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Original Article

Effect of "An Innovative Technology" Active Warming and Passive Warming on Unplanned Hypothermia During Perioperative Period: A Clinical Trial

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Patients are at risk for unplanned hypothermia during the perioperative period due to many reasons, including anesthesia, low room temperature, cold intravenous fluid, and blood transfusion. This study was conducted to examine the effect of active and passive warming methods applied in patients during the perioperative period on unplanned hypothermia. This study is a case–control type study. The population of this study is composed of the patients hospitalized in surgical clinic and undergone abdominal region-related operations. Ninety patients were accidentally included in the study. The first group of patients were actively warmed during the perioperative period (carbon fiber resistive system – W-500D + 190 × 50 cm), the second group was passively warmed at least for 20 minutes during preoperative period (with blanket, socks etc.), and the third group was followed up as the control group. It was established that body temperature average of the active warming group has significantly increased during perioperative period ($p < 0.001$), and this temperature was significantly higher than the other groups until the third hour. It was found that the body temperature average of all groups was equal to 36.2 ± 0.26, 35.4 ± 0.49, and 35.2 ± 0.47, respectively, at the end of operation, and the difference among them was statistically significant ($p \leq 0.001$). The active warming method applied with carbon fiber resistive system during the perioperative period is an effective method.

Keywords: nursing, hypothermia, perioperative care, body temperature, active warming, passive warming

Introduction

Hypothermia is a commonly seen problem, which occurs during the perioperative period. Unplanned hypothermia occurs in almost half of patients undergoing an operation (Adriani and Moriber, 2013). Hypothermia is defined as the situation that body temperature decreases below 36°C (Burger and Fitzpatrick, 2008; Pikus and Hooper, 2010; TARD, 2013). Unplanned hypothermia during perioperative period is the situation that starts 1 hour before anesthesia and the body temperature decreases below 36°C in the first 24 hours after anesthesia during the postoperative period (TARD, 2013). Unplanned hypothermia during perioperative period may occur by the influence of cold surgery room, cold fluid infusion, evaporation on skin that is prepared for operation, and anesthetic medicines (Adriani and Moriber, 2013; TARD, 2013; AORN, 2016). Unplanned hypothermia has some serious negative effects on all systems. It is known that unplanned hypothermia during surgery causes immunosuppression, increases pain, increases cardiovascular system diseases, and wound infections (Sajid *et al.*, 2009; TARD, 2013).

Normal functioning of body metabolism and enzymes depends on body temperature remaining in certain limits (36.5–37°C) and stable. Keeping body temperature stable is enabled with the balance between temperature and loss. Temperature loss in body occurs with four different mechanisms around the patient. These mechanisms include radiation, convection, conduction, and evaporation (Coşar, 2010) (Fig. 1).

Radiation is the heat transmitting from two different degree formations to each other. Temperature loss mostly occurs in this way in surgery rooms (Aksoy, 2013). Temperature is lost with airway flow through the skin in case of heat loss with convection. Then water and heat loss occur by means of

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evaporation to an extent of 600–900 mL in average from skin and lungs. Such way of loss is high because surgery room is cold during perioperative period. Lastly, conduction is the heat loss occurring because of heat difference with contact between two surfaces. Conduction-induced heat loss occurs through contact of patient to some surfaces such as operating table, cushions, or covers in surgery rooms (Aştı and Karadağ, 2012).

In addition, temperature loss from our body is directly correlated with age, gender, ambient temperature, body surface, operation type, operation time, and period of mechanical ventilation application (Özbayır, 2010). In this context, the risk factor of unplanned hypothermia during perioperative period is reported as:

- Anesthesia and premedication medicines.
- Patients with American Society of Anesthesiologists (ASA) score ranging from II to V.
- Decrease in calorification with direct inhibition of hypothalamus.
- Increase in temperature loss in immobile patient.
- Temperature loss with convection as a result of air conditioning and low ambient temperature.
- Ventilation with cold and dry gases.
- Occurrence of radiation-induced temperature loss as a result of exposure of tissues and organs in open chest and abdominal region operations.
- Temperature loss with conduction as a result of contact with operating table.
- Cold intravenous fluid and blood transfusion in patients.
- Antiseptic solutions.

