

Original article

Effect of prewarming on body temperature and shivering in total knee arthroplasty patients after surgery

Ratchanee Sukanthachalathon^a, Usavadee Asdornwised^{b,*}, Orapan Thosingha^b,
Phongthara Vichitvejpaisal^c

^a Program in Nursing Science, Faculty of Nursing, Mahidol University, Bangkok, Thailand

^b Faculty of Nursing, Mahidol University, Bangkok, Thailand

^c Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

Background: Inadvertent hypothermia and shivering is recognized risk in surgery. Core temperature in patients warmed with forced air warming remains poorly characterized. The incidence in patients with total knee arthroplasty (TKA) leading to intraoperative hypothermia 43.9%.

Objectives: This quasi-experimental research study was conducted to compare body temperature and shivering after surgery in patients with total knee arthroplasty who received prewarming and those who received routine nursing care.

Methods: Thirty-first patients were randomly assigned for experimental group and Thirty-first patients for control group. Data were collected by the following tools and methods, namely: patient demographic and clinical characteristic records, tympanic membrane thermometer, ambient temperature and humidity meter and the wrench's scale. Data were analyzed by using One-way analysis of covariance (ANCOVA) to compare the differences between the means of body temperature both groups and shivering was analyzed by Chi-square test.

Results: Body temperature in the experimental group was higher than the control group at the time before discharged from the operating room ($P < 0.001$), at the time they entered the recovery room ($P = 0.001$) and at 30 minutes after they transferred to the recovery room ($P < 0.001$) and 60 minutes after they transferred to the recovery room ($P = 0.001$). The means of body temperature before returning to the recovery room of both groups were not significantly different ($P = 0.391$). In addition, the shivering in the experimental group was significantly lower than the control group at time that entered to the recovery room ($P = 0.009$) and at 30 minutes after transferred to the recovery room ($P = 0.002$). The means temperature at 60 minutes after transferred to the recovery room the experimental group and control group were not significant difference ($P = 0.1$).

Conclusion: Prewarming was more effective than not prewarming in the prevention of postoperative hypothermia and shivering in TKA.

Keywords: Prewarming, body temperature, shivering, total knee arthroplasty surgery.

Hypothermia is a condition in which the core temperature of the body is lower than 36°C.⁽¹⁾ It has been documented that the incidences of postoperative hypothermia in patients undergoing surgery ranges between 20.0% to 60.0%.⁽²⁾ The type of surgery that causes the highest incidence of hypothermia is total knee arthroplasty, making up 43.9%.⁽³⁾ The incidence of postoperative shivering is 43.6% in patients undergoing orthopedics surgery.⁽⁴⁾

A number of factors that lead to hypothermia in postoperative patients included age, gender, body mass index, preoperative core temperature lower than 36°C, and preoperative co-morbidity.⁽⁵⁾ Surgery factors are type of anesthesia, duration of anesthesia, intravenous solutions, sterilization solution, and clothing. These factors affect the functions of different organs and systems in the body⁽⁵⁾, resulting in abnormality of the heart muscles, blood coagulation, and surgical wound infections⁽⁶⁾, as well as longer recovery period, faster heart rates, and hypertension.⁽⁷⁾ In addition, it can have an effect on the patients' mental condition. When they experience physical discomfort of shivering, they can develop more anxiety about the operation.⁽⁸⁾ Such impacts directly affect the overall health system of

*Correspondence to: Usavadee Asdornwised, Faculty of Nursing, Mahidol University, Bangkok 10700, Thailand.

E-mail: usavadee.asd@mahidol.ac.th

Received: June 10, 2019

Revised: March 6, 2020

Accepted: May 28, 2020

the country. Postoperative shivering is associated with increased risk of hypertension, and faster heart rates. It causes cellular oxygen expenditure to rise by 400 times the normal rate, hence delayed wound heal after the operation.⁽⁹⁾

