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CLINICAL PRACTICE

Effect of prewarming on post-induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia

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Background. Inadvertent perioperative hypothermia (IPH) occurs in many patients because warming techniques are insufficient to counteract thermal redistribution resulting from the ablation of thermoregulatory vasoconstriction associated with anaesthesia. We tested the efficiency of a preoperative forced-air warming (FAW) device (Bair Paws®) in preventing IPH.

Methods. Sixty-eight adult patients undergoing spinal surgery under general anaesthesia were randomized to receive either normal care or prewarming for 60 min, at 38°C, using the Bair Paws® system. All patients received routine FAW intraoperatively.

Results. Thirty-one patients were prewarmed and 37 patients were in the control group. There was a 0.3°C smaller decrease in mean core temperature in the prewarmed group at 40, 60, and 80 min post-induction ($P \leq 0.05$). Temperature was maintained above the hypothermic threshold of 36°C in 21 (68%) patients in the prewarmed group, compared with 16 (43%) patients in the control group ($P < 0.05$).

Conclusions. Preoperative warming using the Bair Paws® system results in smaller decreases in core temperature intraoperatively and less IPH in patients undergoing spinal surgery under general anaesthesia.

Inadvertent perioperative hypothermia (IPH) is a common problem.[1] It has been defined as a perioperative core temperature of <36°C.[2] Known complications attributed to IPH include an increased incidence of myocardial ischaemia, wound infections, and coagulopathies. IPH is also associated with prolonged hospital stay and increased hospital costs.[3–6] IPH develops as a consequence of anaesthesia reducing metabolic heat production, heat loss to a cold operating theatre environment, and impaired thermoregulation with resultant core to periphery thermal redistribution. Thermal redistribution occurs after induction of anaesthesia and accounts for a decrease in core temperature of up to 1.6°C.[7] Although forced-air warming (FAW) devices can effectively restore core temperature within 2 h,[8–10] the physiology of thermal redistribution often renders them inadequate for procedures of short duration. However, warming of peripheral tissues before induction of

anaesthesia (prewarming) decreases the central to peripheral temperature gradient, thereby minimizing core heat loss from thermal redistribution.[11] Previous studies of prewarming before surgery have demonstrated a reduction in the decrease of core temperature;[12–15] however, the IPH guidelines from the National Institute for Clinical Excellence (NICE) reported limitations on conclusions which may be drawn, resulting from study design.[2] The objectives of this investigation were to conduct a robust study to evaluate the effect of prewarming on post-induction core temperature and the incidence of IPH.

The device used in the trial is a newly developed preoperative warming system, 'Bair Paws®'. The Bair Paws® perioperative warming system (Arizant Healthcare, UK) is an FAW device developed for preoperative skin surface warming. The system consists of a portable warming unit (1000 BTU h^{-1} average) connecting to a single-use

patient gown via a corrugated hose. The temperature output of the device (measured at the end of the hose) can be varied between ambient temperature and 43°C through the hand-held controller. In the operating theatre, the gown can be connected to a conventional 'Bair Hugger®' warming unit to provide intraoperative warming. It has been shown to reduce patients' preoperative anxiety scores,[16] but to date, no studies have examined its efficiency in preoperative warming or its effect on perioperative IPH.

Methods

The study was granted approval from the local research ethics committee. Seventy-six adults, ASA physical status I and II patients, who were undergoing general anaesthesia for elective spinal surgery were recruited to the study after giving written informed consent.

The patients were randomized using a computer-generated randomization to two groups: a prewarmed group and a non-prewarmed group. In order to detect a difference of 0.2°C in mean core temperature between the groups, with a power of 0.8 and a significance level of 0.05, the sample size for each group was calculated to be 35.

Preoperative core temperature was measured indirectly with a temporal artery scanner (Exergen Corporation, MA, USA). All patients wore a Bair Paws® gown before operation in place of the standard linen theatre gown. The prewarmed patient group received forced warm air prewarming ∼60 min. This was commenced on the ward and continued in the anaesthetic room before induction. The temperature output of the Bair Paws® warming unit was set at 38°C for the duration of the study. The ambient temperature at the patients' bed space was recorded. Indirect core temperature measurement was repeated before induction of general anaesthesia. Propofol target-controlled infusion was used in the majority of patients supplemented with either remifentanil or alfentanil infusion. Two patients in each group received sevoflurane for maintenance. All patients had a temperature probe inserted ∼15 cm into the oesophagus under direct vision, after induction of anaesthesia. The core temperature was recorded immediately after induction and then at 20 min intervals for the duration of the surgery. Intraoperative warming was continued with an FAW unit set to 38°C. A full body blanket was used for patients having cervical spine surgery and a surgical access warming blanket for those undergoing lumbar spine surgery. The ambient theatre air temperature was recorded. I.V. fluids were not warmed.

