Comparison of upper and lower body forced air blanket to prevent perioperative hypothermia in patients who underwent spinal surgery in prone position: A randomized controlled trial

Running title: Upper versus lower warming

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None

**Conflicts of interests**

All authors have no potential conflicts of interests. The data used in this study is available by request to the corresponding author. Due to protection of sensitive patient data, the data used are not publicly available.

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**Author contributions**

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Abstract

**Background**: We compared the upper and lower body forced-air blanket to prevent perioperative hypothermia, defined as a reduction in body temperature to <36.0°C during the perioperative period, in patients who underwent spinal surgery in prone position.

**Methods**: A total of 120 patients scheduled for elective spine surgery under general anesthesia were divided into an upper warming group (n = 60) and a lower warming group (n = 60). After inducing anesthesia and preparing for the patient for surgery, including prone positioning, the upper and lower bodies of patients in the upper and lower warming groups, respectively, were warmed using a forced-air warmer with specified upper and lower blankets. Body temperature was measured using a tympanic membrane thermometer during the pre- and postoperative periods, and using a nasopharyngeal temperature probe during the intraoperative period. Patients were evaluated in terms of shivering, thermal comfort, and satisfaction in the post-anesthesia care unit (PACU).

**Results**: The incidence rates of intraoperative and postoperative hypothermia were lower in the upper warming group than in the lower warming group (55.2% vs. 75.9%; \(P = 0.019\), and 21.4% vs. 49.1%; \(P = 0.002\)). Perioperative body temperature was higher in the upper warming group (\(P < 0.001\)). However, intraoperative blood loss, postoperative thermal comfort scale and shivering scores, patient satisfaction, and PACU duration were similar between the groups.

**Conclusions**: Upper body blanket was more effective in preventing perioperative hypothermia in patients who underwent spinal surgery in prone position than lower body blanket.
Keywords: Body temperature, hypothermia, lower body, spine surgery, prone position, upper body, forced-air warming.
**Introduction**

Perioperative hypothermia, defined as a reduction in body temperature to < 36.0°C during the perioperative period, is typically 50–90%, even in short and simple surgeries [1,2]. Perioperative body temperature management is very important because even mild hypothermia can cause complications including cardiac morbidity, poor drug metabolism, delayed recovery from anesthesia, greater blood loss related to platelet dysfunction and coagulopathy, delayed wound recovery, and greater frequency of surgical site infections [3]. A forced-air warmer is the most commonly used device to prevent perioperative hypothermia, and provides warmth not only by transferring convective heat to the body, but also by preventing heat loss from the covered area [4-6].

Patients undergoing spine surgery in the prone position are tends to be susceptible to hypothermia, because of long surgical duration, degree of exposed skin surface caused by surgical procedure and the positioning [6]. Perioperative hypothermia is also associated with ophthalmic complications during spine surgery in prone position, so the prevention of hypothermia is more important [7]. Recently, the effectiveness of underbody blanket of forced-air warming has been reported, but it was more expensive than conventional warming devices and it still not popular [8]. Therefore, we often have to choose overbody blanket of forced-air warming to the upper or lower body depending on the location of the surgical site in clinical situation.

A previous study reported that, in the supine position, lower body warming was more effective because of the larger body surface area covered [9,10]. However, another study reported that, in the lateral decubitus position, upper body warming was more effective than lower body warming due to the padding between the legs in the latter case [11]. According to a rough retrospective study conducted...
by our institution, upper body warming have shown a significantly lower incidence of hypothermia compared with lower body warming (unpublished data). However, few studies have compared the effectiveness of upper and lower body warming during spine surgery in the prone position. Our hypothesis was that the upper body blanket is superior to lower body blanket in patients who underwent spinal surgery in prone position. Thus, we compared the upper and lower body forced-air blanket warming effects to prevent perioperative hypothermia in patients who underwent spinal surgery in prone position.
Materials and Methods

This prospective randomized controlled trial was approved by the institutional ethics committee (SCHUH 2018-12-009-001) of our hospital and registered at the CRIS clinical trials registry (Clinical Research Information Service in Korea, cris.nih.go.kr. no. KCT0003728). The trial was performed from March 2019 to August 2019. All patients were given information about the trial, and all provided written informed consent. This manuscript adheres to the applicable CONSORT guidelines. The clinical research was done following the ethical principles for medical research involving human subjects according to the Declaration of Helsinki of 1964 and all its subsequent revisions.

