Characteristic Changes between Core and Peripheral Surface Temperature Related with Postanesthetic Shivering Following Surgical Operations

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The relationship between changes in the core and the surface temperature and postanesthetic shivering was studied in 100 patients who underwent general anesthesia. Patients were classified into four groups by the patterns of change in the core and peripheral surface temperature. Type II and type IV groups of patients showed a decrease in surface temperature during the major operation such as gastrectomy and radical mastectomy. Type I and type III groups of patients showed no lowered peripheral surface temperature and with low temperature difference between core and surface temperature during the operation. The patients in type II and IV groups showed increased difference between core and surface temperature. The postanesthetic shivering occured at significantly higher rate compared to the other two groups. As possible reasons of the shivering, operation of long duration and insufficient circulating blood volume were considered. Shivering reduces the temperature difference in the thermoregulatory homeostasis. However, in patients in type I and III, the rate of shivering was low. Evaluation of the difference between core and peripheral surface temperature may be important to manage body temperature at a steady level during the operation. The monitoring of body temperature difference between core and peripheral surface during the operation may be useful for predicting to occurrence of postanesthetic shivering. (Key words: core temperature, peripheral surface temperature, postanesthetic shivering)

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Postanesthetic shivering is a common complication encountered in anesthetized patients. When shivering occurs, an increase in ventilation appears to compensate for the hypermetabolism hypoxia of the tissue[1–3]. Thus, patients with an impaired cardiopulmonary functions may accelate those functions leading cardiopulmonary insuficiency or severe metabolic acidosis[4].

Recently, rectal or esophageal temperature has been monitored for managing the body temperature. But it is very difficult to predict to occurrence of shivering. Only rectal or esophageal temperature can not reflect the whole body temperature. Because the thermoregulation depends on central and peripheral temperature, the monitoring for managing the body temperature should be measured simultaneously both central and peripheral temperature at least.

In this study, we measured simultaneously

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Table 1. Shivering Occurrence Rate Classified According to Age and Type of Operation (%)

type of operation \ age	16–49	50–69	70–	
laparotomy	18.8	11.8	20.0	16.7
non-laparotomy	29.4	4.3	8.3	13.5
	24.2*	7.5	14.8	15.0

*$P < 0.05$, compared to the rate of 50–69 aged gorup

Table 2. Operating Periods and Loss of Blood Volume

	operating periods (min)	loss of blood volume (ml)
shivering (+) $n = 15$	297.0 ± 27.9*	1021.5 ± 253.6*
shivering (–) $n = 85$	238.4 ± 11.1	611.6 ± 65.1

Values are mean ± SEM
*$P < 0.05$, compared to the values of the shivering (–) group

both core and peripheral surface temperature during anesthesia. Thus, the aims of this study were; 1) to evaluate a possible prediction of occurrence of postanesthetic shivering by means of monitoring of difference between core and peripheral surface temperature, 2) to examine possible factors for the occurrence of postanesthetic shivering.

Materials and Methods

As subjects of this study, we chose 100 patients (48 males, 52 females) who were received major operation at our hospital under general anesthesia, and who had an ASA 1-2. Age of the patients were between 16–85 years (mean age 56.6 years). They were divided into two groups; laparotomy (48 cases) such as gastrectomy and non-laparotomy (52 cases) such as radical mastectomy. According to another classification of the patients were grouped into 3 aged groups; 16–49 (33 cases), 50–69 (40 cases) and more than 70 years old (27 cases). Types of anesthesia used in this study were GOẼ (77 cases), GOF (4 cases), GOẼ + NLA (9 cases) and GOẼ + NLA + epidural anesthesia (10 cases).

Both core and peripheral surface temperatures were measured by a digital thermometer (Monatherm Co. model 6500). Skin sensors were placed on the forehead and the dorsal surface of a foot. These two temperatures were monitored and recorded on anesthetic chart at a regular interval of 5 min during the first 30 min. After this period, they were measured at a regular interval of 15 min until complete awakening. We also monitored rectal temperature or esophageal temperature, and room temperature using a thermometer (Termo Co. Termo Finer). An evaluation of shivering was identified by observation of systemic muscular movements.

The values in this text are expressed as mean ± SEM. Statistical comparisons were made using unpaired t-test. A p value less than 0.05 was considered a significant difference.