Study data were analysed using SPSS version 15 (SPSS UK, Woking, Surrey, UK). Patient characteristics data were compared using Student's *t*-test. Multivariate analysis of variance (MANOVA) compared the perioperative core temperature difference between the two groups. An area under the time/temperature graph (AUC) was calculated and Student's *t*-test measured the difference between the two groups. The χ^2 test was used to look at the difference in the proportion of patients remaining normothermic throughout the procedure in each group.

Results

Of the 76 patients recruited, eight patients were excluded due to surgical cancellations. Data were therefore complete for 31 patients in the prewarmed group and 37 in the non-prewarmed group. Patient characteristics, ward and theatre environmental temperatures, core temperatures at induction, duration of surgery, and infused fluid volumes were comparable between the groups. There was also no significant difference between the groups in the proportion of patients undergoing cervical or lumbar spine surgery, or in the ratio of male:female patients (Table 1). The mean duration of prewarming was 72 (SD 26, range 30–120) min. There was no relationship between each individual's duration of prewarming and their maximum intraoperative temperature decrease.

There was a low overall incidence of nausea, vomiting, and shivering, with no significant differences demonstrated between the groups (Table 2).

The MANOVA identified a significantly smaller decrease in core temperature in the prewarmed group at 40, 60, and 80 min (Table 3). Furthermore, Student's *t*-test [using a zero (0°C) baseline] on the AUC of the time/temperature curve (Fig. 1) confirmed that the core temperature of the prewarmed group was greater than the control group (*P*<0.005). The IPH guidelines from the

Table 1 Patient characteristics and perioperative variables. Values are presented as mean values (SD) or numbers of patients. Age is presented as mean (range)

Variable	Prewarmed (*n*=31)	Non-prewarmed (*n*=37)
Age (yr)	54 (19–80)	57 (26–87)
BMI (kg m^{-2})	28.4 (3.8)	28.9 (5.6)
Male:female	20:11	25:12
Lumbar:cervical operations	16:15	22:15
Duration of surgery (min)	138 (36)	131 (40)
Ward air temperature (°C)	22.7 (1.2)	22.8 (1.1)
Core temperature pre-intervention (°C)	36.8 (0.5)	36.8 (0.4)
Core temperature at induction (°C)	36.8 (0.5)	36.9 (0.4)
Operating theatre temperature (°C)	20.7 (1.5)	20.9 (1.2)
Volume of fluids infused (ml)	1125 (400)	1150 (425)

Table 2 Post-anaesthesia care unit observations and numbers of patients in each group remaining normothermic throughout surgery (**P*<0.05)

Variable	Prewarmed (*n*=31)	Non-prewarmed (*n*=37)
Nausea	3	2
Vomiting	3	1
Shivering	2	3
>36.0°C throughout	21 (68%)	16 (43%)*

Table 3 Mean (SD) change in intraoperative core temperature (°C) at 20 min intervals post-induction. It also shows the number of patients (*n*) in each group still under anaesthesia at each time interval

