Relationship between Core-Peripheral Temperature Difference and Shivering Symptom in Patients in Post-Anesthesia Care Unit

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Objective: *To investigate the relationship between shivering symptom and core-peripheral temperature differences of postoperative patients admitted to post-anesthesia care unit (PACU) and evaluate factors related to postoperative shivering.*
Material and Method: *This is a prospective case control study which observed postoperative adult patient, ASA physical class I-III with the operative period of 1 to 4 hours who were admitted to PACU. Core (tympanic membrane) and peripheral (forehead and dorsum of hand) temperature was measured at 0, 15, 30, 45 and 60 minutes PACU admission. Shivering symptom was observed at the same time points of temperature measurement and classified by severity of shivering into grade 0 to 4.*
Results: *Patients with shivering had significantly less core-forehead temperature differences compared with patients without shivering but the core-dorsum of hand temperature differences were similar in both groups. In one hundred patients in the shivering group, 90% of the patients had shivering when immediately admitted to PACU and there were only 26% of patients having the symptom at 60 minutes. Factors related to shivering symptom were vascular surgery (adjusted OR 16.40 (95% CI 1.37 to 195.68), p = 0.03) and abdominal surgery (adjusted OR 4.38 (95% CI 1.06 to 18.09), p = 0.04).*
Conclusion: *The core-forehead temperature difference was related with shivering symptom in PACU while the core-dorsum of hand difference has no relationship. Types of surgery including vascular surgery and abdominal surgery were identified as factors related to shivering symptom.*

Keywords: *Shivering, Temperature Differences, Post-anesthetic care unit*

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Humans are warm-blooded animals or homeotherms; they have an ability to regulate body temperature within physiologic range by balancing heat production and heat loss[1,2]. The body temperature refers to either core temperature or peripheral temperature[1,3]. Core body temperature refers to the temperature of deep tissues of the body which can be measured under tongue as sublingual, in the ear canal as tympanic membrane, or in the rectum. The normal range of human core body temperature is typically between 36.5 and 37.5°C[4]. In contrast to core temperature; peripheral temperature, recorded in tissues such as skin, varies markedly and depends on surroundings environment exposure, duration of exposure, thermoregulatory vasomotor and core temperature[1-3,5].

In the operating theater, patients are exposed to a low ambient temperature with little or no clothing with evaporation from the surgical area and an administration of unwarmed intravenous fluids. Moreover, anesthetic agents have influence on the autonomic thermoregulatory mechanism, the thresholds for vasoconstriction, perspiration and shivering. All these factors promote patients' unintentional loss of heat and cause hypothermia. The term of hypothermia refers to the core body temperature less than or equal to 36.4°C[5]. Consequences of hypothermia include prolong effects of intraoperative anesthetic medication, myocardium infarction, insulin resistance, increased intraoperative blood loss, infection, and poor wound healing[6-10].

Shivering is a physiologic response and compensatory mechanism to early hypothermia in mammals. The mechanism thermogenic shivering related to increased neuronal efferent outflow to skeletal muscle, increased muscle stretch reflexes and

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subsequent feedback oscillations. This is an involuntary process that augments metabolic heat production[1,11]. Sustained shivering augments a 5 to 100% of metabolic heat production in adults and vigorous shivering increases metabolic heat production up to 600% above basal level which leads to increased oxygen demand and workload of the heart[1,9,12]. Postoperative shivering is one of the most common postoperative complications following general anesthesia and also occurs intraoperatively in patients having moderate or deep sedation.

The incidence of postoperative shivering is 65% of patients after general anesthesia and 33% of patients after regional anesthesia[10]. Thermogenic shivering is an obvious etiology of post-anesthetic tremor, however some patients have normal core temperatures until suffering from shivering[5,8-10,13]. This implies that only core temperature is not enough for predicting or detecting patients who have shivering symptom. The hypothesis of this study was the core-peripheral temperature difference at post-anesthesia care unit (PACU) admission could indicate shivering responses and might predict shivering symptom of patients in postoperative period. Therefore, this study was initiated to investigate the relation between shivering symptom and core-peripheral temperature difference of patients when admission at PACU. Additionally, the factors related to postoperative shivering would be evaluated.