Results

Postanesthetic shivering occurred in 15% of all patients (table 1). Patients who received laparotomy showed a slightly higher occurrence of shivering (16.7%) than non-laparotomy group (13.5%), but not significantly. However, the rate of postanesthetic shivering in the younger group was 24.2% and highest within three groups. Also, the rate of postanesthetic shivering in the younger group was significantly higher than that in the 50–69 aged group. As shown in table 2, there were significant difference in operating periods between shivering (+) group and shivering (–) group. And the operating periods in shivering (+) group were longer than that in shivering (–) group. Further, there were significant difference in the loss of blood volume during surgery between shivering (+) group and shivering (–) group (table 2). The loss of blood volume in shiv-

Table 3. Relationship between Changes in Room Temperature and Rectal Temperature and the Occurrence of Shivering

	room temperature		rectal temperature	
	at entering	at extubation	after induction	at extubation
shivering (+) $n = 15$	24.12 ± 0.38	24.33 ± 0.28	36.97 ± 0.06	36.89 ± 0.16
shivering (−) $n = 85$	24.58 ± 0.16	24.68 ± 0.15	36.94 ± 0.05	37.00 ± 0.06

Values are mean ± SEM

Table 4. Relationship between Changes in Core and Peripheral Surface Temperature and Shivering Occurrence

	core temperature		peripheral surface temperature		
	at entering	at leaving	at entering	after induction	at leaving
shivering (+) $n = 15$	34.61 ± 0.30	34.64 ± 0.25	30.45 ± 0.31	34.48 ± 0.40#*	31.20 ± 0.53**
shivering (−) $n = 85$	34.75 ± 0.13	34.71 ± 0.13	31.02 ± 0.20	35.45 ± 0.13#	33.92 ± 0.20#

Values are mean ± SEM
*$P < 0.01$, **$P < 0.001$, compared to the values of the shivering (−) group
#$P < 0.001$, compared to the values of at entering the operating room

ering (+) group was larger than that in shivering (−) group. The rate of shivering, related to different types of anesthetic, was 13% with GOẼ, 25% with GOF, 33% with GOẼ + NLA, and 10% with GOẼ + NLA + epidural. There were no significant differences in the rate of shivering related between different types of anesthetic.

Table 3 showed changes in room temperature and rectal temperature between patients with shivering and without shivering. Changes in room temperature did not affect the rate of shivering significantly.

No significant difference was observed in changes in core temperature between the shivering (+) group and shivering (−) group either at the time of entering or at leaving the operating room (table 4). In the shivering (+) group, peripheral surface temperature after induction of anesthesia was significantly higher than that at entering the operating room. But, at leaving the operating room, peripheral surface temperature fell more than after inductin of anesthesia. In the shivering (−) group, however, peripheral surface temperature after induction of anesthesia or at leaving the operating room was significantly higher than that at entering the operating room. Between the shivering (+) group and the shivering (−) group, significant difference was observed in peripheral surface temperature after induction of anesthesia and at leaving the operating room.

Figure 1 shows changes in the temperature difference between core and peripheral surface. In all patients temperature differ-

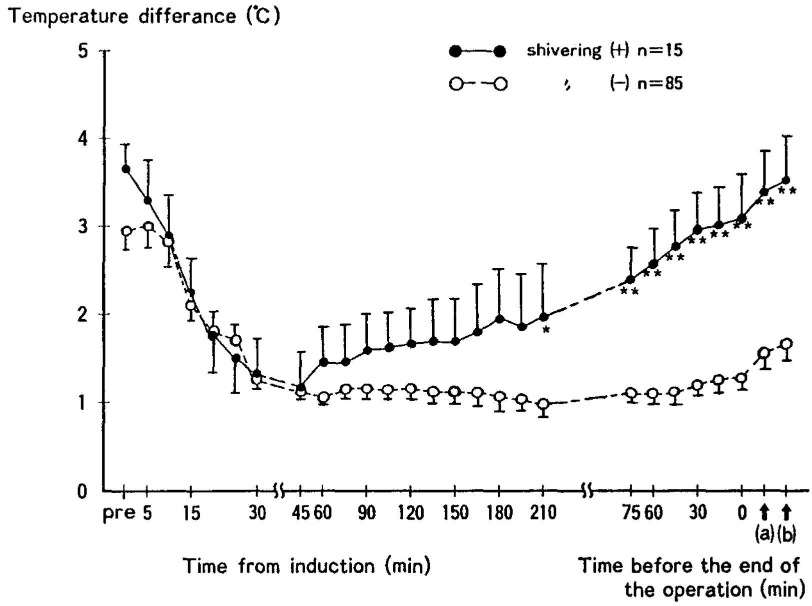


Fig. 1. Changes in the Temperature Difference between Core and Peripheral Surface during the Operation.
(a): at extubation, (b): at leaving the operating room
Values are mean ± SEM
$*P < 0.05$, $**P < 0.001$, compared to the values of the shivering (−) group

ence between core and peripheral surface decreased gradually with rising in peripheral surface temperature after induction of anesthesia. In the shivering (+) group, temperature difference between core and peripheral surface increased with time pass from one hour after induction. In the shivering (−) group, temperature difference between core and peripheral surface was low after induction of anesthesia and remained so during the operation. Differences between core and peripheral surface temperature in each group were statistically significant both at 210 min after induction of anesthesia and at 15 min intervals thereafter.