European hospitals have revealed that only 40.0% of the patients undergoing a surgery with general anesthesia received prewarming before the surgery and only 20.0% of them had their body temperature measured. With regard to those who received regional anesthesia, 20.0% received prewarming and only 6.0% had their body temperature measured during the surgery.⁽¹⁰⁾ The regional anesthesia medication administered is Bupivacaine, which causes numbness in the areas from the spinal cord where the medication is injected down to the tip of the feet.⁽¹¹⁾ It causes the core temperature to be lower than the normal body temperature.⁽⁵⁾ Therefore, prewarming is required to prevent patient's hypothermia.^(12, 13) The duration of prewarming should be around 10 to 30 minutes.⁽¹⁴⁾ There are two methods of prewarming. The first method is active warming. It is a process in which external heat is transferred to the body using a forced-air warming blanket, which is suitable for patients.^(15, 16) The active warming can increase the core temperature by 0.5°C to 1°C. The second method is passive warming.^(15, 17) A study conducted by McSwain JR, *et al.*⁽¹⁸⁾ has shown that 52.0% of the patients undergoing arthroplasty developed hypothermia rating the effect of prewarming to prevent hypothermia and shivering in patients undergoing total knee arthroplasty. Patients undergoing total knee arthroplasty are at risk of inadvertent hypothermia during surgery due to uncovered and exposed tissue skin, anesthesia elimination normal protective thermoregulatory reflexes and using fluid intravenously and wound irrigation.^(3, 19)

The objective of this study was to compare core temperatures and shivering after surgery in patients who received prewarming before undergoing total knee arthroplasty and those who received only routine nursing care.

Materials and methods

The present study was a quasi-experimental research study was conducted after obtaining the approval of the Institutional Review Board of Siriraj Hospital (IRB-NS 2017/36.0911). Written informed consent was obtained from the recruited patients. The population consisted of male and female patients,

aged 18 years old and older who underwent total knee arthroplasty for the first time. They were patients with no pathology of the ear or ear infection, their preoperative body temperature was not lower than 36.5°C or higher than 37.5°C, they received regional anesthesia of spinal block together with localized anesthesia of femoral nerve block or regional anesthesia of spinal block together with localized anesthesia of adductor canal nerve block were assigned to the experimental group and control group. Exclusion criteria was comorbidity such as Thyroid disease or Cushing syndrome. Termination criteria was patients received general anesthesia or postoperative, the patients were referred to critical care unit.

Patients were randomly allocated to either the experimental group or the control group with the SPSS program (version 18). In the experimental group, the subjects received prewarming with a forced-air blanket before entering the operating room for 15 - 30 minutes with forced-air blanket (Warm Touch brand, 501 Model) whose temperature could be adjusted to four levels of 32°C, 38°C, 43°C, and 45°C. It had the automatic over temperature shutdown system, and it was a full body blanket. It was set to medium level (38°C). Prewarming was stated before induction of anesthesia. The control group, the subjects received only routine nursing care. It was only one layer of cotton that was not warmed.

The core temperature was measured by a tympanic membrane thermometer (Omron brand TH839S model). It measured the patients' body temperature with infrared radiation and reported the findings digitally. Both group's core temperature was measured and recorded by only researcher when they arrival in waiting room and they were discharged from the operating room, at the time the subjects entered the recovery room, and at 30 and 60 minutes after the subjects were transferred to the ward. The number of patients who became hypothermic at each time was recorded.

In recovery room, shivering was evaluated by wrensch's scale using a 5 point scale (0 = no shivering observed; 1 = one or more of piloerection peripheral cyanosis without other cause, but without visible muscular activity; 2 = visible muscle activity confined to one muscle group; 3 = visible muscle activity in more than one muscle group; 4 = gross muscular activity involving the entire body). The patients were considered having shivering when their score was equal to 2 points or higher.

The sample size was calculated with the power of analysis. ⁽¹⁸⁾ The power of test was set at 0.09, with the statistical significance level of 0.05 and the effect size of 0.8, based on a study undertaken by McSwain JR, *et al.* ⁽¹⁸⁾ The calculated sample size was 28 subjects in each group, to prevent the subject loss, an additional 10.0% of the calculated sample size, there were 31 patients in each group. Data collection took place between May and July 2018.

Statistical analysis

Data regarding demographic characteristics were analyzed with descriptive statistics of percentage, mean, and standard deviation (SD). In addition, Chi-square test and Independent *t* - test were used to compare the data collected from both groups of subjects. The differences in the means body temperature of the subjects in the experimental group and the control group were compared using One-way analysis of covariance (ANCOVA), with the mean core body temperature as a covariance. The levels of shivering in the experimental group and the control group were analyzed using Chi-square test.