Material and Method

Study design and data collection

This analytical observational study (prospective case control study) was approved by the Institutional Review Board (Si 031/2015). All patients aged more than 18 years, American Society of Anesthesiologists (ASA) physical status classification I-III, scheduled to have a surgery with an operative time of 1 to 4 hours, and planned to have an admission to the fifth floor of PACU at Siriraj Hospital in the study period were informed and obtained their consent preoperatively by one of the authors. Intraoperative and postoperative data were collected from anesthetic record and perioperative nursing record from January to December 2015. Patients having a history of induced hypothermia intraoperatively or intraoperative severe hypotension with continuous infusion of vasopressors, residual neuromuscular blockade, and rejection or unwillingness to participate in this study were excluded.

Intraoperative data from the anesthetic record were collected as patients' demographics, ASA physical status, type of surgery (abdominal, breast, head and neck, urological and vascular surgery), choice of anesthesia (general or regional anesthesia), operative time, volume of fluid administration, estimated blood loss, temperature of operative theater from each operating theater thermometer and using force air warmer.

In the PACU, all recruited patients' core body and peripheral temperature were measured during duration in the PACU by one of the authors. The core body temperature was measured via tympanic membrane using Microlife model ear thermometer IR1DF1-1 with an infrared sensor. The tip of the thermometer was simply positioned in the ear canal and results were obtained in one second. The peripheral temperature was measured at forehead and dorsum of hand using Microlife model non-contact thermometer FR1DL1. Both thermometers have accuracy of $\pm$0.2°C. Both core and peripheral temperatures were measured at 0, 15, 30, 45 and 60 minutes in PACU. Shivering symptom was observed in all patients at the same time points of temperature measurement and classified severity of shivering into grade 0 to 4 by another author (0 = no shivering; 1 = no visible muscle activity, but one or more of piloerection, peripheral vasoconstriction or peripheral cyanosis; 2 = muscular activity in only one muscle group; 3 = moderate muscular activity in more than one muscle group, but not generalized shaking; 4 = violent muscular activity that involves the entire body)[14]. Patient having any grade of shivering at any point in time was categorized to the shivering group.

Sample size calculation and statistical analysis

For sample size calculation, logistic regression with incidence report of shivering was 65%[5] and the estimated number of independent variables of 10 factors including: core-peripheral temperature difference, anesthetic technique, blood loss (mL), volume of intravenous fluid (mL), duration of operation (hours), patient warming (yes/no), patient age (years), operative room temperature, type of surgery and ASA physical status). The total calculated sample size was 154 patients and was increased to 200 patients including a 30% dropout. Therefore one-hundred shivering patients and another one hundred non-shivering patients were collected.

Data were analyzed using PASW Statistics for Windows, 18.0 Chicago: SPSS Inc. Patients' characteristics were presented as mean and standard

deviation or frequency and percentage as appropriated. Comparisons of patients' characteristics between groups were made using Chi-square test. Independent t-test was used for comparing the mean of core-peripheral temperature difference between the shivering and non-shivering group. Spearman rank correlation was used to assess the relationship between core-peripheral temperature difference and shivering grading. The risk factors related postoperative shivering symptom will be calculated by multiple logistic regressions.

Results

A total of 296 patients were potentially eligible; 216 patients were examined for eligibility and 200 patients were finally analyzed in shivering and non-shivering group (Fig. 1). Patients' demographics and intraoperative data were presented in Table 1. There were no statistically significant difference in demographics data, type of surgery, anesthetic technique, duration of operation, intraoperative fluid administration and blood loss; and intraoperative force air heating. However, average operative theater's temperature of patients having postoperative shivering was significantly less than non-shivering group.

