Underbody blankets have a higher heating effect than overbody blankets in lithotomy position endoscopic surgery under general anesthesia: a randomized trial

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Abstract

Background Surgery under general anesthesia results in temperature decrease due to the effect of anesthetics and peripheral vasodilation on thermoregulatory centers. Perioperative temperature control is therefore an issue of high importance. In this study, we aimed to compare the warming effect of underbody and overbody blankets in patients undergoing surgery in the lithotomy position under general anesthesia.

Methods From September 2018 to October 2019, 99 patients undergoing surgery for colorectal cancer in the lithotomy position were included in this randomized controlled trial and assigned to the intervention group (underbody blanket) or control group (overbody blanket).

Results The central temperature was significantly higher in the underbody blanket group than in the overbody blanket group at 90 min after the beginning of the surgery ($p = 0.02$); also in this group, the peripheral temperature was significantly higher 60 min after the beginning of the surgery ($p = 0.02$). Regarding postoperative factors, the underbody blanket group had a significantly lower frequency of postoperative shivering ($p < 0.01$) and a significantly shorter postoperative hospital stay ($p = 0.04$) than the overbody blanket group.

Conclusions We recommend the use of underbody blankets for intraoperative temperature control in patients undergoing surgery in the lithotomy position under general anesthesia. Underbody blankets showed improved rise and maintenance of central and peripheral temperature, decreased the incidence of postoperative shivering, and shortened the postoperative length of hospital stay.

Surgery under general anesthesia causes suppression of the thermoregulatory center and peripheral vasodilation, leading to a decrease in central temperature of 1–3 °C [1–3]. It has been reported that intraoperative hypothermia increases surgical site infection (SSI), prolongs the hospital stay,

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increases the cost of medical care, and increases bleeding risk. The need for maintaining normothermia in the perioperative period has been shown to play a role in postoperative recovery [4–6]. In addition, studies on intraoperative warming and prevention of perioperative complications have reported that hypothermia leads to delayed arousal due to decreased hepatic drug-metabolizing enzyme activity [7–9].

There are four types of heat transfer in the human body: radiation, convection, evaporation, and conduction [10]. Because 90% of the heat is delivered through the skin, this surface is required to safely transfer large amounts of heat to the patient [11]. Specific intraoperative patient warming methods have been used in the past to provide heat through radiation and conduction, and through hot water circulation systems. In recent years, the effectiveness of hot air heaters, which envelop the patient with hot air and transfer

heat by convection, contrary to hot water circulation heaters, which only heat the area in contact with the patient, has been reported [12, 13].

There are two types of hot air heaters: the overbody blanket, which warms the patient from above, and the underbody blanket, which warms the patient from below. However, with the recent development of laparoscopic surgery, the number of surgeries performed in the lithotomy position has rapidly increased, while the number of cases of intraoperative hypothermia has dramatically increased. Therefore, it is necessary to improve the temperature control methods and the body heating area because lithotomy often involves upper extremity restraining. However, the area of warmth is frequently limited to the neck and part of the anterior thorax. If an underbody blanket is used, the patient is heated from the head to the buttocks, which is likely to be more effective in preventing intraoperative hypothermia. Nevertheless, due to the higher cost of the underbody heating system, it is difficult to implement its widespread use without supporting evidence. Although there have already been previous studies showing the effectiveness of underbody heating systems for supine surgery [14–16], there are no reports on their effectiveness for procedures performed in the lithotomy position.

We considered that it is necessary to carry out basic research to clarify the effect of the underbody blanket in surgeries performed with the patient in the lithotomy position.

Materials and methods

Study setting and population

The study was a single-blind randomized controlled trial conducted between September 2018 and November 2019 in the operating rooms of the National Hospital Organization in Nagasaki, Japan. All participants were at least 20 years old at the time of obtaining consent to perform colon cancer laparoscopic surgery under general anesthesia. Patients were fully informed regarding their participation in the study and confirmed their full understanding before providing written consent, which was obtained after confirming that participation in the study was secure. Exclusion criteria were emergency surgery for colorectal cancer, a family history of malignant high fever, and drug sensitivity (i.e., patients with allergies). The research process was fully explained to the participants and their families. The required number of patients was calculated using G * power 3.1.9.4 (Heinrich-Heine Universität, Dusseldorf, Germany) considering an effect size, power, and α of 0.6, 0.9, and 0.05, respectively. Ninety patients (45 patients in each group) were deemed necessary. A total of 100 patients (50 patients in each group) were enrolled considering a dropout rate of 10%.