Study participants and inclusion/exclusion criteria

The trial included 120 patients (aged ≥ 19 years) with an American Society of Anesthesiologists physical status (ASA-PS) of I–III who were scheduled to undergo elective spine surgery in the prone position. Exclusion criteria were body mass index (BMI) > 35 kg/m², preoperative body temperature > 38°C or < 36°C, and pregnancy.

Randomization and masking

Using Excel software (2016; Microsoft Corp., Redmond, WA, USA), patients were randomly allocated to the upper and lower warming groups (both n = 60) by a computer-generated blocked randomization scheme (block size 4, 6; 1:1 allocation ratio). The anesthesiologists (who anesthetized the patients and supervised the warming) were not blinded to the group allocation, whereas the patients and study nurse (who collected the pre- and postoperative data) were blinded.
**General Procedures**

After arrival in the operating room, all patients were fully covered with a cotton blanket. Standardized monitoring and anesthesia induction (using 1–2 mg/kg 1% propofol and 0.6 mg/kg rocuronium) was performed. Catheters were inserted into the urethra, radial artery, or internal jugular vein as needed, with minimal exposure of the skin to ambient air. Then, the patient was placed in the prone position. Standardized anesthesia was maintained using desflurane and remifentanil.

After prone positioning, the specified upper and lower blankets were placed over the back and both arms in the upper warming group, and over the lower buttocks and both legs in the lower warming group by anesthesiologist. Since most surgical field for spine surgery were from T4 dermatome to Coccyx, the upper body blanket (warm touch™ upper body blanket; Medtronic, Dublin, Ireland) was taped above the T4 spinous process level and covered the upper extremities and upper trunk above the T4 dermatome, the lower body blanket (warm touch™ lower body blanket; Medtronic, Dublin, Ireland) was taped below the coccyx and covered both legs and the lower buttocks below the coccyx. In both groups, each patient’s entire body was covered with the surgical drape except surgical field and head. After surgical draping, intraoperative warming using a forced-air warmer (WarmTouch™ WT 6000 Warming Unit; Medtronic, Dublin, Ireland) was applied until the end of the surgery. The temperature was adjusted to 45°C when the core body temperature was < 36.5°C, and to 40°C when the core body temperature was 36.5–37.5°C. The warmer was turned off when the core body temperature was > 37.5°C. For all patients, a breathing circuit that allows for intraoperative heating/humidification was used, and no other warming devices were used.

At the end of surgery, we removed the forced-air blanket after then we turned the patient to
supine and warmed the whole body passively with patients’ cotton blanket during anesthetic emergence. Patient’s consciousness and spontaneous respiration were restored, and the nasopharyngeal thermometer and tracheal tube were removed. The patients were transferred to the post-anesthesia care unit (PACU). After tympanic temperature measurement and the postoperative evaluations, if postoperative hypothermia occurred warming was actively performed using the forced-air warmer as described above.

Measurements

Baseline patients’ characteristics were recorded preoperatively, including age, sex, weight, height, BMI, ASA-PS and level of spine surgery. Body surface area (BSA) was calculated by the Dubois formula.

To evaluate the primary endpoint of perioperative hypothermia incidence, defined as a reduction in body temperature to < 36.0°C, the tympanic temperature was measured using the Thermoscan®, infrared tympanic thermometer (IRT 4020; Braun, Minneapolis, MN, USA) by a masked nurse in the pre-anesthetic holding area, and in the PACU every 10 min (up to 30 min) after arrival in the PACU [12]. The right and left tympanic temperatures were measured, and the average value was calculated. The nasopharyngeal temperature was measured using a thermometer (ETP1040; Ewha Biomedics, Goyang, Korea) at a depth of 9–10 cm in the nasopharynx immediately after the induction of anesthesia [13]. Readings were obtained every 15 min.