Disturbance of heat regulation mechanisms depending on some factors, such as wet covers on patient (Buggy and Crossley, 2000; Kumar *et al.*, 2005; Berry *et al.*, 2008; NİCE, 2008; Weirich, 2008; Coşar, 2010; Hooper *et al.*, 2010).

Surgical team does not want increased room temperature against the possibility of sweating because they work under intensive stress and they are overdressed with some equipment such as sterile apron, gloves etc. to prevent microbial reproduction. However, keeping the room temperature of surgery room too low results in unplanned hypothermia (Dennison, 1995; Hart *et al.*, 2011). Ideal room temperature of the surgery room is 20–24°C (Hooper, 2006), lower room temperatures increase the risk of hypothermia.

Unplanned hypothermia has some serious negative effects on all systems; when the body temperature falls below 36°C, it is the beginning of hypothermia. Blood pressure increases, myocardium irritability increases, and conduction disorder occurs (Rightmyer and Singbartl, 2016). Cerebral blood flow decreases to a ratio of 6–7% with every 1°C temperature reduction. Reflexes decrease upon slowdown in conduction in peripheral nerves. Cerebral and mental functions are depressed (Frank, *et al.*, 2000; Sessler, 2000). Pupillary dilatation occurs below 30°C and loss of consciousness occurs below 28°C. Respiratory rate decreases, tidal volume reduces, and respiratory depression occurs by the decline in body temperature. Metabolism slows down by hypothermia, O_2 and glycolyses necessity decreases, and then local ischemia tolerance of brain increases. Kidney blood flow gradually decreases as a result of hypothermia and so renal functions are damaged (Yılmaz, 1997; Coşar, 2010; Aksoy, 2013). Moreover, shivering that occurs at the early stages of hypothermia negatively influences patient comfort.

Background

According to the Centers for Disease Control and Prevention (CDC), protection from hypothermia also reduces the infection risk (Fettes *et al.*, 2013). ASA recommends that body temperature should be in normal limits to get over the effect of anesthesia and to recover, and the reported minimization of hypothermia during perioperative period as a factor in healing of patients (Adriani and Moriber, 2013).

Patients who will undergo an operation are under risk in terms of hypothermia during every stage of the perioperative period. Protection from hypothermia during perioperative period is a determinable and preventable situation, whereas it is a multidisciplinary problem that requires the collective effort of nurses, anesthesiologists, and surgeons (NİCE, 2008; Leeth *et al.*, 2010). Prevalence of some complications such as pain, wound infection, postoperative shivering, and bleeding decreases by use of appropriate and effective warming methods in patients on whom hypothermia occurred during perioperative and postoperative periods (Sajid *et al.*, 2009). We can collect the methods used in prevention of unplanned hypothermia during the perioperative period under two headings as passive and active warming.

Passive warming methods are composed of cotton, woolen blankets, socks, and caps in services and recovery units; ''special protective equipment,'' such as surgical covers, metal-compounded plastic covers, or caps in operating rooms. The effect of passive warming is directly proportional

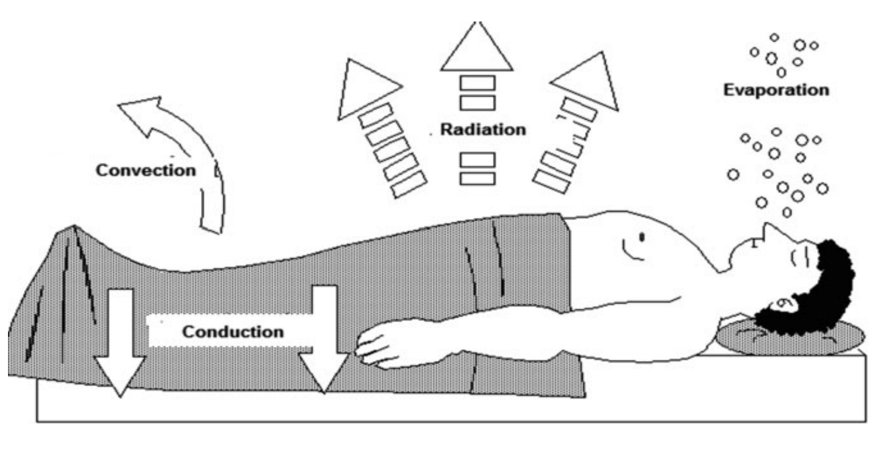

FIG. 1. Mechanisms of temperature loss from body.

to the area being covered and it prevents temperature loss up to 30% (Sessler, 2008; Adriani and Moriber, 2013).

