Brief Report

Heat conservation *vs* convective warming in adults undergoing elective surgery

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Purpose: To determine the relative efficacy of heat conservation and convective warming in maintaining perioperative normothermia, (central temperature $\geq 36^{\circ}\text{C}$).

Methods: Thirty-seven patients undergoing elective gynaecological, orthopaedic, or general surgery scheduled to last two hours were prospectively studied. Patients were randomized to one of two groups. Group 1 patients received heat conservation with reflective blankets (Thermadrape™, Vital Signs, Inc., Totowa, NJ) applied preoperatively and warmed iv fluids (Hotline™ SIMS Level 1 Technologies, Inc, Rockland, MA). Group 2 patients received convective warming (Bair-Hugger, Augustine Medical, Inc., Eden Prairie, MN) after induction of anaesthesia and iv fluids at room temperature. All patients received general anaesthesia with isoflurane. Tympanic membrane and forearm-fingertip skin temperature gradients were measured perioperatively at 15 min intervals.

Results: Central temperature decreased after induction to a minimum level of $35.9 \pm 0.1^{\circ}\text{C}$ in group 1 and $36.0 \pm 0.1^{\circ}\text{C}$ in group 2 and then increased towards pre-induction values in group 2, and were higher ($P < 0.05$) than in group 1: 95% group 2 patients had central temperature $\geq 36.0^{\circ}\text{C}$ at the end of surgery (vs 69% of group 1, $P < 0.05$). During the first 30 min in PACU, central temperatures were higher in group 1 than in group 2 ($36.8 \pm 0.1^{\circ}\text{C}$ vs $36.2 \pm 0.2^{\circ}\text{C}$, $P < 0.05$). After 60 min, central temperatures were similar (36.8°C). The incidence of shivering and degree of peripheral cutaneous vasoconstriction were also similar.

Conclusion: Patients receiving convective warming were more likely to leave the operating room normothermic, and had higher central temperatures during the first 30 min in the recovery room. The intergroup temperature differences were small, and by 60 min, had disappeared.

Objectif : Déterminer l'efficacité relative de la conservation de la chaleur et du réchauffement par convection pour le maintien de la normothermie périopératoire (température centrale $\geq 36^{\circ}\text{C}$).

Méthodes : Trente-sept patient(e)s soumis(es) à une chirurgie gynécologique, orthopédique ou viscérale élective et programmée pour une durée approximative de deux heures ou plus ont participé à cette étude. Les patients ont été répartis aléatoirement entre deux groupes. Les patients du groupe 1 ont été réchauffés par réflexion avec des couvertures appropriées (Thermadrape™, Vital Signs Inc., Totowa, NJ) et des perfusions réchauffées en préopératoire (Hotline™ SIMS Level 1 Technologies Inc, Rockland, MA). Le réchauffeur par convection (Bair-Hugger, Augustine Medical Inc., Eden Prairie, MN) a été appliqué après l'induction de l'anesthésie au groupe 2 et des liquides iv maintenus à la température de la pièce ont été perfusés. Tous les patients ont reçu une anesthésie générale à l'isoflurane. Les gradients de température tympanique et de la peau du bout des doigts et de l'avant-bras ont été mesurés aux 15 min pendant l'intervention.

Résultats : La température centrale a diminué après l'induction à un niveau minimum de $35,9 \pm 0,1^{\circ}\text{C}$ dans le groupe 1 et de $36 \pm 0,1^{\circ}\text{C}$ dans le groupe 2 et a par la suite augmenté vers les valeurs préinduction dans le groupe 2 et de façon plus marquée que dans le groupe 1: 95% des patients du groupe 2 avaient des températures centrales $\geq 36^{\circ}\text{C}$ à la fin de la chirurgie (vs 69% du groupe 1, $P < 0,05$). Pendant les premières 30 min du séjour en salle de réveil, les températures centrales étaient plus élevées dans le groupe 1 que dans le groupe 2 ($36,8 \pm 0,1^{\circ}\text{C}$ vs $36,2 \pm 0,2^{\circ}\text{C}$, $P < 0,05$). Après 60 min, les températures centrales étaient identiques ($36,8^{\circ}\text{C}$). L'incidence des frissons et le degré de vasoconstriction étaient aussi les mêmes.