The secondary endpoints were perioperative temperature changes, postoperative thermal comfort (100-mm visual analogue scale: 0 mm = coldest imaginable, 50 mm = pleasant, 100 mm = warmest imaginable) and shivering (0 = no shivering, 1 = intermittent, low intensity, 2 = moderate
shivering, 3 = continuous intense shivering) scores, patient satisfaction regarding temperature management (0 = very dissatisfied, 1 = dissatisfied, 2 = neutral, 3 = satisfied, 4 = very satisfied), and PACU duration. All patients were trained in the use of the thermal comfort scale in the ward on the day before surgery. The masked nurse asked the patient to indicate the thermal comfort, and shivering scales every 10 min following arrival in the PACU (up to 30 min). Before leaving the PACU, patients were asked to rate perioperative temperature management using a five-point Likert satisfaction scale, and the length of stay in the PACU and any adverse effects from forced-air warming was also recorded.

The ambient temperatures in the operating room (OR) and PACU were recorded on arrival and discharge, and the average temperature was calculated. The duration of the “unwarmed” (from arrival in the operating room to the start of intraoperative warming) and anesthetic periods were recorded. The intraoperative fluid volume, blood loss, and transfusion requirement were also recorded by the anesthesiologist.

**Sample size and Statistical analyses**

Min et al. [11] reported that the incidence of intraoperative hypothermia in the lateral decubitus position during thoracoscopic surgery was 33.87% in their upper warming group and 57.38% in their lower warming group. Assuming that the incidence of intraoperative hypothermia would be reduced by a similar degree in our study, we calculated that 60 patients per group were required with an $\alpha$ of 0.05 for one-tailed test, power of 80% and drop-out rate of 10%.

Statistical analyses were performed using SPSS for Windows software (version 26.0; IBM Corp., Armonk, NY, USA). The two groups were compared using Student’s $t$-test or the Mann–Whitney rank-sum test for continuous data, after checking for normality with the Shapiro–Wilk test,
and by the chi-square or Fisher’s exact test for categorical data. All analyses in this trial were conducted in an intention-to-treat manner, because our dropped out outcome was missing.

Perioperative body temperature data were plotted and analyzed using a mixed-effects model with a first-order autoregressive covariance structure. The fixed effects in the mixed-effects model included group, time, and the interaction between group and time. Subjects were included as a random effect. Post-hoc testing using Bonferroni’s method for pairwise group comparisons was performed when the results of the mixed-effects model were significant.

Multivariable logistic regression analysis was performed as post-hoc analysis to identify variables affect intraoperative hypothermia (<36.0°C) and intraoperative severe hypothermia (<35.0°C). Variation inflation factors of BMI, BSA, weight, height and BSA/weight ratio were more than 10.0, which caused multicollinearity in multiple regression. Therefore, the authors selected BSA/weight ratio as the morphometric variables, and determined a total of eleven variables (BSA/weight*1000, Group, Sex, Age, ASA-PS, Anesthetic duration, Surgical type [>2levels], interval duration, OR ambient temperature, preoperative body temperature, fluid administration [>1000ml]) for independent variable in the multivariable logistic regression. Selection method of variables used the backward stepwise elimination method using log-likelihood ratio statistic.

Continuous data are presented as mean and standard deviation (SD) or median and 25th, 75th percentiles, and categorical data as frequency with percentage. A $P$-value < 0.05 was considered significant, and a temperature difference between the intervention and control groups of 0.2°C was defined as significant based on the National Institute for Health and Clinical Excellence guidelines [14].
Results

A total of 126 patients were screened. Three patients were excluded because they met the exclusion criteria and another three refused to participate. Thus, 120 patients were ultimately enrolled in the study, and were divided randomly into the upper and lower warming groups (both n = 60). Two patients in the upper warming group dropped out just before surgery (one due to hyperthermia [38.4°C] and one due to cancelled surgery). Continuous intraoperative warming was stopped in two patients in the lower warming group (due to a machine error in one patient and failure to record intraoperative core temperature data due to a thermometer module error in another patient). Therefore, data from 116 patients were analyzed (58 patients in each group). Two patients in the upper warming group and one in the lower warming group were transferred to the intensive care unit for post-operative close observation by surgeon; thus, postoperative data from these three patients could not be obtained. Moreover, in two patients (one each in the upper and lower warming groups) who showed postoperative delirium in the PACU, thermal comfort and satisfaction scale data could not be obtained (Fig. 1).

