

CLINICAL INVESTIGATIONS

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Prevention of Intraoperative Hypothermia by Preoperative Skin-Surface Warming

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Background: Intraoperative hypothermia initially results from internal redistribution of heat facilitated by anesthesia-induced vasodilation. Preinduction skin-surface warming minimizes postinduction hypothermia in anesthetized volunteers. However, its efficacy might be reduced in surgical situations, because of multiple sources of heat loss.

Methods: Intraoperative core and mean skin temperatures were measured during total hip arthroplasty in 16 patients, randomly assigned to be covered preoperatively with a warming blanket for ≥ 90 min (prewarmed group) or not covered (unwarmed group).

Results: During the first hour of anesthesia, core temperature decreased more than twice as much in the unwarmed group ($-0.7 \pm 0.1^\circ\text{C}$; mean \pm SE) than in the prewarmed patients ($-0.3 \pm 0.1^\circ\text{C}$). At the end of surgery, core temperature was $36.3 \pm 0.1^\circ\text{C}$ in the prewarmed group and $35.2 \pm 0.2^\circ\text{C}$ in the unwarmed group. During recovery, seven patients obviously shivered in the unwarmed group and none in the prewarmed group.

Conclusions: Preanesthetic skin-surface warming reduces the initial postinduction hypothermia in surgical patients, preventing intraoperative hypothermia and postoperative shivering even for procedures lasting 3 h or longer. (Key words: Temperature; hypothermia; preoperative warming; prevention.)

INTRAOPERATIVE hypothermia is associated with postoperative shivering, which induces discomfort and is potentially harmful because of increasing oxygen uptake during recovery.¹⁻³ Attempts to minimize intraoperative hypothermia thus are appropriate for most surgical patients, especially for those with poor cardiorespiratory reserve.

The intraoperative decrease in core temperature is fastest during the first hour of anesthesia. This initial hypothermia results largely from redistribution of heat from the warm core compartment to cold peripheral tissues, due to anesthesia-induced vasodilation.^{4,5} It cannot be prevented easily, even by using intraoperative skin-surface warming devices.⁶ Heat redistribution could theoretically be reduced by increasing the temperature of peripheral tissues and consequently decreasing the core-to-periphery temperature gradient before induction of anesthesia. Initial hypothermia is reduced by skin-surface warming before induction of anesthesia in volunteers.⁷ However, the surgical situation usually differs. Patients must be transferred to the operating room and uncovered during their preparation for anesthesia. Furthermore, even if cutaneous prewarming proves efficient in decreasing heat redistribution, subsequent heat loss due to skin preparation,⁸ intravenous fluid infusion, inspiration of dry gases, and evaporation from the operating field may reduce or abolish this effect in surgical patients. Accordingly, we evaluated the effect of preoperative skin-surface warming on redistribution-induced hypothermia and postoperative shivering in surgical patients.

Methods and Materials

Patients

After obtaining informed consent, 16 patients (American Society of Anesthesiologists physical status 1 or 2) scheduled for elective total hip arthroplasty were included in this study, which was approved by the local Ethics Committee. None were obese, febrile, or taking vasoactive drugs, and none had a history of endocrine disease.

The patients were divided randomly into two groups, according to the preoperative thermal management. Eight patients (5 male, 3 female) were preoperatively covered up to the shoulders with an electric warming blanket (CM-AN 220, Chromex, Le Mans, France), set at $42-43^\circ\text{C}$, for at least 90 min (prewarmed group), before induction of anesthesia. A sheet was interposed

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between the skin and the blanket, which was warmed before the start of the study. The eight patients (3 male, 5 female) of the unwarmed group wore a paper shirt and were covered with a cotton sheet without other special preoperative precautions. Ambient temperature in the preinduction areas was maintained at 21–23° C for all patients.

Anesthesia

Patients received flunitrazepam (1 mg orally) 1 h before their admission on the operating ward. Anesthesia was induced in the operating room with thiopental (5 mg/kg), fentanyl (5 µg/kg), and vecuronium (0.1 mg/kg), and the trachea was intubated. The lungs were mechanically ventilated using a semiclosed circuit with a fresh gas flow of 2 l/min. Heat and moisture exchangers were not used. Anesthesia was maintained with fentanyl, enflurane, and 60% N₂O in oxygen.

Patients were positioned on their side, and their skin was prepared with iodine before being covered with surgical drapes. During surgery, an electric warming blanket covered the shoulders and the thorax in both groups. Ambient temperature in the operating room was maintained at 21–22° C. At the end of surgery, the trachea was extubated, and each patient was transferred immediately to the recovery room, where they were covered up to the shoulders with an electric warming blanket until they were normothermic.