Conclusion : Les patients réchauffés par convection avaient plus de chance de quitter la salle d'opération en normothermie et avaient des températures centrales plus élevées pendant les premières 30 min de leur séjour en salle de réveil. Les différences entre les groupes étaient faibles et sont disparues après 60 min.

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H EAT loss and hypothermia can lead to a variety of postoperative complications including wound infections,¹ myocardial ischaemia,² arrhythmias,³ elevated catecholamines,⁴ delayed emergence,⁵ coagulopathy,⁶ and shivering.⁷ There are a variety of methods to prevent hypothermia such as higher room temperatures,⁸ insulating blankets,⁹ airway heat conservation,¹⁰ fluid warmers,¹¹ and convective warming.¹² Prevention of hypothermia may be most effective when a variety of methods, begun as early as possible, are used simultaneously.¹⁰

The purpose of this study was to evaluate the ability of a heat conservation method to maintain normothermia (tympanic membrane temperature $\geq 36^{\circ}\text{C}$). Heat conservation was compared with convective warming, a method that has previously been shown to maintain perioperative normothermia.¹³

Methods

The protocol was approved by the Institutional Review Board. Informed consent was obtained. Thirty-seven adults, ASA I-III, undergoing elective major gynaecological ($n=15$), orthopaedic ($n=19$), and general surgery ($n=3$) scheduled to last two hours were randomly assigned to one of two groups.

Group 1 patients ($n=18$) received heat conservation. Thermal blankets, head covers, and leggings (ThermadrapeTM, Vital Signs, Inc., Totowa, NJ) were applied in the holding area. These materials had reflective metal backing that faced the patient and minimized radiative heat loss. Approximately 75–85% of the patient was covered. The ThermadrapeTM coverings were kept in place throughout the operation and recovery period. Group 1 patients received *iv* fluids via the HotlineTM counter-current fluid warmer (SIMS Level 1 Technologies, Inc, Rockland, MA) with a set-point of 42°C using an 8 cm extension.

Group 2 patients ($n=19$) received convective warming and *iv* fluids at $\sim 21^{\circ}\text{C}$. An upper body blanket was applied after induction of anaesthesia (BairHugger, Augustine Medical, Inc., Eden Prairie, MN), and set to deliver forced air at 43°C . At the conclusion of surgery, the blanket was removed and the patient was covered with a standard blanket.

Exclusion criteria were use of calcium blockers, head injury, obesity, otitis, and preoperative temperature $\geq 38^{\circ}\text{C}$ or $\leq 35.5^{\circ}\text{C}$.

Anaesthesia was induced with thiopentone and maintained with isoflurane and N_2O . Adjunct agents were fentanyl, midazolam and non-depolarizing relaxants. Anaesthetic gases were delivered via a tracheal tube using a circle system, heat and moisture exchanger and CO_2 absorber. Ventilation was controlled to

maintain normocarbida using a fresh gas flow of $2\text{ L}\cdot\text{min}^{-1}$. Room temperature was set at 21°C . Fluids were infused to maintain normovolaemia.

Central (tympanic membrane), forearm and fingertip temperatures were measured prior to induction, and at 15 min intervals until discharge from the recovery room using Mon-a-therm thermocouple temperature probes (Mallinkrodt Medical, Inc., St Louis, MO). The temperature probes were attached to a Mon-a-therm electronic readout unit. The forearm-fingertip skin-surface temperature gradient was used as an index of thermoregulatory peripheral vasoconstriction.¹⁴ A gradient $\geq 4^{\circ}\text{C}$ represented significant peripheral cutaneous vasoconstriction.¹⁵

Presence or absence of shivering, and its severity were recorded in the recovery room. Shivering was mild if it did not interfere with monitoring and severe if meperidine treatment was required for patient discomfort or interference with monitoring.