Results

The baseline demographic characteristics were not significantly different between experimental group and control group (Table 1). As regards prewarming

before administration of the spinal block with adductor nerve block, only the subjects in the experimental group received prewarming, with 19.5% receiving prewarming for less than 30 minutes and 80.5% receiving prewarming for more than 30 minutes.

When considering temperature and relative humidity in the operating room before administration of the spinal block with adductor nerve block until discharge of the patients, it was found that for the experimental group, the temperature ranged from 20°C to 23°C and relative humidity ranged from 54.0% to 67.0%. The control group, the temperature ranged from 20°C to 23°C and relative humidity ranged from 53.0% to 63.0%. Comparing the differences in room temperature and relative humidity, there were no statistically significant differences between the two groups of subjects (*P* > 0.05).

Postoperative hypothermia and shivering were significantly different between experimental group and control group. But the mean body temperature before returning to the recovery room was not significantly different between groups (*P* > 0.05). And the incidence of shivering were significantly different between experimental group and control group but at 60 minutes after patients transferred to the recovery room was not significantly different between group (Table 2).

Table 1. Baseline demographic characteristics.

	Experimental group (n = 31)	Control group (n = 31)	<i>P</i> - value
Males	8 (25.8%)	7 (22.6%)	0.5
Females	23 (74.2%)	24 (77.4%)	
Mean age (kg)	68.0 ± 8.9	67.0 ± 9.1	0.16
BMI (kg/m ²)	28.5 ± 3.5	27.2 ± 4.9	0.25
Operative details			
Blood transfusion (ml.)	1 (3.2%)	0	0.317
Duration of anesthesia (minutes)	140.8 ± 37.6	158.7 ± 31.6	0.169
Sterile salutation (ml.)	1,733.9 ± 587.6	1,738.7 ± 610.8	1.0
Intravenous fluids (ml.)	951.6 ± 349.4	914.8 ± 339.7	0.818
Blood loss (ml.)	20.3 ± 25.9	12.9 ± 10.5	0.179
Baseline preoperative patients temperature (°C)	36.6 ± 0.3	36.7 ± 0.2	0.026

Table 2. The incidence of postoperative hypothermia and shivering.

Outcomes	Experimental group (n = 31)	Control group (n = 31)	P-value
Hypothermia (°C)			
Discharged from the operating room	35.7 ± 0.5	35.4 ± 0.5	0.007
At recovery room	35.6 ± 0.5	35.3 ± 0.5	0.047
30 minutes after transferred to the recovery room	35.9 ± 0.4	35.6 ± 0.5	0.017
60 minutes after transferred to the recovery room	36.2 ± 0.5	35.9 ± 0.6	0.045
Returning to the recovery room	36.6 ± 0.3	36.6 ± 0.2	0.698
Shivering, n (%)			
Recovery room	14 (45.2)	25 (80.6)	0.009
30 minutes after transferred to the recovery room	7 (22.6)	20 (64.5)	0.002
60 minutes after transferred to the recovery room	1 (6.4)	6 (19.4)	0.104

Discussion

The findings of the present study showed that prewarming before administration of regional anesthesia of spinal block with adductor nerve block using a forced-air blanket for 15 to 30 minutes could prevent hypothermia in patients undergoing total knee arthroplasty more effectively than a common method of prewarming.

Reduction in body temperature of the subjects in both groups after the surgery was completed until the subjects arrived at the recovery room depends on different factors. To begin with, age is one of the factors that could explain reduction in body temperature. The subjects in both groups were older adults. In general, core temperature of older adults can easily change due to an increase in age which causes the decline in perception of heat and coldness.⁽⁵⁾ Also, older adults experience the decline in metabolism to generate heat because a decrease in muscle mass and their heat ventilation is also reduced due to shrinkage of the sweat glands and a deterioration of the blood ventilation system.⁽⁷⁾ Another factor is the type of surgery.⁽¹⁵⁾ In this study, the patients underwent total knee arthroplasty, which involved uncovering some areas of the body, and their body can lose its heat through evaporation, the degree of which depends on room temperature and relative humidity at the time of the operation. Moreover, during the surgery, intravenous fluid was administered, and their surgical wounds were cleaned. Water is a medium that leads the heat deep in the body up to the skin before it evaporates into the air around the body.⁽²⁰⁾ As a result, patients who undergo a major surgery or a surgery with administration of intravenous fluids and wound cleaning can develop hypothermia after the surgery.^(2, 3) The third factor

