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Evaluation of a forced-air warming system during spinal anesthesia

Michiaki Yamakage, Shin Kawana, Masanori Yamauchi, Shinji Kohro, and Akiyoshi Namiki

Department of Anesthesiology, Sapporo Medical University School of Medicine, S1, W16, Chuo-ku, Sapporo, 060 Japan

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Introduction

Hypothermia, one of the most frequent complications in the operating room, occurs in a typical pattern during general anesthesia: the patient's central temperature decreases rapidly for 1 h (initial hypothermia), then decreases slowly for 2–3 h (linear decrease), and finally becomes constant (plateau phase) [1]. Recent studies suggest that initial central hypothermia after induction of general anesthesia is caused not by an increase in cutaneous heat loss, but by a redistribution of heat within the body [1]. A similar internal redistribution of heat causes initial hypothermia during epidural anesthesia [2].

A device reported to be useful for preventing initial hypothermia during general anesthesia [3] and epidural anesthesia [2] is the Bair Hugger forced-air warming system (Augustine Medical, Eden Prairie, MN, USA). We investigated the effectiveness of the Bair Hugger forced-air warming system in preventing initial hypothermia during spinal anesthesia involving sympathectomy of the lower part of the body. We also studied the effectiveness and thermal comfort of warming devices placed in different locations.

Patients and methods

This study was approved by the Sapporo Medical University Committee on Human Research, and informed consent was obtained from each patient. Twenty-one ASA physical status I or II adult patients who were scheduled for spinal anesthesia for surgery on the lower abdomen or a lower extremity were studied. Patients with a history of smoking or extreme obesity (body mass index >30) were excluded from the study. The mean age and body weight were 56.2 years (range 45 to 72) and 59.4 kg (range 48 to 78), respectively. No premedication was given.

In the operating room, after placement of a peripheral venous catheter, a Mon-a-Therm thermocouple (Mallinckrodt, St. Louis, MO, USA) was inserted into the patient's left external ear canal and connected to a Model 8700 electronic thermometer (Mallinckrodt) to measure the left tympanic membrane temperature (Tty) as the body core value. The tympanic thermocouple was a cotton-covered flexible probe placed in contact with the tympanic membrane. After the Tty reached a steady state, the patients were turned to the lateral decubitus position and spinal anesthesia was performed through the L3–4 interspace: 2.0 to 3.0 ml of 0.5% (w/v) tetracaine with 0.025% (w/v) phenylephrine was injected. After 15 min, the cephalad level of analgesia was determined by the pinprick method. During the period before checking the level of analgesia, 1000 ml of lactated Ringer's solution, warmed to 37°C, was infused intravenously; thereafter, it was continuously infused (10–15 $ml \cdot kg^{-1} \cdot hr^{-1}$).

Patients were randomly assigned to one of three groups: lower-body-warmed group, upper-body-warmed group, or upper-body-blanket group. For the first two groups, the patient's skin was warmed with a Bair Hugger forced-air warmer below the T10 and above the T7 dermatomes, respectively, immediately after the spinal injection. The Bair Hugger, set to "medium," supplied air at about 37°C to a disposable blanket laid over the patient, creating a shell of warm air around the body via flow through linear channels and small openings on the blanket's underside. Skin that was not covered by the Bair Hugger was exposed

Address correspondence to: M. Yamakage
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to room air. The patients in the upper-body-blanket group were covered with a light blanket above the T7 dermatome. Skin that was not covered by the light blanket was also exposed to room air. Room temperature was maintained at around 23°C throughout this study.

Thermal comfort was evaluated at 40 min after spinal injection with a 100-mm visual analog scale (VAS) on which 0 mm was defined as the worst imaginable cold, 50 mm as thermally neutral, and 100 mm as insufferably hot.

To compare the Tty in the three groups, we used one-way analysis of variance (ANOVA) and Fisher's test. VAS values were also analyzed by using one-way ANOVA for intergroup comparisons. $P < 0.05$ was considered statistically significant. Results are expressed as mean ± standard deviation (SD).

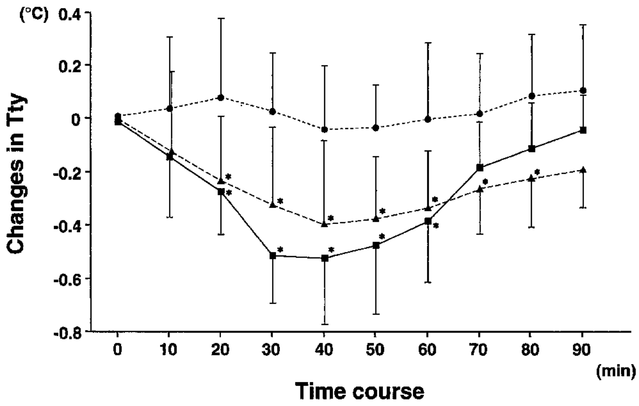

Fig. 1. Changes in tympanic membrane temperature during spinal anesthesia. The tympanic temperature (*Tty*) decreased significantly in both the upper-body-warmed (*closed squares*) and the upper-body-blanket (*closed triangles*) groups after spinal anesthesia. The Tty of the lower-body-warmed group (*closed circles*) remained unchanged throughout the study. $*P < 0.05$ versus lower-body-warmed group. Data are expressed as mean ± SD for 7 patients in each group

Results

There were no significant differences among the three groups in morphometric characteristics (Table 1), nor were there significant differences among the groups in the cephalad level of analgesia (T8.7 ± 1.5 segments in the lower-body-warmed group, T7.9 ± 2.2 segments in the upper-body-warmed group, and T8.2 ± 3.1 segments in the upper-body-blanket group).