The baseline characteristics of the patients, and the level of spine surgery, duration of anesthesia, duration of unwarmed period (from arrival in the operating room to the start of intraoperative warming), body temperature upon arrival in the pre-anesthetic holding area, ambient temperature of the operating room and PACU, and fluid volume are shown in Table 1. There was no clinically significant difference between the two groups in these characteristics (Table 1).

The incidence of intraoperative hypothermia, defined as a reduction in body temperature to <36.0°C, was significantly lower in the upper warming group than in the lower warming group (55.2%
vs. 75.9%, OR 0.392 (0.177-0.866); \( P = 0.019 \). The severity of intraoperative hypothermia was significantly different between the groups \( (P = 0.018) \) (Table 2). The duration of intraoperative hypothermia was also significantly shorter in the upper warming group than in the lower warming group (20.0 min vs 102.5 min, \( P = 0.005 \)). The incidence of immediate postoperative hypothermia in the PACU was lower in the upper warming group than in the lower warming group (21.4% vs. 49.1%, OR 0.282 (0.124-0.643); \( P = 0.002 \)) (Table 2).

The change in body temperature over time differed significantly between the groups \( (P < 0.001) \). The group difference from 75 min after induction of anesthesia to the end of recovery was significant based on the Bonferroni post-hoc test, and was > 0.2°C (which has been defined as a significant clinical difference in hypothermic patients) [14]. The significant decrease in body temperature compared with the preoperative temperature persisted throughout the recovery period. The greatest decrease in body temperature in the upper warming group occurred at 60 min after induction anesthesia (0.98°C); in the lower warming group it occurred at 135 min (1.23°C) (Fig. 2).

Hosmer and lemeshow’s goodness-of-fit test showed that the regression models for intraoperative hypothermia (<36.0°C) and intraoperative severe hypothermia (<35.0°C) were suitable \( (P = 0.704, P = 0.956, \text{respectively}) \), and the regression models were statistically significant (both of \( P < 0.001 \)). There were six variables independently related to intraoperative hypothermia. Upper warming group (OR 0.221 (0.072-0.683); \( P = 0.009 \)), high ambient temperature (OR 0.280 (0.143-0.548); \( P < 0.001 \)) and high preoperative body temperature (OR 0.027 (0.004-0.164); \( P < 0.001 \)) were protective against hypothermia; and, ASA-PS 2, 3 (compared with ASA-PS 1, OR 6.608 (1.138-38.366); \( P = 0.035 \) and OR 6.118 (1.509-24.806); \( P = 0.011 \) respectively), long anesthetic duration (OR 1.009 (1.004-0.164); \( P = 0.005 \)) and high BSA/weight x 1000 (OR 1.659 (1.225-2.247); \( P=0.001 \)) were
independent risk factors for intraoperative hypothermia (Figure 3).

There were four variables in the severe intraoperative hypothermia model. Among them three variables were independently related to severe intraoperative hypothermia. Upper extremity warming Group (OR 0.163 (0.040-0.673); \( P = 0.012 \)), high ambient temperature (OR 0.432 (0.211-0.885); \( P = 0.022 \)) were protective against severe hypothermia; and long anesthetic duration (OR 1.007 (1.001-1.013); \( P = 0.028 \)) was independent risk factor for severe intraoperative hypothermia (Figure 3).