Between group data (means $\pm$ SEM) were compared with Fischer's Exact test and Student's *t*. A *P* value < 0.05 was considered significant.

Results

Two patients were excluded from data analysis (both from group 1) because the surgery lasted < 1 hour ($n=1$) and because of fluid warmer malfunction ($n=1$). Groups were similar except that patients in group 2 were younger (Table). In both groups, there was a decrease in temperature after induction (Figure 1), accompanied by a decrease in the forearm-fingertip gradient (Figure 2). After ~ 150 min of anaesthesia, central temperatures were higher in group 2 than in group 1 (Figure 1). Final central temperatures before leaving the operating room were $> 36^{\circ}\text{C}$ in both groups (Figure 1). However, more patients in group 1 had temperatures $< 36^{\circ}\text{C}$ at the end of surgery (Table, $P < 0.05$).

During the first 30 min in the recovery room, central temperatures were higher in group 2 than in group 1 (Figure 1, $P < 0.05$), but were similar between groups by 60 min. Two patients (10.5%) in group 2 had mild shivering and three (19%) in group 1 had severe shivering requiring meperidine ($P=\text{NS}$). Forearm-fingertip temperature gradients were similar between groups postoperatively (Figure 2).

Discussion

The ability of methods such as skin surface insulation, fluid warming, and airway heat conservation to maintain normothermia is dependent upon factors such as the insulating properties of the material used, amount of surface area covered, efficacy of the fluid warmer, metabolic heat production, and ambient temperature.

TABLE Patient, temperature, and cost data.

	Heat Conservation Group 1, n=16	Convective Warming Group 2, n=19
Age (yr)	49 ± 3	39 ± 3*
Sex (M/F)	5/11	5/14
Height (cm)	167 ± 2.6	167 ± 3.2
Weight (kg)	72 ± 4	77 ± 5
Anesthesia time (min)	224 ± 31	238 ± 22
Surgery time (min)	169 ± 29	170 ± 19
Crystalloid given	2.6 ± 0.3	2.3 ± 0.3
Room temperature (°C)	21.8 ± 0.2	21.0 ± 0.3
Initial temp (°C)	36.6 ± 0.1	36.9 ± 0.1
Minimal intraoperative temp (°C)	35.9 ± 0.1	36.0 ± 0.1
Final intraoperative temp (°C)	36.3 ± 0.2	36.7 ± 0.1
≤35.9°C at end of surgery, n(%)	5 (31%)	1 (5%)*
Cost fluid warmer unit/disposables (\$)	1500/13	0
Cost convective warmer/disposables (\$)	0	2000/15
†Cost Thermadrape adult covers (\$)	8.80	0

Costs (US\$) were obtained from the manufacturers.

†Includes blanket, head cover and leggings.

Temp = tympanic membrane temperature.

Means ± SEM or number of patients (%). **P* < 0.05 between groups.

FIGURE 1 Tympanic membrane temperatures in patients receiving heat conservation with Thermadrape blankets and warmed *iv* fluids versus convective warming.

Mean ± SEM. **P* < 0.05 between groups.

FIGURE 2 Perioperative forearm-fingertip skin-temperature gradients in patients receiving heat conservation with Thermadrape blankets and warmed *iv* fluids versus convective warming. A gradient 4°C indicated cutaneous peripheral vasoconstriction.¹⁵

Mean ± SEM. **P* < 0.05 between groups.