Figure 2 shows changes in the temperature difference between core and peripheral surface related to age at 60 min before and after the end of the operation and at 15 min intervals thereafter. In the shivering (+) group, difference between core and peripheral surface temperature was significantly higher in the older group than in the younger group. However, in the shivering (−) group, difference between core and peripheral surface temperature was lower than that in the shivering (+) group.

Figure 3 illustrated schematical four patterns of changes in core temperature and peripheral surface temperature during surgery. The most frequently observed pattern (type I) occurred at 74% of the patients with a rapid rise in peripheral surface temperature immediately after induction of anesthesia. Thereafter, the temperature remained relatively stable and it fell after awakening from anesthesia. The second pattern (type II) was observed in 16% of patients with a fall in the peripheral surface temperature in comparison with core temperature during the operation. The third pattern (type III) was observed in 4% of patients whose peripheral surface temperature increased gradually during surgery and approached the core temperature with a long period. Another pattern (type IV) was observed in 6% of the pa-

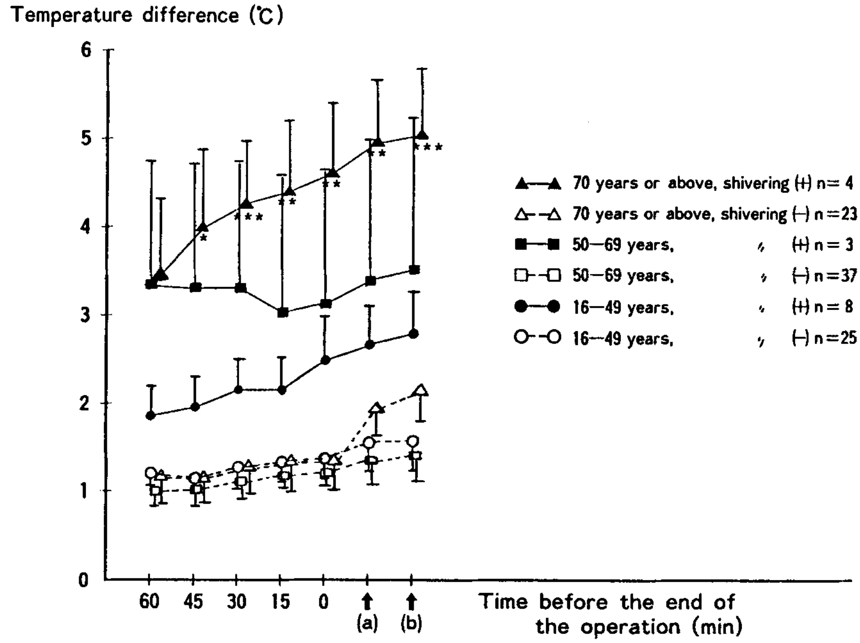
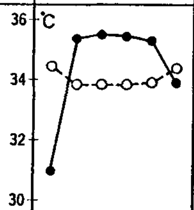
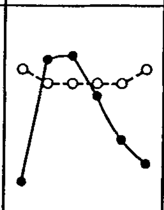
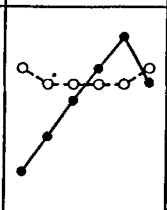
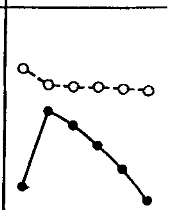


Fig. 2. Changes in the Temperature Difference between Core and Peripheral Surface Classified According to Age.
(a): at extubation, (b): at leaving the operating room
Values are mean ± SEM
$^{*}P < 0.05$, $^{**}P < 0.002$, $^{***}P < 0.001$, compared to the values of 16–49 years of age shivering (+) group

type	I	II	III	IV
pattern				
pattern appearance rate	74.0	16.0	4.0	6.0
shivering occurrence rate	4.1	56.3	0	50.0

○–○ core temperature
●–● peripheral surface temperature

Fig. 3. The Temperature Pattern in All Cases and the Shivering Occurrence Rate (%).

tients whose peripheral surface temperature did not reach to the level of core temperature. The occurrence rate of shivering in patients, who showed patterns of type II and IV, was significantly higher than the other types.

Discussion

Body temperature is regulated by activation of the thermosensitive receptors of the peripheral skin and the internal abdominal organs or thermosensitive neurons into the spinal cord and brainstem. These neurons are distributed into the pre-optic anterior hypothalamus and the anterior hypothalamus (POAH). If the thermosensitive neurons into hypothalamus are activated by the cold stimulation in peripheral surface receptors, the motor organs and the autonomic nervous system, which is distributed to the organs involving the heart and lung, show the reaction of hyperactivity. Thus, hypermetabolism occurs in the motor organs and vasoconstriction in peripheral vessels[5]. In addition, the neural control of peripheral circulation is exercised by α–adrenergic nerves in the peripheral skin and by β–adrenergic nerves in the skin of the trunk region[6]. Therefore, the vascular response of the skin on changes of temperature is altered, because the regional peculiarity of blood flow exists[7].