Intraoperative blood loss and the transfusion requirement were not different between the groups (\( P = 0.241 \) and \( P = 0.496 \), respectively). Postoperative shivering score (\( P = 1.000 \)) and the highest and lowest thermal comfort scale scores (\( P = 0.808 \) and \( P = 0.073 \), respectively) in the PACU did not differ significantly between the groups. Satisfaction with the warming protocol did not differ between the groups (\( P = 0.485 \)), and nor did the length of stay in the PACU (\( P = 0.296 \)) (Table 2). In all patients, there were no adverse effects from forced-air warming, such as skin irritation or burns.
Discussion

This study demonstrated that forced-air warming of the upper body blanket prevented perioperative hypothermia more effectively compared with warming of the lower body blanket during spine surgery in prone position.

Previous studies have reported that warming the lower body is more effective than warming the upper body for patients in the supine position [9,10]. Motamed et al. [9] reported that lower body warming showed greater initial redistribution of the core temperature but faster regained normothermia during major abdominal surgery (120min vs 180 min). Yamakage et al. [10] reported that lower body warming below the T10 dermatome was more effective than upper body warming above the T7 dermatome in patients receiving spinal anesthesia.

Brauer et al. [4,5] explained their results with a Cooper manikin model. They reported that the maximum heat transfer was 18.3 and 26.6 W with a lower and upper body blanket, respectively, but the latter blanket covered a wider area (49 W) than the upper body blanket (37.8 W). The total heat balance result was approximately 10 W higher in the case of the lower body blanket [4,5].

Min et al. [11] reported that upper body warming was more effective than lower body warming when the patient was in the lateral decubitus position during thoracoscopic surgery. They attributed this to the padding between the legs reducing the surface area covered by the lower body blanket. They also suggested that heat distribution inside the blanket may vary more with the larger lower body blanket.
In this study, forced-air warming of the upper body blanket prevented perioperative hypothermia more effectively than warming of the lower body blanket, with the patient in the prone position during spine surgery. This result may be explained as follows.

First, the body surface area covered by the upper body blanket was larger, (covering both arms and hands, and the entire trunk above the T4 spinous process level) than that covered by the lower body blanket. The area covered by the upper body blanket was similar to that reported by Brauer et al. (~0.35 m²). The lower body blanket covered both legs and the lower buttocks below the coccyx, but the lower abdomen was not covered (~0.24 m² in the study of Brauer et al.) [4,5]. This is suggested to be the major reason for the difference between previous result conducted in the supine position and our result; because the lower body warming warmed up to the T10 dermatome in previous studies [10].

Second, heat transfer may be higher with the upper versus lower body blanket, as also reported by Brauer et al [4,5]. They reported that the maximum heat transfer was 18.3 and 26.6 W with a lower and upper body blanket, respectively. Min et al. [11] suggested that the larger size of the lower body blanket may explain the variability in heat distribution and lower efficacy. However, we suggest that the blanket design (upper body blanket: narrow and long, lower body blanket: wide and short) and location of the nozzle access could have been more important in our study, because the upper and lower body blankets were in fact the same size (208 × 71 cm [14,768 cm²] and 104 × 142 cm [14,768 cm²], respectively).

Third, in the upper warming group, continuous monitoring and management of blanket inflation state (whether the forced-air warming blanket inflated evenly) was better performed, because the forced-air warmer was located close to the anesthesiologist. However, in the lower warming
group, the warming blanket was remote from the anesthesiologist and the entire blanket was covered by a surgical drape, making monitoring and management of lower body blanket inflation state relatively uncomfortable. In addition, although the surgeon was aware of the lower warming, surgical instruments were often placed on the lower body blanket during the spine surgery; this could explain the variable heat distribution. This might have affected the conclusions of the study.

Fourth, the difference in distance between the warming site and measurement site might have affected the conclusion of the study. In this study, we used the nasopharyngeal temperatures as intraoperative core temperature; the nasopharyngeal temperature is more reliable compared with bladder temperature, because bladder temperature is strongly influenced by urine flow [15,16]. And, the esophageal probe are at risk of misplacement due to relatively long distance from incisor (approximately 40 cm) compared to nasopharyngeal probe [13,17-19]. However, the distance between the upper body blankets to nasopharynx is closer compared with lower body blanket, and it might raise nasopharyngeal temperature more quickly, even though head was not covered with the upper body blanket in our study. Further studies evaluating the influence on the temperature measurement site according to warming site are needed.