Measurements

Temperatures were measured continuously and recorded from arrival in the operating theater until the end of recovery, using thermistor probes connected to Exacon model MC 8940 (Taastrup, Denmark). Values at the beginning of the study, *i.e.*, before prewarming in the prewarmed patients and just before admission to the operating room in the unwarmed patients, are subsequently referred to as basal values. Core temperature (T_{core}) was measured at the tympanic membrane. Four skin surface thermistors were taped on the chest, upper arm, lateral unoperated mid thigh, and mid calf; mean skin temperature (MST) was calculated according to the formula given by Ramanathan⁹:

$$MST = 0.3 (T_{chest} + T_{arm}) + 0.2 (T_{thigh} + T_{calf}).$$

Thermal comfort of prewarming was assessed before surgery and classified as comfortable, indifferent, or unbearably hot at 5-min intervals. Sweating was evaluated qualitatively at the same times as absent or present on touch.

In the recovery room, shivering was evaluated as obvious or absent by an independent observer blinded to the preoperative treatment. During postanesthetic recovery, pain was treated with intravenous paracetamol; no opioids were administered. The study ended when the tympanic temperature was similar to its basal value.

Statistics

Statistical analysis was performed using two-way analysis of variance (between periods in each group), modified *t*-test (for periods between groups), Fisher's exact test (for shivering rate between groups), or unpaired *t* test (between groups).¹⁰ Values are expressed as mean ± SE; *P* < 0.05 was considered statistically significant.

Results

The two groups did not differ significantly in age, weight, height, operating room temperature, duration of surgery, administered opioids, or volume of intravenous fluid (table 1). Basal values of core and mean skin temperatures were similar in the two groups (table 2).

Preoperative skin-surface warming lasted 124 ± 9 min. Mean skin and core temperatures increased 4.2 ± 0.1 and 0.5 ± 0.1° C, respectively, by the end of prewarming (fig. 1; table 2). Sweating was observed in all prewarmed patients after 60 min of heating. Prewarming was assessed as comfortable or indifferent by all patients.

Anesthesia was induced 12 ± 2 min after admission to the operating room and 17 ± 3 min before surgical

Table 1. Characteristics of Patients and Anesthesia

	Unwarmed (n = 8)	Prewarmed (n = 8)
Age (yr)	63 ± 3	65 ± 3
Weight (kg)	65 ± 4	75 ± 6
Height (cm)	162 ± 2	170 ± 3
Preinduction room temperature (° C)	21.5 ± 0.4	22.7 ± 0.3
Operating room temperature (° C)	21.7 ± 0.2	22.2 ± 0.2
Fluids volume (ml)	2,000 ± 177	1,500 ± 198
Fentanyl (µg)	366 ± 35	397 ± 32
Duration of surgery (min)	174 ± 10	180 ± 13

Values are mean ± SE.

There were no differences between groups.

Table 2. Core and Mean Skin Temperatures in Unwarmed and Prewarmed Patients

	Core Temperature (° C)		Mean Skin Temperature (° C)	
	Unwarmed	Prewarmed	Unwarmed	Prewarmed
Basal	36.5 ± 0.1	36.5 ± 0.1	31.6 ± 0.5	32.3 ± 0.2
End of prewarming	—	37.0 ± 0.1	—	36.5 ± 0.2
Admission to operating room	36.5 ± 0.1	36.9 ± 0.1*	31.6 ± 0.8	35.7 ± 0.2*
60 min of anesthesia	35.8 ± 0.1	36.5 ± 0.1*	31.7 ± 0.7	34.2 ± 0.3*
End of surgery	35.2 ± 0.2	36.3 ± 0.1*	31.9 ± 0.6	33.4 ± 0.3*

Values are mean ± SE.

* $P < 0.05$ between groups.

incision without significant difference between groups. Between the end of the prewarming period and the induction of anesthesia, mean skin temperature decreased $2.1 \pm 0.1^\circ \text{C}$. In the first hour after induction of anesthesia, core temperature decreased in both groups, but hypothermia developed more rapidly in the unwarmed than in the prewarmed patients (-0.7 ± 0.1 vs. $-0.3 \pm 0.1^\circ \text{C}$; $P < 0.01$; table 2). Both core and mean skin temperatures remained higher in prewarmed than in unwarmed patients throughout surgery (fig. 1). At the end of surgery (≈ 3 h), core temperature was similar to basal values in prewarmed patients but had decreased significantly in the unwarmed patients (fig. 1; table 2).

During recovery, seven unwarmed patients obviously shivered whereas none shivered in the prewarmed group ($P < 0.05$).

Discussion

Effective treatment of intraoperative hypothermia is difficult. Passive cutaneous insulation, heat-and-moisture exchanging filters, circulating-water mattresses, and warming of infused fluids and blood products are, at best, partially effective.^{11–15} Transcutaneous heat transfer is the major part of intraoperative loss.¹⁶ Conversely, skin-surface warming can transfer heat to the body.^{16,17} Recent studies demonstrate the efficacy of skin-surface warming in minimizing intraoperative hypothermia using either an electric^{||} or a forced-air

warming cover.¹⁵ Nevertheless, intraoperative cutaneous heat transfer does not prevent the redistribution-induced hypothermia that occurs immediately after induction of anesthesia and persists to a varying extent until the end of surgery.^{6,15}

Internal transfer of heat, with the subsequent decrease in core temperature, depends on the temperature gradient between the core and the peripheral compartment. A reduction of this initial hypothermia could be expected from storing heat in the peripheral compartment, using skin-surface warming before the induction of anesthesia. Moayeri *et al.* successfully tested this hypothesis in healthy volunteers.⁷ The present study demonstrates that skin-surface prewarming also is effective in surgical patients.