Ethical considerations

This study was approved by the Ethics Committee of the Nagasaki University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences (No. 18071204) and by the Ethics Committee of the Nagasaki Medical Center (No. 30071), where the research was conducted. This study was registered with the University Hospital Medical Information Network Center (ID: 000,034,019). The CONSORT checklist was used to report the study [17].

Design and randomization

We stratified patients into those under and over 70 years old, respectively, taking into account the median age of patients who underwent elective colorectal cancer surgery under general anesthesia between 2016 and 2018. Equal randomization to the intervention (the underbody blanket) and control (the overbody blanket) groups was achieved via a computer-generated random sequence list. Concealed allocation was ensured as the research assistant conducting randomization received the group assignment without access to participant information.

Outcomes

The primary endpoint was intraoperative central temperature. Secondary endpoints were intraoperative peripheral temperature, intraoperative blood loss, postoperative shivering, postoperative complications, and postoperative hospital length of stay.

As central temperature, we measured the tympanic temperature when patients entered and exited the operating room, and measured the esophageal temperature from the time of induction of anesthesia until the end of surgery: during anesthesia initiation; at the initiation of surgery; 30, 60, 90, 120, and 180 min later; and after surgery completion. The measurement of tympanic temperature shows errors depending on the angle; thus, the average of three tympanic membrane temperature measurements was used to correct for errors due to the angle at the time of measurement.

We measured the skin temperature on the dorsum of the hands at the same timepoints used for the central temperature.

Warming methods

A 3 M™ Bear Hugger™ Patient Warming Model 675 (Arizant Healthcare Inc., Prairie, MN) was used as an air heater. The operating table was warmed using the 3 M™ Bear Hugger™ Postoperative Blanket Model 300 (Arizant Healthcare

Inc., Prairie, MN). The temperature was increased to 43 °C 30 min before the patient was scheduled to enter the operating room.

Preoperative warming from entry into the operating room to the initiation of surgery was performed using the 3 M™ Bear Hugger™ postoperative Blanket Model 300 (Arizant Healthcare Inc., Prairie, MN). The subjects were warmed at 43 °C in the supine position from the time they were lying on the operating table until just before the initiation of surgical positioning.

The heating fluid used was Physio® 140 (Otsuka Pharmaceutical Co., Ltd, Japan), which was warmed in an operating room warming cabinet (set at 37 °C).

Intervention group (underbody blanket group)

A 3 M™ Bear Hugger™ Underbody Blanket 585 (Arizant Healthcare Inc., Prairie, MN) was used in the intervention group. To enhance the heating effect, the attached head drape was used on the head and neck of the study participants. To heat the thighs, the strips on either side of the lower body blanket were tied to the thighs of the participants. The hot air heater was activated after the surgical position was fixed and before the start of the surgery so that the hot air was not cut off during surgery.

Control group (overbody blanket group)

A 3 M™ Bear Hugger™ Patient Warming Blanket 622 (Arizant Healthcare Inc., Prairie, MN) was used. The head drapes attached to the head and neck of the participants were used to increase heat retention. Both upper and lower extremities were covered with towelettes for insulation.

Warming area

The warming area of the under- and overbody blankets were calculated using the formula of Lund and Browder [18]. This formula, which is used to calculate the area of burns, was adopted because it is possible to calculate the area of each body part in detail, and it was deemed applicable to the measurement of the heated area in this study.

Anesthesia procedure

After entering the operating room, the electrocardiogram leads, blood pressure cuff, and pulse oximeter were fixed with the patient in the supine position. The anesthesiologist in charge administered 0.6–1.0 mg/kg of propofol, 0.3 μg/kg/min of remifentanil, and 0.6 mg/kg of rocuronium to induce anesthesia. When sufficient muscle relaxation was obtained, the tracheal tube was intubated into the main bronchus by direct or video laryngoscopy.