There is a study on the difference between upper and lower body blanket warming during spine surgery in prone position. Buraimoh et al. [20] reported that no warming effect difference between the upper and lower body blanket in patients undergoing spine surgery. As a result of this study, the incidence of severe hypothermia (< 35°C) and mild to moderate hypothermia (35-36°C) in upper body blanket warming group was similar to our study (18.4%, 34.2% respectively), but the severe and mild to moderate hypothermia incidence in lower body blanket warming group was lower than ours (11.1%, 30.6% respectively). The reason was probably that the body surface area covered with lower body
The warming blanket they used was larger than ours; the lower body warming blanket used by the authors were underbody warming blanket covered under the torso and legs. In addition, the bladder temperature they used might have affected the results. Recently, the effectiveness of underbody blanket of forced-air warming has been reported, but it was more expensive than conventional warming devices and it still not popular [8]. Therefore, if given the option between using an over-covered upper and lower body blanket, our findings may help with your blanket selection.

In this study, reduced perioperative complications and enhanced patient satisfaction due to the low incidence of hypothermia in the upper warming group were not confirmed because of small power of this study to prove it. The lack of any differences in intraoperative blood loss and the transfusion requirement may have been partially influenced by the minimally invasive surgery that was performed. The lack of any differences in postoperative shivering, thermal discomfort, and patient satisfaction may have been due to the continuous full-body warming in the PACU in both groups.

In our study, heat redistribution within the first hour was greater than that in a previous study of spine surgery patients [21]. Differences in participant characteristics and warming blankets may explain this result. We only included patients undergoing thoracolumbar spine surgery, in whom the center of the body is more widely exposed, while the previous study included cervical spine surgical patients who were warmed using a full-body blanket or spine-specific blanket [21]. The long unwarmed period (38 min) in our study could explain the greater decrease in core temperature.

Our results showed that higher ASA-PS, lower preoperative body temperature and large surface area-to-body mass ratio were the independent risk factors for intraoperative hypothermia. The effect of the lower preoperative body temperature has also been reported in the previous studies [22,23].
The effect of the large surface area-to-body mass ratio on the thermoregulation and the relationship between the surface area-to-body mass and ambient temperature has been known [24]. Therefore, it is considered valid that the large surface area-to-body mass ratio was the independent risk factor for intraoperative hypothermia of this study. However, they were not the independent risk factors for severe intraoperative hypothermia. Long anesthetic duration and low ambient temperature were the independent risk factor for intraoperative hypothermia and severe intraoperative hypothermia, consistent with previous studies [22,23]. Therefore, to prevent severe hypothermia, we suggest that it will be helpful to set the ambient temperature high, and if long anesthetic duration are expected, further warming efforts will be required.

This study had some limitations. Firstly, tympanic temperature was measured to help reduce discomfort in conscious patients, but the pre- and postoperative tympanic temperatures can differ from the intraoperative nasopharyngeal temperature. Nevertheless, tympanic temperature is the most accurate and precise peripheral temperature measurement [12]. Secondly, for the reasons mentioned above and their reliability, nasopharyngeal temperature was measured as core temperature in our study [15]. For accurate measurement, we placed the nasopharyngeal temperature probe at a depth of 9-10 cm in the nasopharynx according to previous imaging study, and it was fixed with a tape so that the position did not change [13]. However, the prone position could cause biases due to change in probe position and nasal secretions. Thirdly, the results may not inform the effect of the level or location and type of spine surgery; the present study was conducted on the patients that surgical characteristics showed no group difference. Also, the results may not generalized for the patients undergoing major thoracolumbar spine surgery, since most of the patients participated in this study were underwent spine surgery below two levels. Further studies examining additional surgical factors is required.
Fourthly, no follow up was performed so long-term complications could not be checked for. Randomized controlled trials including larger samples and evaluating long-term complications of mild perioperative hypothermia are required.