The median core-peripheral temperature differences were shown in Fig. 2 and 3. The median core-forehead temperature differences in patients with shivering were significantly less than patients without shivering (Fig. 2) at 0, 15, 30, 45 and 60 minutes after admitted to PACU while the core-dorsum of hand temperature differences were similar in both groups at all time points (Fig. 3). In shivering patients, core temperatures were less than forehead temperature (negative temperature difference) especially in early postoperative period (0, 15 and 30 after PACU admission). In contrast, patients without shivering had core temperatures higher than forehead (positive temperature difference) at all times in postoperative period. However, the difference in core-dorsum of hand temperature were positive in both shivering and non-shivering groups. A Spearman correlation analysis revealed a significant and positive relationship between the core-dorsum of hand temperature differences and shivering grading ($r<0.20$, $p<0.05$). The correlation was weak in strength. However, the results revealed a significant and negative relationship between the core-forehead temperature differences and shivering grading ($r<-0.20$, $p<0.05$) and the correlation was weak in strength.

In one hundred patients in shivering group, grading of severity was presented in Table 2. Ninety patients had shivering when immediately admitted to PACU. After initial management, the number of patients having shivering and severe shivering decreased gradually over time in PACU. Regarding management of shivering, all patients in the shivering group (100%) received a warm blanket, forty-five patients had force

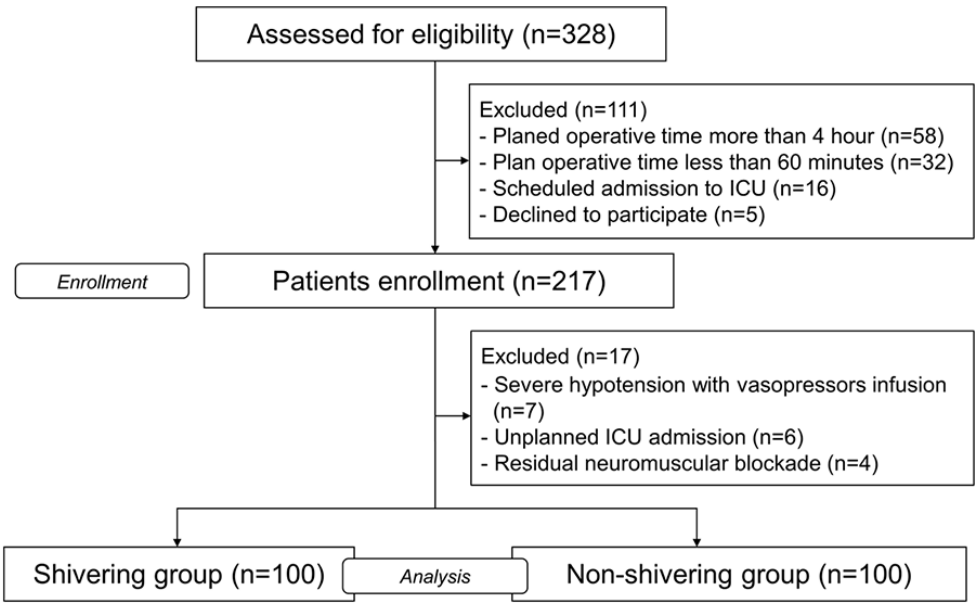


Fig. 1 Study flow diagram.

air warmer and only one patient required intravenous pethidine. Only 26% of patients experiencing shivering at 60 minutes after PACU admission. Eighteen patients had shivering at all five points in time of assessment in PACU, eleven patients had four episodes, thirty-two patients had three episodes, twenty patients had two episodes and nineteen patients had one episode of shivering.

Multiple logistic regressions for evaluating factors related shivering symptom were shown in Table 3. Factors related to shivering symptom were vascular surgery (adjusted OR 16.40 (95% CI 1.37 to 195.68), p = 0.03) and abdominal surgery (adjusted OR 4.38 (95% CI 1.06 to 18.09, p = 0.04).

Discussion

In this study, patients' demographic data in both shivering and non-shivering groups were not different except the operative theater temperature. The operative theater temperature in shivering group was significantly less than non-shivering group. In general, heat loss occurs from the skin of a patient to the environment through several processes including radiation, conduction, convection, and evaporation with convection and radiation playing a major role of intraoperative heat loss. Increased air speed in operating theater can increase the convecting heat loss from the patient to the environment, but it still remains unclear for the operative theater temperature setting[8,13,15]. The results showed several factors related to shivering such as various type of operation including abdominal and vascular surgery. Further study is required to prove and confirm these factors, because when the operative theater temperature setting increases from 21.2°C to 22.2°C, it can provide non-shivering patient in PACU.