Anesthesia was maintained using sevoflurane, desflurane, remifentanil, or rocuronium in most cases at the discretion of the anesthesiologist in charge. Total intravenous anesthesia with propofol was performed in a few cases. Intraoperative ventilator settings were set at a tidal volume of 6–8 ml/kg, positive end expiratory pressure of 4–8 cm H_2O, respiratory rate of 10–14 cycles/min, and fraction of inspired oxygen of 0.4. An open arterial pressure line was placed in the radial artery of the study subjects. The anesthesiologist administered ephedrine, phenylephrine, dopamine, and hydroxyethyl starch 6% so that the mean blood pressure was greater than 60 mmHg.

Fifteen mg/kg of acetaminophen and 50 mg of nonsteroidal anti-inflammatory drugs were administered for analgesia purposes before the end of surgery. Using a pharmacokinetic simulation, fentanyl was administered so that the effective site concentration at the time of awakening was 1–2 ng/ml. Four mg/kg sugammadex were administered before extubation, which was performed after the stabilization of spontaneous ventilation and the recovery from muscle relaxation. After extubation, the patient was transferred to the postoperative observation room or the intensive care unit.

Data collection and statistical analyses

The primary and secondary endpoints, patient background data, intra- and postoperative factors, and pre-post surgery differences in median central and peripheral were compared between groups. Two-sided *p*-values were used, and values under 0.05 were considered to indicate statistical significance. All statistical analyses were performed using JMP® 14 (SAS Institute Inc., Cary, NC). A *t*-test or one-way analysis of variance was used for between-group comparisons of continuous variables if data were normally distributed or Mann–Whitney *U* test if normality was not found. Chi-squared and Fisher's exact tests were used for discrete variables.

Results

Overview of participants

Among the 106 patients scheduled for surgery during the study period, 100 patients provided consent and were enrolled and randomly allocated into the study groups. Of these, 99 were included in the analysis because one patient withdrew consent after participating in the study. There were no cases lost to follow-up (Fig. 1). Patient background data are shown in Table 1. There was no significant difference in patient background characteristics between groups.

Fig. 1 Trial CONSORT diagram. Among the 106 patients scheduled for surgery during the study period, 100 patients provided consent and were enrolled and randomly allocated into the study groups. Of these, 99 were included in the analysis because one patient withdrew consent after participating in the study
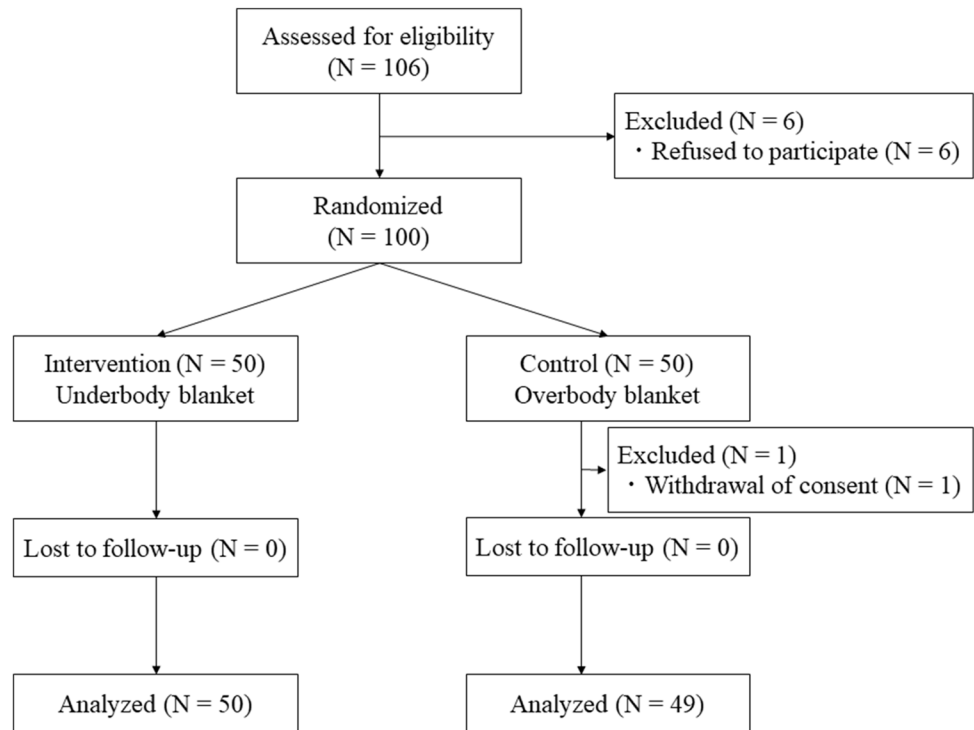
Table 1 Patient characteristics