During the preoperative warming period, mean skin temperature initially increased rapidly, when the temperature gradient between the skin and the warming device was the greatest; it then increased more slowly, and stabilized after about 1 h of prewarming, when mean skin and core temperatures were similar. Thereafter, core temperature increased slightly. This increase might be attributed to a possible impairment of thermoregulation, related to patients' premedication, since most anesthetic drugs are known to modify the thermoregulatory threshold.¹⁶ Additionally, the absence of evaporation under the warming blanket limited the efficacy of sweating. However, core temperature never exceeded 37.5°C , and no patient complained of thermal discomfort.

Skin temperatures are measured at the surface and do not represent temperature of the entire peripheral compartment, especially during rapid changes in the thermal environment. Thus, the rapid increase in mean skin temperature observed at the beginning of the prewarming period is likely associated with slower changes in body heat content. Prewarming was continued for

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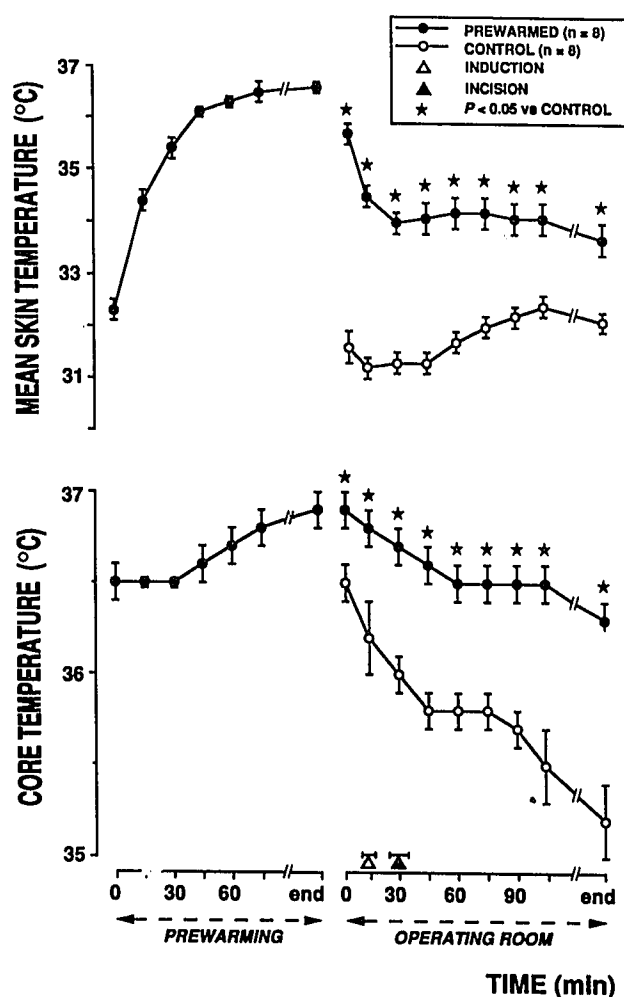


Fig. 1. Time course of mean skin temperature (top) and core temperature (bottom) in the prewarmed (filled circles) and unwarmed (open circles) patients. Values are mean \pm SE. * $P < 0.05$ between groups.

more than 1 h, even though mean skin temperature was constant. After admission to the operating room, mean skin temperature rapidly decreased in prewarmed but not in the unwarmed patients, in accordance with the greater temperature gradient between their skin and the environment. However, greater heat loss during this period probably was only a small fraction of the heat transferred by prewarming. Mean skin temperature then stabilized in both groups, because the patients were insulated by surgical drapes and their skin surfaces were warmed partially.

Core temperature decreased twice as fast after induction of anesthesia in the unwarmed than in the pre-

warmed patients. This is consistent with the reduced temperature gradient between the core and peripheral compartments in the prewarmed patients, resulting in a decreased postinduction heat redistribution. Thereafter, core temperature stabilized at basal values in prewarmed patients, whereas it continued to decrease in unwarmed patients. The beneficial effect of prewarming continued throughout the surgical procedure, as indicated by the return of core and mean skin temperatures at their basal level at the end of surgery in prewarmed patients. This effect suggests that preoperative heat storage was at least equal to intraoperative heat loss.

Finally, unwarmed patients in this study became hypothermic during surgery, despite the use of a warming blanket, probably because the blanket was small and the patients were in the lateral position. By contrast, the prewarmed patients were nearly normothermic at the end of surgery and did not obviously shiver during recovery, which is consistent with tremor being thermoregulatory.^{3,18}

In summary, warming a large skin-surface area before induction of anesthesia reduces the initial intraoperative decrease in core temperature. Combined with moderately efficient intraoperative skin-surface warming, such prewarming prevents intraoperative hypothermia and postoperative shivering.

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