Based on the above physiological facts, in managing body temperature during surgery, we measured the dorsal skin temperature of the foot as peripheral surface temperature and the forehead temperature as core temperature. The forehead temperature by utilizing the heat flow compensation law is reported to reflect the temperature of the CNS via the skin of the forehead[8,9]. Results of this study have demonstrated that shivering occurred in twelve of 22 patients (about 55%) in which peripheral surface temperature fell during surgery. In these patients the temperature difference between core and peripheral surface increases as time passed by (fig. 1). Thus, the shivering is an important physiological mechanism to keep homeostasis of body temperature even during surgery.

Many hypotheses concerning etiology of postanesthetic shivering have been reported; enhancement of spinal reflex due to suppression of higher nervous functions[10], pain[11], reduction in sympathetic nerve activity[12], release of pyrogens[13], changes in the setpoint of the core body heat regulation[14]. Recently, Sessler et al.[15] showed the existence of two different wave types on an electromyogram of patients with the tremors in middle recovery from anesthesia. These patients showed clonic muscular activity or irregular rigid muscular activity. Those tremors were similar to that in patients with spinal damage. In the middle recovery from anesthesia, suppression via the higher nervous centers is released, resulting in an advancement of spinal neuron activity. Those tremors were also triggered by excitation of the spinal neurons from stimulation of cutaneous cold receptors. Thus these postanesthetic tremors differ from thermoregulating shivering due to cold. In our study, the EMG or the concentration of endtidal inhalation anesthetic were not measured. However the tremors described by Sessler et al. and the thermoregulating shivering were recognized as shivering in our study. These findings together with the present study may suggest that the occurrence rate of shivering is significantly higher in patients with the lowering of peripheral surface temperature.

Furthermore, we studied the factors which reflect on shivering in the clinical observations. The occurrence rate of shivering in younger patients was higher compared with elderly patients. But the temperature difference in younger patients was significantly smaller than in elderly patients. These results may suggest that defensive mechanism of human subjects, whose temperature difference were lowered, are maintained by shivering in younger patients rather than aged subjects. Takiguchi et al.[16] measured both core and peripheral surface temperature following the operation. They showed that the reduction in the temperature difference delayed extremely in elderly patients, suggesting that a defensive capability in elderly patients is impaired. Vaughan et al.[17] showed that elderly patients had both more pronounced and prolonged hypothermia than did younger patients following the operation. From those results, they suggested that elderly patients appeared to have delayed ability to compensate for hypothermia. These findings are consistent with our result showing that there was greater temperature difference in elderly patients than that in younger patients in shivering (+) group.

In this study, the occurrence rate of shivering was significantly higher in patients with long duration of operation. The long duration of anesthesia and surgical procedure is very stressful to the patients. The stress promotes an increase of circulating norepinephrine and endogenous hormones such as angiotensin from the adrenal medula and the kidney. Catecholamines and angiotensin II cause vasoconstriction in peripheral skin resulting in decrease in blood flow[18]. The present study shows that the lowering of peripheral surface temperature occurs when duration of operation is prolonged. In patients with a lack of the circulating blood volume, the occurrence rate of shivering was also greater. Hypovolemia causes a centralization of the circulating blood from peripheral organs to the vital organs. Therefore the peripheral skin circulation is impared resulting in lowering of the peripheral surface temperature. Another cause to postanesthetic shivering may be the different anesthetic agents used during surgery. However, this possibility was ruled out from this study.

It has been reported that various methods are effective in suppressing shivering. Sharkey et al.[19] reported that when shivering occurred, the radiant heat was more effective in suppressing shivering than wrapping in blanket. Murphy et al.[20] reported that in animals warming of the peripheral skin with radiant heat and taurine were effective. By the heat receptors of the peripheral skin perceive the hasty change of skin temperature, the shivering may be suppressed. Our study showed a relationship between the occurrence rate of shivering and the lowering of peripheral surface temperature. If the keeping warm in peripheral skin would be performed more actively, the occurrence rate of shivering could be reduced to less than 15%. Further observation are necessary to reevaluate this possibility.

In conclusion, postanesthetic shivering occurred in 15% of 100 patients. The occurrence rate of shivering was significantly higher in patients with a lowered peripheral surface temperature. And in these patients, the temperature difference between core and peripheral surface increased with a prolongation of surgical procedure. The prolonged duration of the operation and the loss of the circulating blood volume may cause peripheral vasoconstriction resulting from an activation of the sympathetic nervous system related with the thermoregulatory system. There followed a reduction of the peripheral surface temperature.

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