	Underbody blanket (N=50)	Overbody blanket (N=49)	p-value
Age (years)	71 (35–87)	70 (24–91)	0.68
Sex			0.18
Male	23 (46%)	29 (59.2%)	
Female	27 (54%)	20 (40.8%)	
Height (cm)	158.3 (141.6–176)	159.9 (133–177.7)	0.98
Weight (kg)	56 (35.8–81.8)	57 (35–80.1)	0.96
Body surface area (cm^2)	15,639 (12,108–18,529)	16,002 (11,630–18,924)	0.98
Body mass index (kg/m^2)	22.3 (16.6–29.1)	21.9 (18.1–29.7)	0.71
Preoperative total protein (g/dl)	6.9 (5–7.9)	6.7 (4.7–9.9)	0.10
Preoperative albumin (g/dl)	3.9 (2.2–4.7)	3.8 (2.2–5)	0.37
Preoperative hemoglobin (g/dl)	12 (7.7–15.2)	11.6 (6.7–20.1)	0.65
Stages of cancer			0.68
Stage I	8 (16%)	12 (24.5%)	
Stage II	10 (20%)	11 (22.4%)	
Stage III	24 (48%)	20 (40.8%)	
Stage IV	8 (16%)	6 (12.2%)	

Values are presented as medians (ranges) or number of patients (%). Mann–Whitney–U test was used for comparisons of ordinal data. Nominal data were compared using the Chi-squared test

Comparison of intraoperative factors

Intraoperative factors for the intervention and control groups are shown in Table 2. There was no significant difference in intraoperative factors between groups.

Comparison of changes in central temperature

Changes in the central temperature are summarized in Table 3 and Fig. 2. Ninety minutes postoperatively, central

Table 2 Intraoperative factors

	Underbody blanket (N = 50)	Overbody blanket (N = 49)	p-value
Preoperative room temperature (°C)	26 (25–27)	26 (25–27)	0.54
Intraoperative room temperature (°C)	23.5 (22.5–24.5)	23.5 (22–24.5)	0.22
Postoperative room temperature (°C)	26 (24.5–27)	26 (24.5–27)	0.84
Operative time (min)	324 (178–900)	330 (182–671)	0.98
Anesthetic time (min)	414.5 (252–977)	453 (225–816)	0.81
Type of anesthesia			0.57
Sevoflurane	29 (58%)	32 (65.3%)	
Desflurane	19 (38%)	14 (28.6%)	
Propofol	2 (4%)	3 (6.1%)	
Amount of bleeding (ml)	30 (2–795)	30 (3–635)	0.75
Urine volume (ml)	332.5 (70–2250)	30 (3–635)	0.64
Total fluid volume (ml)	2233 (1240–4819)	2553 (1039–5719)	0.15
Warming area (cm^2)	5708 (4419–6763)	2400 (1744–2839)	< 0.01*
Infusion warming apparatus			0.11
Used	0 (0%)	3 (6.1%)	
Not used	50 (100%)	46 (93.9%)	
Intraoperative blood transfusion			0.61
Required	1 (2%)	2 (4.1%)	
Not required	49 (98%)	47 (95.9%)	
Intraoperative warming blanket stopped			0.61
Stopped	18 (36%)	10 (20.4%)	
Not stopped	32 (64%)	39 (79.6%)	