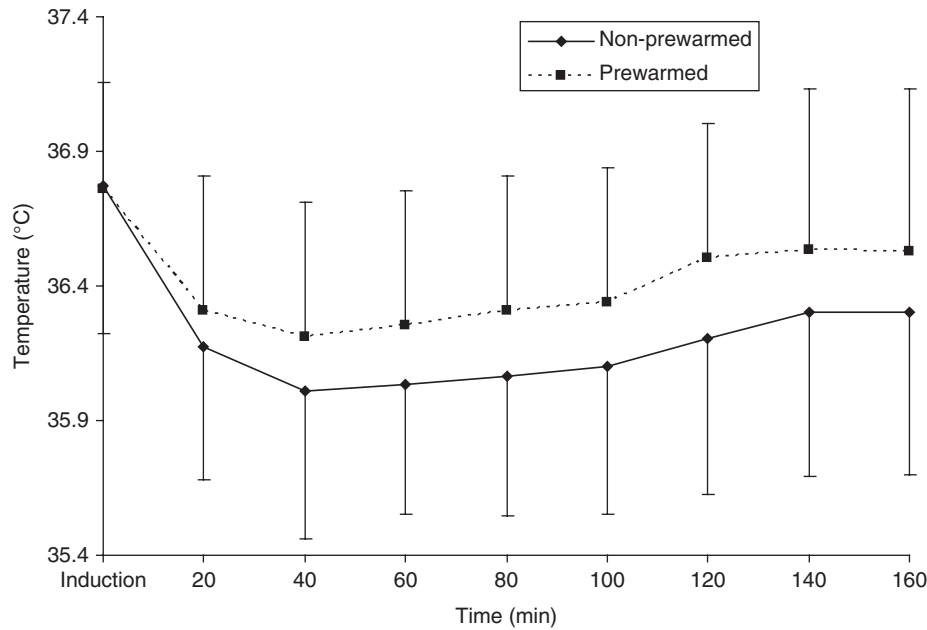| Time (min)	Prewarmed		Non-prewarmed		Mean temperature difference between groups (°C)	*P*-value
	Change in core temperature	*n*	Change in core temperature	*n*		
20	−0.4 (0.4)	31	−0.6 (0.5)	37	0.2	0.09
40	−0.5 (0.5)	31	−0.8 (0.6)	37	0.3	0.05
60	−0.5 (0.5)	31	−0.8 (0.6)	36	0.3	0.02
80	−0.4 (0.6)	31	−0.7 (0.7)	35	0.3	0.03
100	−0.4 (0.6)	27	−0.7 (0.7)	30	0.3	0.10
120	−0.3 (0.6)	22	−0.6 (0.8)	23	0.3	0.17
140	−0.3 (0.6)	16	−0.4 (0.8)	17	0.1	0.75
160	−0.4 (0.5)	13	−0.4 (0.7)	12	0.0	0.78

Fig 1 Mean intraoperative temperatures (°C) used for calculation of the AUC. Error bars represent SD of core temperature readings at each time interval.

NICE consider perioperative hypothermia to be a core temperature <36°C. Figure 2 shows that three patients in the non-prewarmed group (8%) were hypothermic at induction and illustrates the percentage of patients in each group who were hypothermic (<36°C) at each time interval thereafter. The χ^2 test showed that a larger proportion of patients ($P<0.05$) remained normothermic throughout surgery in the prewarmed group (68%) compared with the control group (43%).

Discussion

We have demonstrated that prewarming patients, undergoing spinal surgery under general anaesthesia, with the Bair Paws® warming system resulted in a smaller decrease in core temperature between 40 and 80 min post-induction. Prewarming also resulted in a decreased incidence of IPH. After this time, the difference between the groups does not achieve statistical significance and is arguably less clinically relevant, since the intraoperative FAW is effective.

NICE has defined a temperature difference of 0.2°C between any intervention and control groups as being of clinical significance in hypothermic patients.[2] The mean core temperature difference (0.3°C) between our study groups at 40, 60, and 80 min exceeded this.

Although some patients in each group received volatile maintenance of anaesthesia, there is no evidence that either the choice of maintenance or the type of opioid infusion affects the incidence of IPH.[17][18] Blinding would have been difficult to achieve in this study, since most of the patients who were in the active prewarming group made comments about their thermal comfort, even though this was not itself an outcome measure.

The ethical approval of this trial predated the NICE recommendations for the warming of *all* administered fluid; however, the small volume of unwarmed fluid, administered equally to both groups in this study, is unlikely to
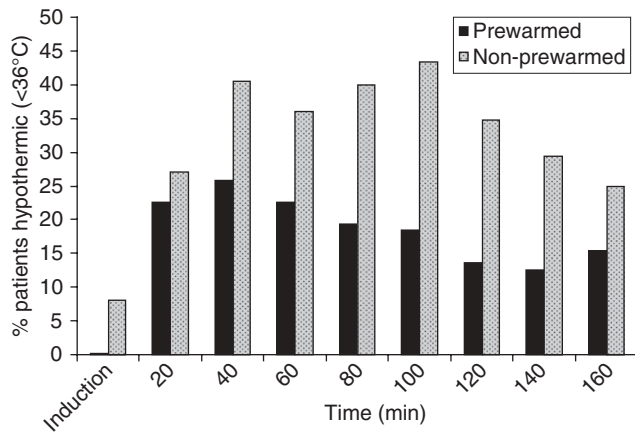
Fig 2 Percentage of patients in each group who were hypothermic (<36°C) at each time interval post-induction.