Skin temperature depends on environmental temperature but core temperature remains relatively constant due to a thermoregulatory system[16]. According to normal body response to hot and cold stimuli, the peripheral receptors generate nerve impulse to the temperature center at the hypothalamus. The hypothalamus calculates mean body temperature by integrating thermal signal and comparison with the setpoint or threshold temperature which results in in altered behavior, a vasomotor response (consisting of vasoconstriction and piloerection in cold and vasodilatation in hot), sweating and decrease metabolic

Table 1. Patients demographics

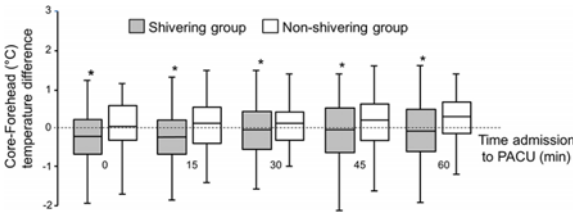
	Shivering (n = 100)	Non-shivering (n = 100)	*p*-value
Gender (male/female)	46/54	44/56	0.77
Age (yr)	58.5±14.7	60.0±14.3	0.96
ASA physical classification I/II/III	29/56/15	19/61/20	0.22
Type of surgery			0.35
Abdominal surgery	42	33	
Breast surgery	22	22	
Urological surgery	20	21	
Vascular surgery	8	11	
Head-neck surgery	5	12	
Anesthetic technique			0.32
General anesthesia	71	64	
Combined general and regional anesthesia	14	14	
Spinal anesthesia	13	14	
Peripheral nerve block	2	5	
Intravenous sedation	0	3	
Operative time (min)	110±52	121±53	0.16
Intraoperative fluid administration (mL)	899±835	773±597	0.66
Estimated intraoperative blood loss (mL)	139±63	114±85	0.63
Having intraoperative force air warmer	77	85	0.15
Operative theater temperature (°C)	21.2±0.9	22.2±0.9	<0.01

Data are presented as number or mean ± SD
ASA = American society of anesthesiologists

rate (in hot), and shivering and increase metabolic rate (in cold)[5]. This can imply that patients might suffer with shivering when body temperature is below the threshold. On the other hand, when body temperature is above the threshold patients might not suffer with shivering. This study presented that the median core-dorsum of hand temperature differences were similar in both groups. This results is consistent with the recent study which revealed shivering that could happen in non-hypothermic patients and not in some hypothermic patients[10]. In another peripheral temperature study, Crossley's study revealed scattered plots of shivering grade against axillary temperature on entry into the recovery room is shown in similar plots, obtained after 15 minutes and again after 30 minutes[14]. There was no relationship between axillary temperature and the onset of shivering or the shivering grade at any time[14]. The median core-dorsum of hand temperature differences has no relationship with shivering because it provides the same result as only core body temperature. There was no benefit in predicting the patient who would suffer from shivering.

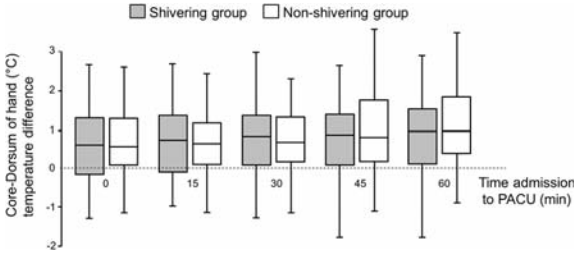
Additionally, the results present that the median core-forehead temperature differences in patients with shivering were less than in patients without shivering. That means if the core and forehead temperature is not too different, the patients suffer with shivering.

Although the temperature measurements on the forehead and dorsum of the hand are both peripheral temperature, they can be dissimilar because of different skin perfusion. In general, when skin cold stimuli is stimulated the heat transfers from the central part to the peripheral part of the body; core to peripheral redistribution. If core and peripheral temperature are equal, hypothalamus senses as equilibrium and response when the temperature is out of the threshold. General and regional anesthesia can modulate this response[13]. In this study, the core-forehead temperature differences which were near zero provided weak stimuli to thermoregulatory center in



PACU = Post-anesthesia care unit; * p<0.05

Fig. 2 Comparison of median core-forehead temperature difference between shivering and non-shivering group at 0, 15, 30, 45 and 60 minutes postoperative care unit admission.