Values are presented as medians (ranges) or number of patients (%). Mann–Whitney–U test was used for comparisons of ordinal data. Nominal data were compared using the Chi-squared test or Fisher's exact test

*Significant difference between groups

Table 3 Between-group differences in intraoperative central temperature over time

	Underbody blanket (N = 50)	Overbody blanket (N = 49)	p-value
When entering the operation room (°C)	36.3 (35.1–37.5)	36.4 (34.9–37.7)	0.51
Anesthesia initiation(°C)	36.5 (35.1–37.3)	36.4 (35.3–37.6)	0.52
Initiation of surgery (°C)	36.5 (35.6–37.2)	36.4 (35.5–37.6)	0.48
30 min later (°C)	36.7 (35.5–37.2)	36.6 (35.4–37.5)	0.41
60 min later (°C)	36.9 (35.6–37.2)	36.6 (35.7–37.5)	0.09
90 min later (°C)	37.0 (35.8–37.7)	36.7 (35.8–37.7)	0.02*
120 min later (°C)	37.1 (35.6–37.8)	36.8 (35.7–37.9)	0.01*
180 min later (°C)	37.2 (36.1–37.9)	36.8 (35.7–37.9)	0.03*
Completion of surgery (°C)	37.5 (36.4–38.6)	37.1 (35.2–38.2)	< 0.01*
When leaving the operating room (°C)	37.0 (35.8–38.5)	36.7 (35.3–38.3)	0.05

Values are presented as medians (ranges) or number of patients (%). Mann–Whitney–U test was used for comparisons of ordinal data

*Significant difference between groups

temperature was significantly higher in the intervention group. In the control group, a temperature lower than 36 °C was observed in two subjects.

Comparison of changes in peripheral temperature

Changes in peripheral temperature are summarized in Table 4 and Fig. 3. Sixty minutes postoperatively, peripheral
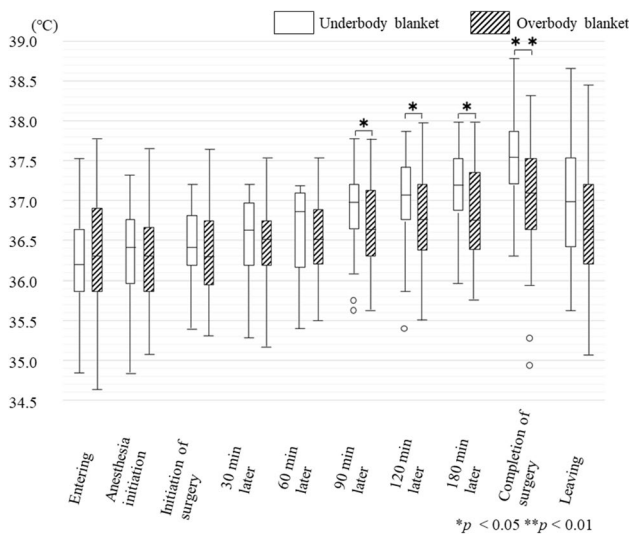
Fig. 2 Ninety minutes postoperatively, central temperature was significantly higher in the intervention group

temperature was significantly higher in the intervention group.

Comparison of differences between central and peripheral temperatures

The median temperature difference (median central–median peripheral temperature) was 0.7–1.5 °C in the intervention group and 1.2–2.1 °C in the control group. The difference between the central and peripheral temperatures was significantly smaller in the intervention group ($p < 0.01$).

Comparison of postoperative factors

Postoperative factors for the intervention and control groups are shown in Table 5. There were no postoperative complications other than SSI in both groups. The intervention group had a significantly lower frequency of postoperative shivering ($p < 0.01$) [19] and a significantly shorter postoperative length of hospital stay ($p = 0.04$) than the control group.