Active warming techniques include forced air systems, resistive systems (electrical, carbon fiber, jelly coats etc.) and radiant heaters, intravenous fluid, blood and blood product heaters, heat and moisture exchanger filters, and negative pressure warming systems.

Carbon fiber is the innovation used in many areas. Carbon fiber is a strong, lightweight, harsh material that has the potential to replace steel and is popularly used in specialized, high-performance products such as aircrafts, sporting equipment, and race cars (Zhuang, 2015).

Resistive heating with carbon fiber is one of the innovative technologies in healthcare. Resistive heating system with carbon fiber is advantageous over other heating systems, such as forced air. It is also resistant to disinfection and is a cost-effective heating method. We can protect patients from infections by using disposable covers when using resistive heating systems.

Prevalence of some complications, such as pain, wound infection, postoperative shivering, and bleeding decreases by the use of appropriate and effective warming methods in patients on whom hypothermia occurred during perioperative and postoperative periods (Sajid *et al.*, 2009). Nurses may prevent this occurrence with some effort, which decreases unplanned hypothermia incidence if all these complications are taken into consideration (Yılmaz, 1997).

Researches point out that unplanned hypothermia during perioperative period have some consequences, such as increase in surgical area infections, increase in blood loss during perioperative period, occurrence of shivering after anesthesia, longer recovery and hospitalization period, and increase in mortality (Weirich, 2008; TARD, 2013). This study is conducted to determine the prevalence of unplanned hypothermia during the perioperative period and examine whether or not passive warming and an innovative technological active warming are effective methods in the prevention of hypothermia.

Methods

Aim

This study is conducted to examine the effect of active and passive warming methods on unplanned hypothermia applied in patients during the perioperative period.

Design

This is a prospective and experimental clinical trial. Three groups of patients, each including 30 patients, were accidentally selected from patients hospitalized in the relevant surgery service. Passive warming was applied on the first group and active warming on the second group, and then both was monitored. The third group was followed up as the control group. The patients in all three groups were informed about the process during the course of application.

Sample

The study was conducted in The Training and Research Hospital, Surgery Clinic, and operating room between January 1, 2016 and January 6, 2016. The population of this study composed of patients admitted in hospital, surgery clinic, and had undergone abdominal region-related operations. The sample size was determined by power analysis in a computer program. The accidental sampling method was used by the investigator to divide the patients into groups and to prevent bias. Three groups of patients, each including 30 individuals, were accidentally selected from patients hospitalized in the surgery service. The patients who are in the age range of 18–45, whose ASA score is ASA-I-II-III, body mass index (BMI) is below 40 and above 18.5, who will undergo a surgical operation related with abdominal region, who was informed and given consent, can communicate verbally, were included in the study to minimize the effect of other variables. Written consent was obtained from all participants.

Interventions

The patients included in the passive warming group in the first group were ensured to wear polar blanket, caps, and socks at least 20 minutes before moving to the surgery room. Passive warming was applied until the time they went to the surgery room, including the period of transfer to the operating room.

Active warming method (patient warming equipment) was applied to the second group during the perioperative period.

Any intervention other than standard care was not applied on the third group and they have been just followed up as the control group. The patient warming is not normally performed in the perioperative setting in a hospital. Body temperatures of all patients were recorded after measuring with noncontact thermometer from temporal artery at 15-minute intervals during the preoperative, perioperative, and postoperative periods. Blood pressure, pulse, respiration, O_2 saturation, and pain scores were evaluated synchronously.