PACU = Post-Anesthesia care unit; * p<0.05

Fig. 3 Comparison of median core-dorsum of temperature difference between shivering and non-shivering groupat 0, 15, 30, 45 and 60 minutes postoperative care unit admission.

Table 2. Severity of shivering at entry to PACU, after 15,30,45 and 60 minutes

Entry to PACU (min)	Severity of shivering (n = 100)				
	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
0	10	71	7	10	2
15	23	67	6	2	2
30	40	55	1	2	2
45	64	30	1	3	2
60	74	20	3	3	0

Data are presented as number

Severity of shivering is classified to Grade 0 = no shivering; Grade 1 = no visible muscle activity, but one or more of piloerection, peripheral vasoconstriction or peripheral cyanosis; Grade 2 = muscular activity in only one muscle group; Grade 3 = moderate muscular activity in more than one muscle group, but not generalized shaking; Grade 4=violent muscular activity that involves the entire body; PACU=post-anesthesia care unit

Table 3. Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) of shivering symptom

	Adjusted OR (95% CI)	*p*-value
Type of surgery		
Vascular surgery	16.4 (1.37, 195.68)	0.03
Abdominal surgery	4.3 (1.06, 18.09)	0.04
Urological surgery	3.2 (0.66, 16.06)	0.15
Breast surgery	2.5 (0.58, 10.96)	0.22
Head-neck surgery	1	-
Type of anesthesia		
General anesthesia	1.3 (0.76, 2.50)	0.18
Spinal anesthesia	0.9 (0.41, 2.07)	0.50
Peripheral nerve block	0.3 (0.08, 2.05)	0.22
Combined general and regional anesthesia	1	-
Operative time (hr)	0.6 (0.39, 0.98)	0.04
Estimated intraoperative blood loss (mL)	1.0 (1.00, 1.00)	0.22
Intraoperative forced air warming (No)	1.7 (0.65, 4.65)	0.27
Operative theater temperature (°C)	0.2 (0.16, 0.40)	<0.01

Multivariate logistic regression, adjusting for the other factors shown in the table

hypothalamus as in equilibrium state during intraoperative period and the response could only be from the core temperature. It is inconclusive that the median core-forehead temperature differences have a relationship with shivering, thus further study is required to prove this result.

This study revealed that the number of shivering patients and the severity were high for those admitted to PACU, and the number of patients and severity declined until discharge. In PACU, the PACU personnel always provide all effective prevention and treatment of shivering such as force air warmer, increased environment temperature, and anti-shivering drug administration[10].

From multiple logistic regressions for evaluating factors related to shivering symptom, there were vascular surgery and abdominal surgery. From previous studies the risk factors for postoperative shivering were young age, endoprosthesis surgery, core hypothermia, blood loss volume, and core temperature at the end of surgery[15,16]. This study revealed that intraoperative blood loss was not a factor related to postoperative shivering. The authors' institute always provided extensive warming material in patients who expected to have above average intraoperative blood loss more. In the authors' center, vascular and major intraabdominal surgery usually required general anesthesia and the patients have a trend to expose themselves without warming material during intraoperative period. This could be one of this study's limitations. Further study is still required to exclude all bias and identify the factors related to shivering in PACU.

The study has some limitations. First, there were two different thermometers used in this study; tympanic membrane thermometer and peripheral thermometer which are used as in instructions indicate. The authors did not know the exact temperature if the authors used in comparison. The second was the sites of temperature measurement selection. Tympanic membrane was not the preferable site and strongly representative core body temperature but it was comfortable to patient in PACU to measure. The same as forehead for peripheral temperature, this was close to tympanic membrane. If the authors measured the forehead temperature near the auditory meatus, the core and peripheral temperature might be the same temperature.

Conclusion

The core-forehead temperature difference was related with shivering symptom in PACU while the core-dorsum of hand difference has no relationship. Type of surgery including vascular surgery and abdominal surgery is identified as factor related to shivering symptom. By the way further study is still required to prove and confirm this study's result to predict the patients who have a chance of shivering in PACU.