Discussion

Unplanned periodic hypothermia (UPH) has been reported in multiple studies of anesthetized patients, and the importance of normothermia is stated in clinical guidelines [20–23]. The normal central temperature is 36.8–37.0 °C; UPH is defined as a central temperature below 36.0 °C [24]. It has been reported that the occurrence of UPH leads to the reduction of hemostatic function, the occurrence of ischemic heart disease, increased risk of pressure ulcers, and patient discomfort [25–29]. It is important to prevent UPH using intraoperative heating. In this study, the use of an underbody blanket was found to prevent UPH compared with an upper body blanket because UPH was observed in only two cases in the control group.

We hypothesized that the underbody blanket would provide a wider and more effective heating area than the overbody blanket for surgeries performed in the lithotripsy position. The median value of each body surface area showed that about 3.3 times more warm air was provided by the underbody blanket. Differences in the heated area were also reported in previous studies [30]. When the prevention of hypothermia is considered, it has been reported that the clinically effective temperature difference is 0.2 °C or more [31]. In this study, there was a difference of 0.4 °C
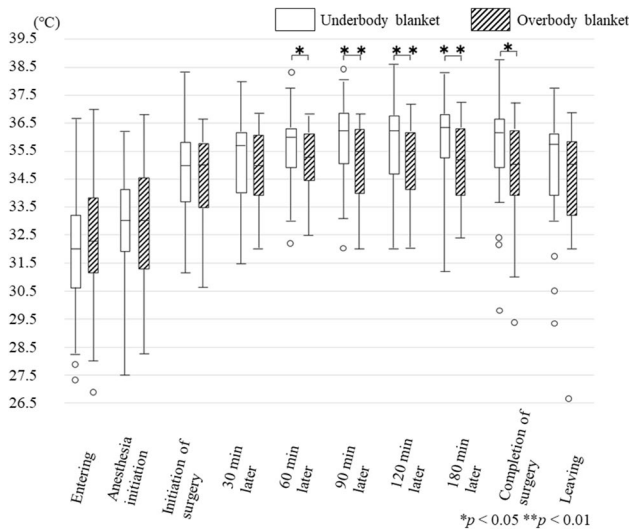
Table 4 Between-group differences in intraoperative peripheral temperature over time	Underbody blanket ($N = 50$)	Overbody blanket ($N = 49$)	p-value
When entering the operation room (°C)	32.0 (27.4–36.6)	32.3 (26.9–37.0)	0.18
Anesthesia initiation (°C)	33.0 (27.5–36.2)	33.0 (28.4–36.8)	0.59
Initiation of surgery (°C)	35.0 (31.1–38.4)	35.0 (30.6–36.6)	0.96
30 min later (°C)	35.7 (31.5–38.0)	35.0 (32.0–36.9)	0.39
60 min later (°C)	36.0 (32.2–38.4)	35.3 (32.5–36.9)	0.02*
90 min later (°C)	36.2 (32.0–38.5)	35.5 (32.0–36.9)	<0.01*
120 min later (°C)	36.2 (32.0–38.6)	35.5 (32.0–37.1)	<0.01*
180 min later (°C)	36.4 (31.1–38.3)	35.2 (32.4–37.3)	<0.01*
Completion of surgery (°C)	36.1 (29.8–38.8)	35.0 (29.4–37.3)	0.03*
When leaving the operating room (°C)	35.7 (29.4–37.7)	35.0 (26.6–36.9)	0.22

Values are presented as medians (ranges) or number of patients (%). Mann–Whitney–U test was used for comparisons of ordinal data

*Significant difference between groups

Fig. 3 Sixty minutes postoperatively, peripheral temperature was significantly higher in the intervention group

between the intervention and control groups in the median central temperature at the end of surgery. We assume that the increased heated area of the underbody blanket played a role in the changes in central temperature recorded in the intervention and control groups during surgery.