is type and duration of anesthesia.⁽⁵⁾ In the present study, all subjects received regional anesthesia. It is believed that regional anesthesia makes patients susceptible to hypothermia as the medication dilates their blood vessels approximately 15 minutes after its administration, hence the heat is transferred to the peripheral areas and heat loss occurs through the skin, with the vein as the conductor.⁽²¹⁾ As regards duration of anesthesia, during the first hour of administration, the blood vessels all over the body are dilated, hence heat loss. During the second to the fourth hours, the body experiences more heat loss than heat production, so the core temperature is significantly reduced. It has been found that if the duration of anesthesia is longer than one hour, the patients are more susceptible to hypothermia.^(1 - 3, 9) In addition, after the surgery is done, there is a collapse of the tourniquet on the leg that is operated on after the surgical wound is closed, and all the cloth is removed, so the patients' skin is exposed to the low temperature in the operating room.⁽⁴⁾ Generally, heat loss occurs when there is heat radiation, heat conduction, heat convection, and heat evaporation. However, it has been reported that heat convection and heat radiation are the two most important causes of heat loss, as much as 85.0%.^(2, 5) Even though the air conditioning system in the operating room is turned off before the sterilized cloth is removed, the temperature inside the operating room can still be low, hence a significant heat loss.⁽⁶⁾ In this study, the differences in the means of operating room temperature and relative humidity of the subjects in the experimental group and control group were not statistically significantly different. According to Pei L, *et al.*⁽²²⁾, the temperature of the operating room should be around 20°C to 23°C and the relative

humidity should be around 40.0% to 60.0%. In the present study, the subjects in both groups experienced heat loss due to heat conduction as the gurney that was used to transfer them to from the operating room to the recovery room was cold due to the low operating room temperature. Therefore, the subjects' body temperature had reduced by the time they arrived at the recovery room. In addition, it has been documented that the patients' clothing can have an effect on changes in body temperature. Patients undergoing a surgery generally wear very few pieces of clothing, which tend to be thin, and this can cause further heat loss.^(8, 10, 11) In this study, a forced-air blanket was used to increase body temperature before administration of regional anesthesia. The effects of the anesthesia rapidly reduce the body temperature within 30 minutes after administration.^(12, 13) Prewarming with a forced-air blanket or active warming can increase the core temperature by 0.5°C to 1°C by stimulating the body to generate more heat before the surgery⁽¹³⁻¹⁶⁾, hence reducing the incidence of postoperative hypothermia.

With regard to shivering, it was found that the subjects who received prewarming with a forced-air blanket before administration of the spinal block with adductor nerve block had less shivering than those who received only routine prewarming (45.2% and 80.6%, respectively). Likewise, Muensakul S, *et al.*⁽²³⁾ compared the effects of prewarming before administration of the spinal block with adductor nerve block and routine prewarming in patients undergoing a Cesarean section and found that more of the subjects in the control group experienced shivering than the subjects in the experimental group, making up 70.0% and 16.7%. In addition, De Bernadis RC, *et al.*⁽²⁴⁾ conducted a study with patients undergoing a Cesarean section and found that prewarming before administration of anesthesia could reduce postoperative shivering, as 10.0% and 40.0% of the subjects in the experimental group and the control group experienced shivering. Similarly, Shin KM, *et al.*⁽²⁵⁾ examined the use of prewarming 30 minutes before administration of general anesthesia using a forced-air blanket with the temperature of 38°C in patients undergoing endovascular coiling of cerebral aneurysms. The body temperatures were measured immediately and every 20 minutes after the administration until the surgery was done. It was discovered that only 10.0% of the experimental subjects experienced shivering, whereas 22.2% of

the subjects did. In addition, Horn EP, *et al.*⁽²⁶⁾ conducted a study with 200 patients undergoing a surgery whose duration ranged from 30 to 90 minutes with prewarming being used at 10, 20, and 30 minutes before administration of general anesthesia. Visual inspection was employed to assess shivering, and it was found that 6.0%, 7.0%, and 2.0% of the patients who received prewarming 10, 20, and 30 minutes experienced shivering when they arrived at the recovery room, respectively, while 18.0% of the subjects who received routine prewarming had shivering.