The resistive system carbon fiber patient warming 190×50 cm adult bed and 180×45 cm chest–arm warmer were applied together for the purpose of active warming in the experimental group. Chest–arm warmer and warming bed were used with double outlet W-500D control unit that is adjustable to 38–40°C. The chest–arm warmer and warming bed were adjusted to 38°C for normothermic patients and to 40°C for hypothermic patients. Warming application was kept ongoing during the whole perioperative period. Disposable mattress covers were used for each patient to prevent surgical area infections.

Data collection

Measurements were taken in the surgical clinic and in the operating room. First of all, patients' age, gender, smoking, and BMI were recorded by the researcher. Vital signs were measured every 15 minutes in the intraoperative period and it was continued for 3 hours postoperatively. Additionally, surgery room ambient temperature (°C), surgery time, intravenous solution quantity (mL), type of anesthesia, and ASA score were recorded. Noncontact thermometer (Braun) from temporal artery (Braun) was used as the body temperature measurement instrument. All measurements were taken from patients by the first researcher (Fig. 2).

Questionnaire

Data were gathered with the data collection form created by the researchers in direction of the literature related with

FIG. 2. Patient warming bed, control unit, chest–arm warmer. (İstanbul Medical-Medwarm 190 × 50 cm warming bed+W-500D control unit +185 × 45 cm chest–arm warmer).

the topic. The first chapter of the questionnaire form is composed of demographical characteristics and the second chapter is composed of patients' monitoring in preoperative, perioperative, and postoperative periods.

Ethical considerations

Ethics approval date, December 30, 2015, and No. 2015/95 were obtained from Clinical Researches Ethics Board. Necessary permissions were obtained from the hospital where the study is conducted.

Data analysis

Analysis of data which had been previously obtained was made by coding them in SPSS (Statistical Package for the Social Sciences) 20.0 program. Data were expressed as percentage and mean ± standard deviation. One-way analysis of variance and Kruskal–Wallis tests were used to determine which variables differentiate.

Results

If we look at the identifier characteristics of patients, 90 patients, including 30 patients in each group, were included in the study. It was determined that age average of all patients included in the study is 53.5, and their BMI average is 25.7 (Table 1).

It was determined that the difference among the active warming group, passive warming group, and the control group is not statistically significant in terms of age, BMI, gender, and smoking, therefore, two experimental groups and one control group were homogenous in terms of age, BMI, gender, and smoking ($p \geq 0.05$).

Average surgery room ambient temperature was recorded as 24.5°C, average surgery time as 89.3 minutes, and the average intravenous fluid quantity used as 1341.1 mL, and irrigation fluid quantity average as 295.8 mL in all the operations included in the scope of the study (Table 2).

The difference among the active warming group, passive warming group, and the control group was not found to be

Table 1. Some Identifier Characteristics of Patients (*n*: 90)

	Group A (n*: 30)*		*Group P* (n*: 30)*		*Group C* (n*: 30)*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Statistical analysis*
Age	52.6	11.6	53.9	13.2	54.2	12.7	*F*: 0.135 *p*: 0.874
Body mass index	25.0	4.1	25.5	4.5	26.7	2.9	*F*: 1.475 *p*: 0.234
	N	%	n	%	n	%	*Statistical analysis*
Gender							
Female	9	10.0	13	14.4	17	18.9	X^2: 4.344
Male	21	23.3	17	18.9	13	14.4	*p*: 0.114 df: 2
Smoking							
Yes	10	11.1	8	8.9	6	6.7	X^2: 1.364
No	20	22.2	22	24.4	24	26.7	*p*: 0.506 df: 2

A, active warming group; P, passive warming group; C, control group.
Ort, Mean; SD, standard deviation.

