cold, and 1 (3%) hot before prewarming, while 18 (60%) felt thermally comfortable, 11 (37%) hot, and 1 (3%) very hot after prewarming.

Discussion

We found that inadvertent hypothermia at the start of the operation was lowered by 72% when using the FAU blanket preoperatively and intraoperatively compared with the use of passive prewarming and active warming with the FBBSA commencing at the start of the operation. This corresponds partly with the study by Pu et al,²³ who found that significantly fewer patients with intraoperative hypothermia were observed in a group of patients who were actively warmed using an underbody warming system intraoperatively than in a passively warmed group of patients. Also, they found no significant alteration in the temperature at the beginning of surgery until 30 minutes later, despite differences in warming methods.²³ We found no significant difference in the number of patients with inadvertent hypothermia between the control group and intervention group when the patients' bladder catheters were connected to the monitor. However, both our groups experienced a small decrease in bladder temperature at the start of the operation. This corresponds with the study by Akhtar et al²⁴ who found only a small redistribution of hypothermia in patients who were not prewarmed, thus supporting our findings. Leslie and Sessler argue that the initial reduction in core temperature is difficult to treat since it is caused by redistribution of heat

Table 1. Demographic and Morphometric Characteristics and Treatment-Related Variables

	Control Group		Intervention Group	
	Mean (SD)	Range	Mean (SD)	Range
Age, years	38.6 (24.0)	14 to 78	39.4 (24.1)	14 to 79
Gender, n	15 women and 15 men		22 women and 7 men	
Weight, kg	73.5 (18.7)	(46 to 121)	68.1 (18.0)	(14 to 79)
ASA group, n	ASA 1 = 14 ASA 2 = 13 ASA 3 = 3		ASA 1 = 11 ASA 2 = 17 ASA 3 = 2	
Tympanic temperature at arrival, °C	36.7 (0.5)	35.1 to 37.5	36.9 (0.5)	36.0 to 37.8
Ambient room temperature, °C	19.6 (0.6)	18.8 to 21.2	19.4 (0.5)	18.4 to 20.3
Length of stay, min.	491.2 (72.8)	330 to 660	423.8 (94.6)	220 to 651
Length of operation, min.	336.2 (71.0)	180 to 555	279.7 (64.6)	130 to 385
Length of prewarming, min.*			11.6 (4.8)	2 to 23

ASA, American Society of Anesthesiologists; SD, standard deviation.

*The control group was not actively prewarmed.

from the core to the peripheral tissue due to anesthetic induced vasodilatation and impaired autonomic temperature regulation.²⁵ Prewarming is effective in preventing redistribution hypothermia, especially 1 hour after induction of anesthesia.²⁵ Sessler et al found that prewarming for as little as 30 minutes probably prevents considerable redistribution,²⁶ whereas Horn et al,²⁷ comparing three periods of prewarming at 10, 20, and 30 minutes,

respectively, suggest that prewarming for only 10 or 20 minutes in most cases prevents hypothermia. Connelly et al²⁸ suggest that 10 minutes of prewarming is sufficient in reducing intraoperative hypothermia. In our study, patients in the intervention group were actively prewarmed for 2-20 minutes and significantly maintained their bladder temperature $\geq 36^{\circ}\text{C}$ from start and throughout surgery in contrast to the control group. According to

Table 2. Incidence of Hypothermia (Temperature < 36°C) When Connecting the Bladder Catheter, at the Start of the Operation and at the End of the Operation

	Control Group	Intervention Group	P Value	Relative Risk (95% CI)
Hypothermia when connecting the bladder catheter	Cotton and reflective blanket	Full Access Underbody blanket		
Yes	5	1	.20	0.20 (0.03 to 1.61)
No	25	29		
Hypothermia at the start of the operation	Bair Hugger surgical access blanket	Full Access Underbody blanket		
Yes	21	6	< .001*	0.28 (0.13 to 0.59)
No	8	24		
Hypothermia at the end of the operation	Bair Hugger surgical access blanket	Full Access Underbody blanket		
Yes	3	1	.61	0.33 (0.04 to 3.03)
No	27	29		

CI, confidence interval.