The research hypothesis that prewarming 15 - 30 minutes before administration of the spinal block with adductor nerve block could reduce shivering in patients undergoing total knee arthroplasty. Shivering is a result of a striated muscles that rapidly produce heat when the body is in a cool condition.⁽⁴⁾ It has been documented that when patients are in a room with the average temperature of 20°C to 24°C with relative humidity of 50.0% to 55.0%⁽¹²⁾ the cold receptors on the skin and in the spinal cord will send the data that there is a reduction in body temperature to the dorsomedian portion of the posterior hypothalamus, which will process the data and send the order back down the spinal cord to let the motor neuron controls the functioning of the striated muscles.⁽¹¹⁾ The command is not rhythmic and increases the tone of the striated muscles all over the body.⁽²⁷⁾ Once the tone reaches a critical point, asynchronous muscle contraction will take place, which is involuntary control.⁽²¹⁾ It is believed that shivering of the striated muscles is a reflex mechanism of muscle spindle, and it can produce the heat up to four to five times of the heat that is generated in a normal condition.⁽²⁷⁾

Implications of the findings

It could be concluded that the use of the forced-air blanket can help reduce the incidence of hypothermia in patients undergoing total knee arthroplasty. A guideline on the use of a forced-air blanket should be developed to reduce shivering and discomfort in patients undergoing total knee arthroplasty.

Recommendations

Further researches should be conducted to investigate the effects of prewarming longer than 30 minutes or compare different durations of

prewarming to determine the duration of prewarming that most effectively reduces hypothermia and shivering. In the present study, all subjects received regional anesthesia. Studies should be carried out to compare the use of prewarming with a forced-air blanket with patients who receive general anesthesia and those who receive regional anesthesia. The present study examined the effects of prewarming with a forced-air blanket on hypothermia and shivering. In the future, the effects of prewarming with a forced-air blanket on anxiety and pain should also be explored.

This research was done at a university hospital. The sample group was maintained by a health team with specialized expertise and equipment, receiving equal treatment for all rights of treatment. Therefore, there might be a limitation in applying the results to refer to patients with different contexts with this study.

Conclusion

The results showed prewarming before administration of the spinal block together with localized anesthesia of femoral nerve block or regional anesthesia of spinal block together with localized anesthesia of adductor canal nerve block is effective in reducing the occurrence of hypothermia and postoperative shivering. Therefore, this should be a guideline for improvement of nursing care.

Acknowledgements

The authors would like to acknowledge and thank the Faculty of Nursing, Faculty of Graduate Mahidol University, Charoenkrung Pracharak Hospital, for support of this research.

Conflict of interest

The authors, hereby, declare no conflict of interest.