In conclusion, upper body blanket warming was more effective than lower body blanket warming to prevent perioperative hypothermia during thoracolumbar spine surgery in the prone position.
References


<table>
<thead>
<tr>
<th></th>
<th>Upper warming group (n=58)</th>
<th>Lower warming group (n=58)</th>
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</tr>
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<tbody>
<tr>
<td>Age (y)</td>
<td>69 (59.8, 77.0)</td>
<td>69 (59.8, 76.3)</td>
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<td>Sex (M/F)</td>
<td>24/34</td>
<td>26/32</td>
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<tr>
<td>Weight (kg)</td>
<td>62.6 ± 11.17</td>
<td>65.1 ± 12.99</td>
<td>0.266</td>
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<tr>
<td>Height (cm)</td>
<td>158.3 ± 8.0</td>
<td>160.1 ± 9.3</td>
<td>0.276</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>24.9 ± 3.49</td>
<td>25.2 ± 3.12</td>
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<td>BSA (m²)</td>
<td>1.631 ± 0.171</td>
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<td>16/33/9</td>
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<td></td>
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<tr>
<td>Discectomy</td>
<td>7 (12.1)</td>
<td>7 (12.1)</td>
<td></td>
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<tr>
<td>PD only</td>
<td>19 (32.8)</td>
<td>19 (32.8)</td>
<td></td>
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<tr>
<td>Single-level PLIF and PD</td>
<td>22 (37.9)</td>
<td>20 (34.5)</td>
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<td>Two-level PLIF and PD</td>
<td>4 (6.9)</td>
<td>8 (13.8)</td>
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<td>Multilevel lumbar surgery (&gt; 2 levels) *</td>
<td>3 (5.2)</td>
<td>1 (1.7)</td>
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<td>Expanded to thoracic level (&gt; 2 levels) †</td>
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<td>Duration of anaesthesia (min)</td>
<td>183 (130.0, 250.0)</td>
<td>200 (123.8, 289.8)</td>
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<td>Duration of unwarmed period (min) ‡</td>
<td>38 ± 10.5</td>
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<td>Initial body temperature (°C)</td>
<td>37.0 ± 0.37</td>
<td>36.9 ± 0.34</td>
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<td>OR temperature (°C)</td>
<td>21.3 ± 0.94</td>
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<td>PACU temperature (°C) §</td>
<td>26.0 (24.85, 26.48)</td>
<td>25.8 (24.75, 26.50)</td>
<td>0.598</td>
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<td>Fluid volume (ml)</td>
<td>600 (300, 1225)</td>
<td>750 (300, 1163)</td>
<td>0.474</td>
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</table>

* With or without instrumentation. † Some multilevel surgery included the lower thoracic spine. ‡ unwarmed period is defined as the period from arrival in the operating room to the start of intraoperative warming, and refers to the period of exposure to the operating room ambient temperature without warming after arrival in the operating room. § The ambient temperature of the post-anesthesia care unit was maintained at 26 ± 1°C according to institutional regulations.
Values are presented as numbers (%) for categorical data. Values are presented as mean ± standard deviation or median (25th, 75th percentiles) as appropriate for continuous data.

BMI = body mass index, BSA = Body surface area, ASA = American Society of Anesthesiologists, OR = operating room, PACU = post-anesthesia care unit, PD = posterior decompression, PLIF = posterior lumbar inter-body fusion.
Table 2. Intraoperative and postoperative outcomes.