*Significant ($P < .05$) between-group difference. P Value was determined using Fisher's exact test due to small numbers (< 5) in some cells for the test of hypothermia when connecting the bladder catheter and at the end of the operation, whereas Pearson's χ^2 test was used for the test of hypothermia at the start of the operation.

Leslie and Sessler,^{25,26} 1 hour of active FAW with 43°C before anesthesia is sufficient to counteract a redistribution core temperature drop, but may result in sweating and discomfort for the patient. We found that 40% of the patients felt hot and very hot after between 2 and 20 minutes of prewarming with 43°C. The National Institute for Health and Care Excellence recommends that active warming be maintained throughout the intraoperative phase.²⁹ In our study, active warming of the patients in the intervention group was resumed immediately after positioning and draping, thus minimizing the heat loss before the start of the operation in contrast to the patients in the control group where active warming was initiated just before the start of the operation. This might suggest that active warming be continued during further preparation of the patient before the start of the operation.

Length of operation and length of stay in the operating room were significantly lower in the intervention group than in the control group. Length of operation and length of stay in the operating room could have contributed to the significantly lower heat loss in the intervention group. Journaux³⁰ suggests in a review that patients undergoing longer procedures are at increased risk of hypothermia. Lynch et al¹¹ argue that to prevent hypothermia in procedures lasting more than 1 hour, it might be advisable to increase the operating room temperature. However, a recent study showed that the operating room ambient temperature has a negligible effect on core temperature when patients are warmed with forced air.³¹ The effect is larger when the patient is passively insulated, but with a small magnitude.³¹

Wagner et al³² problematized the lack of research on the benefits of prewarming as a comfort intervention or anxiolytic mean to decrease patient anxiety. Fossum et al³³ indicated that application of forced warm air preoperatively provides positive feelings of comfort. However, thermoregulation also presents a nursing care challenge.¹⁰ We found that 20% of the patients felt cold arriving to the operating theater. This correlates with the study by Wagner et al³³ where patients often mentioned that they felt cold in the preoperative phase of the surgery. Most of the patients in our study, however, felt comfortable. After prewarming, the patients no longer felt cold (37% felt hot; 3% felt very hot,

adding risk for discomfort). This underlines the need for nurses to intervene successfully and effectively preoperatively and intraoperatively to increase thermal comfort, and be aware of and control the thermal environment. It is possible to adjust the active warming device from 43°C to either 38°C or 32°C. Further research on patient experiences of thermal comfort is needed.

Limitations

The validity of this study would have been strengthened if the study was a randomized controlled trial because this would have eliminated selection bias and ensured that any known and unknown confounders would have been balanced between groups.³⁴ Alongside further standardization of the practical methods applied during surgery between treatment groups, this would have ensured that any potential inconsistencies in time of prewarming and preparation after induction of anesthesia, clothing worn when the patients arrived at the operation theater, and differences in time uncovered during, for example, catheterization and positioning would have been equally distributed between groups. However, as these were individual and not systematic differences between groups, we have no reason to believe that they would affect the results significantly. Finally, because we did not conduct a sample size calculation a priori, we cannot rule out that significant between-group differences in hypothermia would have also been found when connecting the bladder catheter or at the end of the operation, had we included more patients.

Conclusion

Patients using the FAU blanket were at a 72% lower risk of hypothermia at the start of the operation, suggesting that this might be an appropriate preoperative and intraoperative warming method in major spinal surgery. When using the FAU blanket, the time and amount of skin surface receiving FAW were extended because the blanket allowed all the preoperative procedures to go on due to its placement underneath the patient, thus minimizing the loss of heat to the environment, thereby leaving heat production to exceed heat loss. The comfort scores indicate that nurses should pay careful attention to the patient's thermal comfort and adjust accordingly.

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