References

1. Bashaw MA. Guideline implementation: Preventing hypothermia. *Aorn J* 2016;103:305-10.
2. Ratanatherawichian Y, Asdornwiset U, Thongkam N, Kanlayanakoo K. Incidence and predictive factor of postoperative hypothermia of patients in Post-Anesthesia Care Unit (PACU). *J Nurs Sci* 2014;31:34-44.
3. Frisch NB, Pepper AM, Rooney E, Silverton C. Intraoperative hypothermia in total hip and knee arthroplasty. *Orthopedics* 2017;40:56-63.
4. Sharma M, Kharbuja K, Khadka B. Comparison of pethidine and tramadol for the control of shivering in patients undergoing elective surgery under spinal anesthesia. *J Lumbini Med Coll* 2016;4:64-7.
5. Kurnat-Thoma EL, Roberts MM, Corcoran EB. Perioperative heat loss prevention-a feasibility trial. *Aorn J* 2016;104:307-19.
6. Billeter AT, Hohmann SF, Druen D, Cannon R, Polk HC, Jr. Unintentional perioperative hypothermia is associated with severe complications and high mortality in elective operations. *Surgery* 2014;156:1245-52.
7. Sessler DI. Temperature monitoring: the consequences and prevention of mild perioperative hypothermia. *SAJAA* 2014;20:25-31.
8. Koenen M, Passey M, Rolfe M. Keeping them warm-a randomized controlled trial of two passive perioperative warming methods. *J Perianesth Nurs* 2017;32:188-98.
9. Diaz M, Becker DE. Thermoregulation: Physiological and clinical considerations during sedation and general anesthesia. *Anesth Prog* 2010;57:25-32.
10. Torossian A, Brauer A, Hocker J, Bein B, Wulf H, Horn E-P. Preventing inadvertent perioperative hypothermia. *Dtsch Arztebl Int* 2015;112:166-72.
11. Kishore N, Payal YS, Kumar N, Chauhan N. In spinal anaesthesia for cesarean section the temperature of bupivacaine affects the onset of shivering but not the incidence: A randomized control trial. *J Clin Diagn Res* 2016;10:Uc18-21.
12. Nicholson M. A comparison of warming interventions on the temperatures of inpatients undergoing colorectal surgery. *Aorn J* 2013;97:310-22.
13. Roberson MC, Dieckmann LS, Rodriguez RE, Austin PN. A review of the evidence for active preoperative warming of adults undergoing general anesthesia. *Aana J* 2013;81:351-6.
14. Horn EP, Bein B, Bohm R, Steinfath M, Sahili N, Hocker J. The effect of short time periods of pre-operative warming in the prevention of peri-operative hypothermia. *Anaesthesia* 2012;67:612-7.
15. Paulikas CA. Prevention of unplanned perioperative hypothermia. *Aorn J* 2008;88:358-65.
16. Kellam MD, Dieckmann LS, Austin PN. Forced-air warming devices and the risk of surgical site infections. *Aorn J* 2013;98:354-66.
17. Alderson P, Campbell G, Smith AF, Warttig S, Nicholson A, Lewis SR. Thermal insulation for preventing inadvertent perioperative hypothermia. *Cochrane Database Syst Rev* 2014: Cd009908.
18. McSwain JR, Wolf BJ, Wilson SH. Neuraxial hypothermia incidence misinterpreted. *J Clin Anesth* 2017;40:125.

19. Rosenkilde C, Vamosi M, Lauridsen JT, Hasfeldt D. Efficacy of prewarming with a self-warming blanket for the prevention of unintended perioperative hypothermia in patients undergoing hip or knee arthroplasty. *J Perianesth Nurs* 2017;32:419-28.
20. Horosz B, Malec-Milewska M. Inadvertent intraoperative hypothermia. *Anaesthesiol Intensive Ther* 2013;45:38-43.
21. Maniar A, Koh KF. Heat balance and anaesthetic implications in the elderly. In: Dodds C, Kumar CM, Veering BT, editors. *Oxford textbook of anaesthesia for the elderly patient*. New York: Oxford University Press; 2014. p. 280-87.
22. Pei L, Huang Y, Xu Y, Zheng Y, Sang X, Zhou X, et al. Effects of ambient temperature and forced-air warming on intraoperative core temperature: A factorial randomized trial. *Anesthesiology* 2018;128:903-11.
23. Muensakul S, Kunsongkeit W, Deenan A. Effects of warming program on core temperature and shivering among women receiving cesarean section under spinal anesthesia. *J Fac Nurs Burapha Univ* 2013;21: 62-73.
24. De Bernardis RC, Siaulyis MM, Vieira JE, Mathias LA. Perioperative warming with a thermal gown prevents maternal temperature loss during elective cesarean section. A randomized clinical trial. *Braz J Anesthesiol* 2016;66:451-5.
25. Shin KM, Ahn JH, Kim IS, Lee JY, Kang SS, Hong SJ, et al. The efficacy of pre-warming on reducing intraprocedural hypothermia in endovascular coiling of cerebral aneurysms. *BMC Anesthesiol* 2015;15:8.
26. Horn EP, Bein B, Broch O, Iden T, Bohm R, Latz SK, et al. Warming before and after epidural block before general anaesthesia for major abdominal surgery prevents perioperative hypothermia: A randomised controlled trial. *Eur J Anaesthesiol* 2016;33:334-40.
27. Yang L, Huang CY, Zhou ZB, Wen ZS, Zhang GR, Liu KX, et al. Risk factors for hypothermia in patients under general anesthesia: Is there a drawback of laminar airflow operating rooms? A prospective cohort study. *Int J Surg* 2015;21:14-7.