<table>
<thead>
<tr>
<th></th>
<th>Upper warming group</th>
<th>Lower warming group</th>
<th>Odds ratio (95% CI)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Intraoperative variables</strong></td>
<td>(n=58)</td>
<td>(n=58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraoperative hypothermia</td>
<td>32 (55.2)</td>
<td>44 (75.9)</td>
<td>0.392 (0.177-0.866)</td>
<td>0.019</td>
</tr>
<tr>
<td>Severity of intraoperative hypothermia</td>
<td></td>
<td></td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>mild (35.5–36.0°C)</td>
<td>20 (34.5)</td>
<td>21 (36.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>moderate (35.0–35.4°C)</td>
<td>8 (13.8)</td>
<td>9 (15.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>severe (34.5–34.9°C)</td>
<td>3 (5.2)</td>
<td>10 (17.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>very severe (&lt;34.5°C)</td>
<td>0 (0.0)</td>
<td>4 (6.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of intraoperative hypothermia (min)</td>
<td>20.0 (0, 112.5)</td>
<td>102.5 (11.3, 186.3)</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Blood loss (ml)</td>
<td>150 (93, 320)</td>
<td>200 (100, 400)</td>
<td>0.241</td>
<td></td>
</tr>
<tr>
<td>Transfusion (n)</td>
<td>0</td>
<td>2 (3.4)</td>
<td>0.496</td>
<td></td>
</tr>
<tr>
<td><strong>2. PACU objective variables</strong></td>
<td>(n=56)</td>
<td>(n=57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PACU hypothermia</td>
<td>12 (21.4)</td>
<td>28 (49.1)</td>
<td>0.282 (0.124-0.643)</td>
<td>0.002</td>
</tr>
<tr>
<td>Shivering score (0/1/2)</td>
<td>53/3/0</td>
<td>53/4/0</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>LOS at PACU (min)</td>
<td>37 (34.3, 45.0)</td>
<td>40 (34.0, 47.5)</td>
<td>0.296</td>
<td></td>
</tr>
<tr>
<td><strong>3. PACU subjective variables</strong></td>
<td>(n=55)</td>
<td>(n=56)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest TCS</td>
<td>50 (50, 50)</td>
<td>50 (50, 50)</td>
<td>0.808</td>
<td></td>
</tr>
<tr>
<td>Lowest TCS</td>
<td>50 (50, 50)</td>
<td>50 (50, 50)</td>
<td>0.073</td>
<td></td>
</tr>
<tr>
<td>Patient's satisfaction (4/3/2)</td>
<td>32/21/2</td>
<td>29/22/5</td>
<td>0.485</td>
<td></td>
</tr>
</tbody>
</table>
Hypothermia defined as a reduction in body temperature to < 36.0°C.

Values are presented as numbers (%) for categorical data. Values are presented as mean (standard deviation) or median (25th, 75th percentiles) as appropriate for continuous data.

CI: confidence interval, TCS = thermal comfort scale, LOS = length of stay, PACU = post-anesthesia care unit.
Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) diagram.
Fig. 2. Perioperative body temperature

Error bars indicate ± 1 standard deviation of temperature at each time.
Preoperative and postoperative core temperatures of the patients were measured using a tympanic membrane thermometer. The intraoperative core temperature measured using a nasopharyngeal probe was recorded every 15 min after anesthesia was induced. In both groups, there were statistically significant drop of body temperature from their baseline value (all \( P < 0.001 \)). The temperature was higher in the upper warming group from 75 min after anesthesia was induced to the end of the post-anesthesia care unit (PACU) stay compared with the lower warming group. * \( P \)-values < 0.05 in intergroup statistical difference.

Baseline: immediately after arrival in the pre-anesthetic holding area; intraoperative 0 min: immediately after insertion of the nasopharyngeal probe; PACU arrival: immediately after arrival in the PACU; PACU 10, 20, and 30 min: 10, 20, and 30 min after arrival in the PACU.
Fig 3. Risk factors for intraoperative hypothermia (<36.0°C) and severe intraoperative hypothermia (<35.0°C).

(a) The risk factors of intraoperative hypothermia (<36.0°C), (b) the risk factors of severe
intraoperative hypothermia (<35.0°C). Multivariable logistic regression analysis was performed as post-hoc analysis to identify variables affect intraoperative hypothermia and intraoperative severe hypothermia. Total of eleven variables (BSA/weight x 1000, Group, Sex, Age, ASA classification, Anesthetic duration, Surgical type [>2 levels], interval duration, OR ambient temperature, preoperative temperature, Fluid administration [>1000ml]) for independent variable in the multivariable logistic regression. Selection method of variables used the backward stepwise elimination method using log-likelihood ratio statistic. *ASA classification risk compared with ASA 1. †P-values < 0.05 ‡P-values < 0.001

ASA = American Society of Anesthesiologists, BSA = Body surface area, OR = operating room.