Reduction of cutaneous heat loss was achieved in group 1 by covering the patient with Thermadrape blankets, head covers, and leggings prior to induction. The Thermadrape materials were chosen over other passive insulators because the insulator efficiency of the Thermadrape has been shown to be superior to other materials.⁹ Covering a large portion of the patients using reflective blankets has previously been shown to result in near normal (>36°C) oesophageal temperatures in patients undergoing carotid

endarterectomy.¹⁶ In the present study, reduction of heat loss between the patient's circulating blood volume and *iv* fluids was achieved using the Hotline warmer. This warmer was chosen because it delivers normothermic fluids over a wide range of clinically relevant flow rates.¹⁷ Use of the Hotline warmer has been associated with maintenance of near normal tympanic membrane temperatures in patients undergoing major gynaecological and orthopaedic surgery of more than two hours with general anaesthesia.¹¹

Despite the use of a combination of heat conservation methods in the study, five patients (31%) had temperatures $<36^{\circ}\text{C}$ upon leaving the operating room. In contrast, group 2 patients were unlikely to leave the operating room hypothermic (1/19, 5%). However, it should be noted that the incidence of shivering and the degree of postoperative peripheral vasoconstriction were similar between groups. Furthermore, there were no differences in central temperatures between groups after one hour in the recovery room. It is, therefore, unlikely that patients in group 1 would have been at high risk for haemostatic, metabolic, cardiovascular, or impaired wound healing complications of mild perioperative hypothermia, since these effects have mainly been associated with central temperatures $<35^{\circ}\text{C}$.^{1-4,6}

The effectiveness of convective warming in maintaining perioperative normothermia has been previously described.^{13,19} It has been estimated that convective warming transfers about 43 kcal·hr⁻¹ across cutaneous surfaces which, when combined with the patient's metabolic heat production, increases body temperature by 1.5°C·hr⁻¹ in an anaesthetized adult.¹² Thus, if the surgery lasts long enough (e.g., two to three hours), it is possible to increase temperatures of anaesthetized patients safely and effectively using convective warming. The efficacy of convective warming can be further improved on by warming *iv* fluids, as demonstrated in patients undergoing total hip arthroplasty¹⁹ and colorectal resection.¹ Fluid warming is an important method of heat conservation, and assumes even greater importance when large volumes of fluid are required. This is because the negative thermal balance resulting from the infusion of 3 L of unwarmed crystalloid would be ~51 kcal,¹⁷ which represents about one hour's heat production in an anaesthetized adult.²⁰

A great deal of emphasis is currently being placed on the cost of using equipment to maintain normothermia during anaesthesia. The obvious benefit gained from the use of convective warming is that it helps to insure that the patient leaves the operating room normothermic at a reasonable cost (disposable= \$15.00). Normothermia may in turn reduce the frequency of adverse events associated with the metabolic cost of rewarming in the recovery period (shivering, elevated catecholamines and oxygen consumption, cardiac arrhythmias, possible myocardial ischaemia, peripheral vasoconstriction, increased catabolism, etc.),^{2-4,7} reduce the incidence of postoperative wound infections and shorten duration of hospitalization,¹ and improve patient comfort and satisfaction. The convective warmer unit costs \$2000, but at most institutions, the unit is free with purchase of disposables.

In the heat conservation group, only ~70% of patients left the operating room normothermic despite the use of reflective blankets, fluid warming, and airway heat conservation. Moreover, this technique was associated with slightly higher disposable costs than with convective warming (fluid warming disposable= \$13.00, Thermadrapes= \$8.80). Based on the results of the study, it was more cost-effective to use convective warming disposables than heat conservation ones. Therefore, Thermadrapes are no longer in use at MetroHealth Medical Center, although fluid warmers are used whenever large volumes (>2.5 L) of fluid are required, or blood products are transfused.

In summary, the study showed that, compared with heat conservation, patients actively warmed with a convective device were more likely to be normothermic at the conclusion of surgery and during the first 30 min in the recovery room. Intraoperative convective warming, when used during the conditions of the study, required ~2.5 hr to increase tympanic membrane temperature to pre-induction levels.

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