Table 2. Findings with Respect to Surgical Treatment (*N*: 90)

	Group A (n: *30*)		*Group P* (n: *30*)		*Group C* (n: *30*)		
	Ort	*Ss*	*Ort*	*Ss*	*Ort*	*Ss*	*Statistical analysis*
Surgery room ambient temperature (°C)	24.3	1.3	24.8	1.1	24.6	1.1	*F*: 1.420 *p*: 0.247[b]
Surgery time (minutes)	94.5	41.1	74.5	25.3	99	60.0	*F*: 2.574 *p*: 0.082[b]
IV solution quantity (mL)	1466.6	667.7	956.6	551.2	1600.0	1056.9	*F*: 5.558 *p*: 0.005
	n	%	n	%	n	%	*Statistical analysis*
ASA[a]							
I	14	15.6	8	8.9	10	11.1	X^2: 3.575
II	12	13.3	19	21.1	17	18.9	*p*: 0.467[b]
III	4	4.4	3	3.3	3	3.3	df: 4
Type of anesthesia							
General	24	26.7	24	26.7	23	25.6	X^2:1.495
Spinal	4	4.4	2	2.2	4	4.4	*p*: 0.828[b]
Epidural	2	2.2	4	4.4	4	4.4	df: 4
Surgery type							
Open	15	16.7	14	15.6	12	13.3	X^2: 0.627
Laparoscopic	15	16.7	16	17.8	18	20.0	*p*: 0.731[b] df: 2

[a]ASA (American Society of Anesthesiologists) Classification.
[b]$p \geq 0.05$.
IV, intravenous.

statistically significant in terms of surgery room temperature, operation time, irrigation fluid quantity used, ASA score, type of anesthesia, and surgery type ($p \geq 0.05$).

The surgical treatments applied on patients included in the study composed of cholecystectomy with a ratio of 40.0% (*n*: 36), hernia repair with a ratio of 28.9% (*n*: 26), gastric interventions with a ratio of 13.3% (*n*: 12), colon-related interventions with a ratio of 7.7% (*n*: 7), rectum-related interventions with a ratio of 3.3% (*n*: 3), appendectomy with a ratio of 4.4% (*n*: 4), and pancreatectomy operations with a ratio of 2.2% (*n*: 2).

It was seen that body temperature is continuously decreasing in the active warming group, passive warming group, and the control group in the measurements taken in 15-minute intervals. While no intergroup significant difference was seen in body temperature at the time of patients' admission to surgery room ($p \geq 0.05$), the intergroup difference in body temperature was statistically significant in the measures taken until the 180th minute during the perioperative period and until the first 1 hour and second hour during the postoperative period ($p \leq 0.05$). The intergroup difference was not found statistically significant in terms of the measurement taken at the third hour during the postoperative period ($p \geq 0.05$) (Fig. 3).

It was determined that the significant difference between the groups in body temperature for the first 120 minutes after operation was a result of the fact that the body temperatures of the patients in the active warming group were higher than those of the patients in the passive warming group and those in the control group (Fig. 3).

While all of the patients in the active warming group were normothermic for the first 15 minutes of operation, 13.3% (*n*: 4) of the patients were hypothermic in at least one of the measurements taken during the entire operation. It was determined that 36.7% (*n*: 11) of the patients in the passive warming group and 40.0% (*n*: 12) of the patient in the control group were hypothermic for the first 15 minutes of operation. Around 86.7% (*n*: 26) of the patients in the passive warming group and 97.6% (*n*: 29) of the patients in the control group were hypothermic in at least one of the measurements taken during the entire operation.

A statistically significant difference was obtained between the groups in terms of being hypothermic both for the first 15 minutes of the operation and for the entire operation ($p \leq 0.001$).

It was determined that 6.7% (*n*: 2) of the patients in the active warming group, 86.7% (*n*: 26) of the patients in the passive warming group and 90.0% (*n*: 27) of the patients in the control group after operation were hypothermic in at least one of the measurements and this difference between the groups was statistically significant ($p \leq 0.001$).

Discussion

When data were analyzed, the patients in three groups were found homogenous in terms of age, BMI, gender, and smoking.

When the study results were examined, the average age was found to be 52.6 ± 11.6 in the active warming group, 53.9 ± 13.2 in the passive warming group, 54.2 ± 12.7 in the control group, and the intergroup difference is not significant ($p \geq 0.05$). For that reason, it may be said that the data are homogenous in terms of age. This is a desirable situation in terms of comparing the effectiveness of warming. Mehta and Barclay (2014) reported that hypothermia risk is high in patients over 70 years of age.