have affected the outcome. Similarly, a setting of 38°C was chosen for intraoperative warming. Future studies will no doubt follow NICE recommendations by warming all i.v. fluids and using the maximum setting of the FAW from the beginning of surgery and adjusting its thermal output according to clinical requirements.

The optimum duration of effective prewarming is unknown. Sessler and colleagues[19] estimated 30–60 min to be sufficient, using an FAW device capable of generating 1644 BTU h^{-1}. Bair Paws® thermal output is lower (average of 1000 BTU h^{-1}), so with the temperature control preset at 38°C, the gown was applied for a longer target time of ~60 min. This is similar to the duration chosen by other prewarming studies.[12 13 15 20] It is difficult to predict the exact start time of anaesthesia, so the actual mean duration of prewarming was slightly longer than the target.

It is noteworthy that preoperative skin surface warming, for an average of 72 min, reduced the impact of core-periphery temperature redistribution *without significantly elevating preoperative core temperature*. Core temperature is not significantly increased because of the thermoregulatory vasodilatation that occurs when humans are subjected to an increase in ambient temperature, in this case preoperative warming. The consequent redistribution of core temperature results in an increase in peripheral temperature and maintains core normothermia. If prewarming is continued for too long, thermoregulatory vasodilatation becomes less efficient at maintaining normothermia, potentially resulting in an increase in patients' core temperature, usually preceded by perspiration and a feeling of being uncomfortably warm.[19]

Previous publications in the area of prewarming, although showing positive results, do not stand up to close scrutiny. The study by Vanni and colleagues[15] showed an impressive effect of prewarming, but was flawed both by inadequate power (10 patients per group) and by having a control group that was significantly hypothermic before anaesthetic induction. Two other studies also showed a smaller decrease in core temperature during surgery after a

period of prewarming, but neither study warmed patients intraoperatively.[12 13] This resulted in the non-prewarmed patients in the study by Just and colleagues waking with temperatures of only 35.2°C. In addition, both of these small studies had only eight patients per group with resultant wide confidence intervals.

The largest randomized trial of prewarming to date was that by Melling and colleagues[20] involving more than 400 patients. This was powered to look for differences in postoperative complications and showed a significant decrease in postoperative wound infections in patients who were prewarmed either locally or systemically. However, the incidence of perioperative hypothermia was not actually different between the groups. The authors postulated that prewarming improved peripheral circulation in the preoperative period, thus increasing tissue oxygenation. They suggested that the protective effect of this increased tissue partial pressure of oxygen may last into the postoperative period, in short-duration surgery.

In conclusion, 60 min of prewarming appears to attenuate the redistributive hypothermia after anaesthetic induction and decrease the incidence of IPH. The Bair Paws® system appears to be an effective system for prewarming. Recent NICE guidelines emphasize the importance of maintaining normothermia even for short procedures, and advocate warming patients who are cold before operation.[2] The Bair Paws® system might prove useful in these cases. The results of this study suggest that a prewarming strategy may warrant being extended to patients at high risk of IPH who, although overtly normothermic, may nevertheless benefit from having their initial redistributive hypothermia attenuated by prewarming. If prewarming is used in this subset of patients, an increase in preoperative core temperature should not be used as a clinical endpoint. The Bair Paws® was developed as a 'comfort device' and it is worth noting it is capable of cooling patients if forced air is delivered at ambient temperature. If this 'cooler' setting is chosen by the patient, then preoperative patient comfort might be achieved at the expense of an adverse affect on perioperative temperature. Further evaluation of the Bair Paws® is therefore required before allowing full patient control of the thermal output of the unit, if it is to be used to prevent IPH. Future studies should also address the question of what the minimum effective duration of prewarming is, with the different warming devices available.

Acknowledgements

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