The Tty decreased significantly in both the upper-body-warmed and the upper-body-blanket groups after induction of spinal anesthesia (Fig. 1). Both showed the lowest values at 40 min after spinal injection (−0.52° ± 0.30°C and −0.40° ± 0.28°C, respectively). Thereafter, the Tty of both groups gradually returned to the original temperatures. By contrast, the Tty of the lower-body-warmed group remained unchanged throughout this study.

All patients in the upper-body-warmed and the upper-body-blanket groups said they were thermally comfortable. For these two groups, the VAS of thermal comfort averaged, respectively, 50.6 ± 7.2 and 48.2 ± 7.4 mm at 40 min after spinal injection (Fig. 2). Four

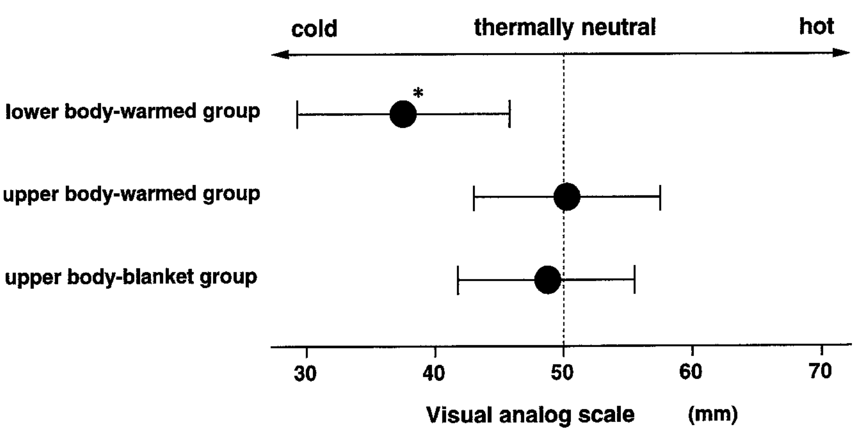

Fig. 2. Visual analog scale of thermal comfort at 40 min after spinal injection. The thermal comfort of the lower-body-warmed group, as evaluated by a visual analog scale, was significantly lower than that of the other two groups ($*P < 0.05$). Data are expressed as mean ± SD for 7 patients in each group

Table 1. Morphometric characteristics of subjects

Group	Sex (F/M)	Age (years)	Weight (kg)	Height (cm)
Lower-body-warmed group	2/5	54.8 ± 6.2	58.4 ± 6.2	160.5 ± 10.8
Upper-body-warmed group	3/4	56.9 ± 5.6	62.1 ± 6.7	162.2 ± 8.5
Upper-body-blanket group	3/4	56.6 ± 6.4	60.4 ± 4.9	158.5 ± 9.2

Values are mean ± SD.

patients in the lower-body-warmed group complained of a chilly sensation; the VAS of this group was 37.5 ± 8.9 mm, significantly lower than that of the other two groups ($P < 0.05$).

Discussion

Body core temperature, represented by Tty, was significantly decreased after induction of spinal anesthesia, but this decrease was prevented by positive lower-body-warming using a Bair Hugger warmer. It is natural to suppose that the decrease in Tty is due to the increase in heat loss to the environment by suppression of normal thermoregulatory vasoconstriction [4]. However, Sessler et al. [2] showed that the increase in heat loss was small and completely compensated for by shivering thermogenesis during lumbar epidural anesthesia. They also showed that sympathectomy-induced vasodilation produced central hypothermia via net convection of heat from warmer central tissues to cooler peripheral tissues [5]. Therefore, it would seem that the initial hypothermia during spinal anesthesia results primarily from redistribution of heat within the body, as has been shown in general anesthesia [1] and epidural anesthesia [5].

The initial hypothermia during spinal anesthesia was prevented by positive lower-body-warming using a forced-air warmer (37°C). Warming up the skin-surface in the area to be anesthetized would have helped prevent the initial hypothermia from heat redistribution in the body. Warming the skin-surface of the upper half of the body did not prevent the initial hypothermia and may have had little effect on the compensationally vasoconstricted skin-surface.

All of the patients in the upper-body-warmed and upper-body-blanket groups reported feeling comfortable, whereas four patients in the lower-body-warmed group complained of a chilly sensation even though their Tty remained unchanged. Subjective thermal sensations and physiologic responses are controlled by different hypothalamic structures and do not necessarily respond synchronously [6]. It has also been revealed that an artificial change in hypothalamic temperature does not modify subjective environment behaviorally [7].

These observations suggest that an individual's subjective thermal sensation is controlled mainly by the skin-surface temperature. Cutaneous cold receptors (A-δ fibers) fire tonically at comfortable ambient temperatures, whereas warm receptors (C-fibers) are quiescent. A spinal anesthesia-induced absence of tonic cold input may thus be perceived as a warm sensation. However, subcutaneous blood vessels of the upper part of the body may constrict during spinal anesthesia. In that case, the skin-surface temperature of the upper part of the body could significantly decrease, and cutaneous cold receptors would have increased firing. Considered as a whole, increased skin-surface cold sensation could contribute to a chilly sensation during spinal anesthesia, even though the body core temperature remains unchanged. Conversely, warming up the upper part of the body would make the patients thermally comfortable, even though their body core temperature significantly decreases.

In conclusion, body core temperature significantly decreases after spinal anesthesia, but this decrease is prevented by warming up the lower part of the body, where anesthetized. The patient's subjective chilly sensation during spinal anesthesia can be prevented by keeping the upper part of the body warm.

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