Postoperative shivering increases the risk of ischemic heart disease, delayed wound healing, and postoperative pain by increasing oxygen consumption from 300 to 400% and increasing the cardiac burden [32–35]. Shivering after surgery under general anesthesia is frequently preceded by vasoconstriction of apical and toe arteriovenous shunts, an autonomic thermoregulatory response different to symptoms observed during central hypothermia [36]. Vasoconstriction functions to maintain normal central nervous system temperature by decreasing skin and muscle blood flow and reducing

heat loss, with significant effects on body heat distribution [37, 38]. The difference between central and peripheral temperature was significantly different between shivering and non-shivering patients. It was reported that shivering occurs in patients whose peripheral temperature decreased during surgery [39]. In this study, the difference between central and peripheral temperature was significantly lower in the intervention group; this is considered to be one of the factors that limits the generation of postoperative shivering. In addition, it has been reported that increased peripheral temperature linearly decreases the central temperature at which arteriovenous shunt vasoconstriction and shivering occur [40]. According to our findings, the peripheral temperature of the intervention group was significantly higher than that of the control group after 60 min of surgery. The use of the underbody blanket enables warm air heating to the end of the upper extremity, which has been proven to increase peripheral temperature. It is therefore assumed that the underbody blanket decreased the incidence of postoperative shivering by maintaining the peripheral temperature and preventing a decrease in central temperature, thereby reducing the difference between them.

The postoperative length of hospital stay was significantly shorter in the intervention group. We hypothesized that preventing intraoperative hypothermia would lead to the prevention of SSI and affect the postoperative hospital length of stay. However, there was no significant difference in SSI between groups. There were also no significant differences in disease staging, nutritional status, or blood loss, which may be related to the postoperative hospital length of stay. Significant differences between groups were only observed in intraoperative central and peripheral temperature, postoperative shivering, and length of stay. More specifically, postoperative shivering is related to increased oxygen consumption immediately after surgery, which lowers

Table 5 Postoperative factors

	Underbody blanket (N=50)	Overbody blanket (N=49)	*p*-value
Postoperative shivering			<0.01*
Yes	1 (2%)	9 (18.4%)	
Score 1	1 (100%)	2 (22.2%)	
Score 2	0	6 (66.7%)	
Score 3	0	1 (11.1%)	
No	49 (98%)	40 (81.6%)	
Surgical site infection			0.36
Yes	4 (8%)	1 (2%)	
No	46 (92%)	48 (98%)	
Postoperative hospitalization (days)	11 (6–75)	13 (7–42)	0.04*

Values are presented as medians (ranges) or number of patients (%). Mann–Whitney–*U* test was used for comparisons of ordinal data. Nominal data were compared using the Fisher's exact test

*Significant difference between groups

the oxygen supply to the wounded tissues. This may have influenced the delay in wound healing. In a previous study, it was suggested that not only SSI, but also the initiation of solid food and the removal of sutures, affected the postoperative hospital length of stay [5]. In this study, we analyzed the relationship between intraoperative central temperature and SSI, although we did not collect any information on the relationship between SSI and initiation of solid food intake or removal of sutures. In future studies, we will aim to clarify the relation between intraoperative central temperature, suture removal, and initiation of solid food, and their effects in the postoperative hospital length of stay.

The results of this study showed that the use of an underbody blanket in surgery performed in the lithotomy position under general anesthesia led to an increase in central temperature compared with an overbody blanket. It also contributed to prevent postoperative shivering by decreasing the difference between central and peripheral temperature. We, therefore, recommend performing intraoperative temperature control using an underbody blanket in surgeries performed in the lithotomy position under general anesthesia.

Limitations

The results of this study may not be applicable to all surgeries performed with general anesthesia because this was a single-center, single-disease, randomized controlled trial. Moreover, intraoperative heating was stopped in 36% of cases in the intervention group after consulting the anesthesiologist due to persistent hyperthermia. Hyperthermia at the time of awakening may lead to patient discomfort. In addition, it was decided that the timing to stop intraoperative heating should be decided after consultation with the anesthesiologist in charge, since the appropriate intraoperative central temperature has not been clearly determined. In the future, the range of intraoperative normothermic central temperature to be maintained even after the warm air heater is stopped should be determined.

In conclusion, the use of the underbody blanket had the following effects in comparison with the overbody blanket in the lithotomy position surgery under the general anesthesia. Adequate intraoperative central and peripheral temperature maintenance appears to have a preventing effect on postoperative shivering and to shorten the postoperative hospital length of stay.

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