What is already known on this topic?

Incidence of postoperative shivering has

been demonstrated up to 65%. Thermoregulatory is a normal response in human. Core temperature and temperature threshold are important factors influencing shivering. Intraoperative and postoperative shivering has many consequences and requires treatment.

What this study adds?

This study demonstrated the risk factors related to postoperative shivering and presented that the differences between core and forehead temperatures might predict shivering symptom in post-anesthesia care unit.

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Trial registration

ClinicalTrial.gov registration as NCT03157648.

Potential conflicts of interest

None .

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ความสัมพันธ์ระหว่างผลต่างระหว่างอุณหภูมิส่วนกลางกับส่วนปลายกับอาการหนาวสั่นในผู้ป่วยหลังผ่าตัดในห้องพักฟื้น

ภูริพงศ์ ทรงอาจ, ไพรินทร์ ชิ้มเจริญ, มิ่งขวัญ วงษ์ยิ่งสิน

วัตถุประสงค์: เพื่อหาความสัมพันธ์ระหว่างผลต่างระหว่างอุณหภูมิส่วนกลางกับส่วนปลายกับอาการหนาวสั่นในผู้ป่วย หลังผ่าตัดในห้องพักฟื้นและปัจจัยที่มีความเกี่ยวข้องกับอาการหนาวสั่นของผู้ป่วย

วัสดุและวิธีการ: การศึกษาไปข้างหน้าแบบจำกัดอาการผู้ป่วย (สั่นหรือไม่สั่น) ทำในผู้ป่วยผู้ใหญ่ที่มีลักษณะทางกายภาพ ASA classification 1-3 และมีระยะเวลาผ่าตัด 1 ถึง 4 ชั่วโมง โดยการสังเกตอาการในห้องพักฟื้นหลังผ่าตัด ผู้ป่วยทุกคนจะได้รับการวัดอุณหภูมิกายส่วนกลางผ่านทางเยื่อแก้วหูและอุณหภูมิกายส่วนปลายทางหน้าผากและหลังมือที่เวลา 0, 15, 30, 45, และ 60 นาทีในห้องพักฟื้นร่วมกับสังเกตอาการหนาวสั่นและจำแนกความรุนแรงของอาการสั่นเป็นระดับ 0 ถึง 4 ณ เวลาเดียวกับที่วัดอุณหภูมิกาย

ผลการศึกษา: ผู้ป่วยที่มีอาการหนาวสั่นมีค่าผลต่างระหว่างอุณหภูมิส่วนกลางกับหน้าผากต่ำกว่าอย่างมีนัยสำคัญทางสถิติ เมื่อเปรียบเทียบกับผู้ป่วยที่ไม่มีอาการหนาวสั่น ในขณะที่ค่าผลต่างระหว่างอุณหภูมิส่วนกลางกับหลังมือไม่แตกต่างกัน ในผู้ป่วยทั้งสองกลุ่มผู้ป่วยร้อยละ 90 มีอาการหนาวสั่นทันที เมื่อเข้ามารับการดูแลในห้องพักฟื้น และมีผู้ป่วยร้อยละ 26 ที่ยังมีอาการหนาวสั่นที่เวลา 60 นาทีในห้องพักฟื้น ปัจจัยที่มีความสัมพันธ์กับอาการหนาวสั่น ได้แก่ คือ การผ่าตัดหลอดเลือด (OR 16.40 (95% CI 1.37 ถึง 195.68), p = 0.03) และการผ่าตัดในช่องท้อง (OR 4.38 (95% CI 1.06 ถึง 18.09), p = 0.04)

สรุป: ผลต่างระหว่างอุณหภูมิส่วนกลางกับหน้าผากมีความสัมพันธ์กับอาการสั่นในห้องพักฟื้นในขณะที่ค่าผลต่างระหว่างอุณหภูมิส่วนกลางกับหลังมือไม่มีความสัมพันธ์ประเภทของการผ่าตัด ซึ่งได้แก่ การผ่าตัดหลอดเลือดและการผ่าตัดช่องท้องถือเป็นปัจจัยที่มีความสัมพันธ์กับอาการหนาวสั่น