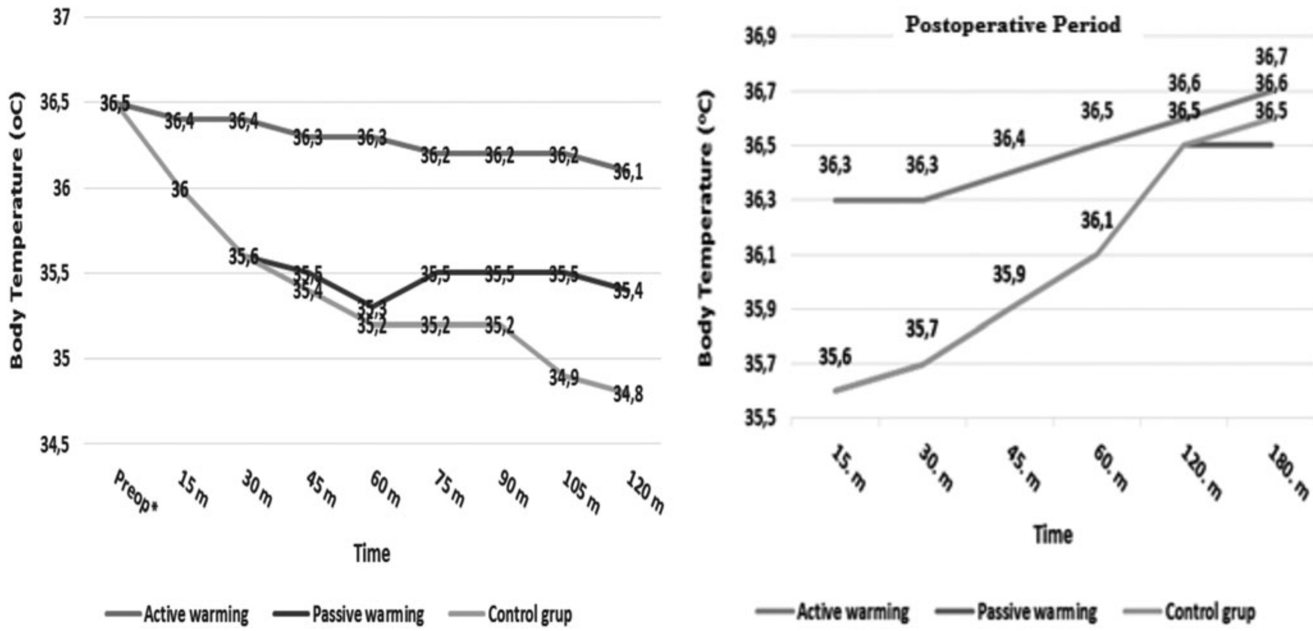

FIG. 3. Change in body temperature during preoperative, intraoperative, and postoperative periods.*Preop.: body temperature at the time of admission in the surgery room.

As a factor that determines body temperature, BMI in the range of 18.5–24.9 kg/m^2 was considered normal, 25–29.9 kg/m^2 was considered overweight, 30–39.9 kg/m^2 was considered obese, and 40 and over is considered as morbidly obese (Özbayır, 2010). When the BMI averages were analyzed, it was determined that BMI average is 25.0 ± 4.1 in the active warming group, 25.5 ± 4.5 in the passive warming group, 26.7 ± 2.9 in the control group, and the intergroup difference is not significant ($p \geq 0.05$). Elderliness and high BMI were considered as risk factors for occurrence of hypothermia (El-Gamal *et al.*, 2000; Hooper *et al.*, 2010). However, there was no morbidly obese patient that may affect data in our study.

The ''Guideline for Preventing Unplanned Hypothermia in the Operation Process'' issued by the Turkish Anesthesiology and Reanimation Association in 2013 defines the female gender as a risk factor for hypothermia (Hooper *et al.*, 2010; TARD, 2013). According to Lassen *et al.* (2013) although the literature does not provide a clear evidence for smoking and hypothermia, it is suggested for regular smokers that quitting smoking 1 month before the operation would be useful for the patient after the operation. Our study reported that the difference between the groups, in terms of gender and smoking, was not significant ($p \geq 0.05$).

AORN suggests the operating room temperature should be 20–25°C during operation (Hooper *et al.*, 2010). According to the results of the study of El-Gamar *et al.* (2000), the operating room below 23°C is reported as a risk factor for hypothermia and above 26°C reduces the frequency of hypothermia, but is known to be disruptive for the comfort of the surgical team and to increase infections. Our study reported that the operating room temperature average values were not enough to cause a negative effect for unplanned hypothermia; they were 24.3°C ± 1.3°C for the active warming group, 24.8°C ± 1.1°C for the passive warming group, and 24.6°C ± 1.1°C for the control group, and no difference was obtained between the groups in terms of the operating room temperature.

Extending the operation time elevates the risk of hypothermia (Burns *et al.*, 2009). Sessler (2008) reports that hypothermia and the time in the operating room is directly proportional and the fastest temperature drop occurs in the first hour of the operation. Similar to the other studies, the longer the operation takes the lower the body temperature of patients and the higher the risk of hypothermia in our study (Adriani and Moriber, 2013; Pu *et al.*, 2014). Although active warming is recommended for all patients undergoing an operation, there is no clear evidence that supports the active warming results for operations, which take shorter than 30 minutes. However, it is suggested to use active warming irrespective of the operation time for the patients in the hypothermia risk group (Hooper *et al.*, 2010; Hart *et al.*, 2011).

Studies report a higher risk of hypothermia in patients with a high amount of cold intravenous liquid intake (Kumar *et al.*, 2005). It is recommended to heat intravenous and irrigation liquids to the normal body temperature before administering to the patient. Although studies have demonstrated (medium-level proof) that the patients whose intravenous fluids are heated in the first half hour of the operation have higher core temperatures compared with those whose intravenous fluids are administered at room temperature, this difference disappears with extended operation time (Campbell *et al.*, 2015), and guidelines about care in the perioperative period report that it is not solely an efficient method (TARD, 2013; Campbell *et al.*, 2015). There was no difference between the irrigation solution amounts provided to the patients in the test group and the control group.

The fact that the three groups in the study are homogenous in terms of room temperature, operation time, irrigation solutions, ASA, type of anesthesia, and method of operation, supports the applicability of the study results for the variables that affect heat loss.

Hypothermia risk factors are grouped into two, internal and external risk factors. External factors include the contact of the patient's body with the operating table, long and open surgeries, cold operating room etc. Internal risk factors include age, BKİ physical condition, and morbid obesity etc. (Weirich, 2008). According to Burns *et al.* (2009), in 50–90% of surgical patients, the compensation mechanism, which maintains the normal body temperature, does not function sufficiently and therefore, hypothermia occurs in patients.

Not only the patients under general anesthesia, but also those under local anesthesia are at risk of hypothermia. Horn *et al.* (2016) suggest active warming for 15 minutes before and after operation with epidural anesthesia would protect from hypothermia after the operation.

While this study did not obtain a statistically significant difference between the body temperatures at acceptance to the operating room of active warming, passive warming, and control groups ($p \geq 0.05$), there was a highly significant difference ($p \leq 0.05$) in the body temperatures between the 15th minute of the operation and the end of the operation. The body temperatures of the patients in the active warming group were significantly higher than the patients in the passive warming group and the control group. Similarly, the body temperatures of the patients in the active warming group were higher in all 15-minute measurements taken during the operation up to the 180th minute ($p \leq 0.05$). While 86.7% of the patients rendered active warming during operation maintained normothermic body temperature (≥36°C), it was 13.3% in patients who rendered passive warming and 3.3% in the patients in the control group.

According to the study of Mehta and Barclay (2014) on postoperative body temperatures of patients, they report that most of the patients (74%) enter hypothermia at the end of anesthesia. Horn *et al.* (2016) similarly report that most of the patients (72%), who undergo an abdominal surgery and are not heated, enter hypothermia after anesthesia. In this study, 93.3% of the patients rendered active warming also after the operation and maintained normothermic body temperature (≥36°C), it was 13.3% in patients rendered passive warming, and 10.0% in the patients in the control group. Based on these results, it was determined that carbon fiber resistive active warming system, one of the active warming methods, is an efficient way to protect patients from hypothermia during the perioperative period and passive warming solely fails to protect patients.

In Aksoy's randomized controlled study on patients who undergo an abdominal surgery, it is reported that active warming was applied for 15 minutes before induction, outside the routine protocol, in the test group, and when it was compared with the control group, the body temperature was below 35°C in 86.7% of the patients in the control group and in 40% of those in the test group (Aksoy, 2013). Horn *et al.* (2016) indicate preoperative warming is not solely sufficient and suggest active warming too for those who are rendered preoperative active warming for protection from hypothermia after operation. Comparing to our study, it was determined that warming patients while undergoing an abdominal surgery is a more efficient method to prevent hypothermia in the perioperative period.

According to the results of the study of Williams *et al.* (2005), who applied rewarming for patients in light hypothermia and compared two active methods (forced air system, radiant heater) and a passive warming method (polyester filled blanket), there is no statistically significant difference between these three warming methods and the efficiency of active warming methods is weakened after occurrence of hypothermia. Therefore, for an efficient warming to prevent hypothermia, preventive measures should be taken on time and target the patients at the highest risk (Mehta and Barclay, 2014).

According to the results of the prospective and randomized controlled study of Perl *et al.* (2012) on 40 patients, it is reported that the body temperatures of the patients in the test group were significantly higher than those in the control group at the 45th, 60th, 75th, 90th, 105th, and 120th minutes of operation; applying active warming in combination with passive warming is an efficient way to protect from hypothermia. In this study, it is determined that preoperative passive warming alone is not sufficient and it would be more efficient to use with active warming.

Matsuzaki *et al.* (2003) in their study, which applied both hot air blow (forced air) and carbon fiber-equipped systems, among active warming methods, reported that both methods prevent hypothermia in the perioperative period; there is no difference in between, but due to the configurable warming compartments, carbon fiber-resistive warming systems have more advantages. Again, similarly, Nieh and Su (2016) in their meta-analysis study, which compared active warming methods reported that hot air blow (forced air) system and carbon fiber-equipped systems have similar patient warming results and are efficient in preventing hypothermia. In their study, Rao Kadam *et al.* (2009) applied hot air blow (forced air) and carbon fiber warming systems, among active warming systems, to two groups of patients, and both systems prevented hypothermia in the perioperative period and have similar efficiencies. Measures should be taken to prevent decontamination while using carbon fiber-equipped systems (Wood *et al.*, 2014). Single-use cases were used for every patient to prevent decontamination in our study.

There is no available data on how many patients, who undergo a surgery under general anesthesia in Turkey, are actively heated. However, the numbers are assumed to be very low, because certain standards are not available on warming surgical patients in our country. However, studies demonstrate that patients who have planned a surgical operation are at unplanned hypothermia risk in the perioperative period (Franklin *et al.*, 2012; Aksoy, 2013; Bashaw, 2016).

Limitations

Inability to fix the room temperature in the operating room, and inability to measure and control temperatures of intravenous and irrigation liquids are the limitations of this study.

Conclusions

Under the light of these results, the body temperature average during and after operation in the passive warming group is not a statistically significant difference than the cases in the control group. The body temperature average during and after operation in the innovative technological active warming group is statistically significantly higher than the cases in the control group and in the passive warming group. It was determined that an active warming method, carbon fiber resistive warming system, is an efficient method to protect patients from hypothermia in the perioperative period and passive warming fails to protect patients when applied alone.

Other than the study results, it is recommended to measure and record the body temperatures of all patients in the perioperative period, use efficient measures to ensure normal body temperature in the perioperative period, not mix different active warming methods, include it in medicine and nursing education programs to increase initiatives to prevent unplanned hypothermia during the perioperative period, define unplanned hypothermia in the perioperative period at hospitals among the operating room principles of patient security, and provide suitable active and passive warming tools and equipment at hospitals.

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Author Disclosure Statement

No competing financial interests exist.

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