

## APPARATUS

# Comparison of forced-air warming and electric heating pad for maintenance of body temperature during total knee replacement

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### Summary

We conducted a randomised controlled trial to compare the efficacy of forced-air warming (Bair Hugger<sup>TM</sup>, Augustine Medical model 500/OR, Prairie, MN) with that of an electric heating pad (Operatherm 202, KanMed, Sweden) for maintenance of intra-operative body temperature in 60 patients undergoing total knee replacement under combined spinal-epidural anaesthesia.

Intra-operative tympanic and rectal temperatures and verbal analogue score for thermal comfort were recorded. There were no differences in any measurements between the two groups, with mean (SD) final rectal temperatures of 36.8 (0.4) °C with forced-air warming and 36.9 (0.4) °C with the electric pad. The heating pad is as effective as forced-air warming for maintenance of intra-operative body temperature.

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Core hypothermia (< 36 °C) is common in anaesthetised patients and may be associated with an increased incidence of cardiac morbidity [1], surgical wound infections [2] and postoperative shivering. Therefore it is accepted practice to monitor and maintain body temperature during surgery.

The most commonly used method of active warming is forced-air warming [3]. However, the warming units and even the brand new commercial blankets have been shown to be potential sources of nosocomial infection [4–6], with pathogenic organisms found in the interior of the hose, which is difficult to clean. The Operatherm 202 electric heating pad (KanMed, Bromma, Sweden) comprises a control unit, an electric cable and a heating pad. It has no hidden space for bacterial colonisation and is theoretically easier to clean.

The aim of this study was to compare forced-air warming and the Operatherm 202 electric heating pad. We hypothesised that the latter was as effective as forced-air warming for maintaining body temperature during total knee replacement.

### Methods

After approval by the hospital Ethics Committee, 60 patients were recruited. Inclusion criteria included age between 18 and 80 years, ASA physical status I–III and elective total knee replacement. Exclusion criteria included pregnancy, history of head injury, core temperature  $\geq 37.5$  °C and contra-indication to neuraxial blockade. Written consent for the study was obtained from each patient. Baseline data were collected and each patient's temperature was measured with an infrared tympanic thermometer (Thermoscan Pro 1, Braun, Germany) immediately after transfer to the operating table and hourly thereafter. Non-invasive blood pressure monitoring, electrocardiography and pulse oximetry were applied. An intravenous catheter was placed and Hartmann's solution infused at  $10 \text{ ml.kg}^{-1}$  over 20–30 min and subsequently according to vital signs and blood loss. Combined spinal-epidural (CSE) anaesthesia was performed by the investigators (VN or AL) at L3–4 or L4–5, using 0.5% plain bupivacaine intrathecally. The epidural catheter was left *in situ* and epidural morphine was given

at the end of surgery for postoperative pain relief. A rectal thermistor temperature probe was then inserted and surgery started after an adequate level of anaesthesia was achieved. Rectal temperature was monitored continuously until the end of anaesthesia.

Patients were randomly allocated by drawing lots to receive active warming using forced-air (Bair Hugger™, Augustine Medical model 500/OR, Prairie, MN) or electric heating pad (Operatherm 202) systems. For the forced-air group, the patients were positioned supine after the CSE with both arms extended. A cotton blanket was folded once to make two layers in thickness, with the forced-air warming blanket sandwiched between the two layers. It was then applied to cover the patient's anterior chest and both arms. Warming was started and continued until the end of surgery. The forced-air warming unit temperature output was set to 43 °C. For the heating-pad group, the 104 × 45 cm pad was placed on the operating table and a prewarmed gel pad was placed on top of it, as suggested by the manufacturer, covered in turn with a sheet. The patient warming system was set to a temperature of 39 °C and warming started 10 min before patients were transferred to the operating table. The patient then lay on the hospital bed sheet and a double-folded cotton blanket was applied to cover the anterior chest and both arms, as for the forced-air group.

All intravenous fluids were warmed to 37 °C with an infusion warmer (BW 485 I, Biegler GmbH, Austria). The ambient temperature of the operating rooms and the postanesthetic room were thermostatically adjusted to 20 ± 1 °C by the engineering department of the hospital. These temperatures were recorded every 5 min by a thermometer positioned level with, and not further than 50 cm from, the patient. A verbal analogue score (VAS) for thermal comfort (0 – extremely cold, 5 – thermally neutral, 10 – extremely hot) was obtained before anaesthesia, at hourly intervals intra-operatively and in the postanesthetic care room. Presence of shivering during surgery and in the postanesthetic room was recorded. All patients were given a forced-air warming blanket in the postanesthetic room if the core temperature was <36 °C or shivering occurred. Warming was stopped at any time if any patient complained of discomfort.

The duration of anaesthesia (from transfer to the operating table to transfer to the postanesthetic room), performance of the CSE (from transfer to the operating table to insertion of the rectal temperature probe), surgery (from skin incision to the last suture), and application of the tourniquet, the volume of crystalloid given and the estimated blood loss were recorded. The surgical procedure was performed by the same team of surgeons.

Power analysis assuming a clinically important difference of 0.3 °C in final core temperature suggested that 28

patients were required in each group ( $\alpha = 0.05$ ;  $\beta = 0.2$ ; SD = 0.4 °C) [7]. Comparisons of normally distributed data were made using the unpaired two-tailed *t*-test. Comparisons of nominal data were made using the Chi-squared test or Fisher's exact test. Changes in rectal temperature from control over time were compared with repeated measures ANOVA. A value for  $p < 0.05$  was considered statistically significant.

## Results

Patients' characteristics and anaesthetic/surgical details were similar in the two groups and are shown in Table 1. Changes in rectal temperatures over time are shown in Fig. 1, and were not statistically significant in either group. First and final rectal and tympanic temperatures were also similar, as were VAS for thermal comfort (Table 2, Fig. 2). No patient in either group had a final rectal temperature <36 °C. Two patients in the forced-air group and one patient in the heating pad group experienced shivering in the postanesthetic care room.

## Discussion

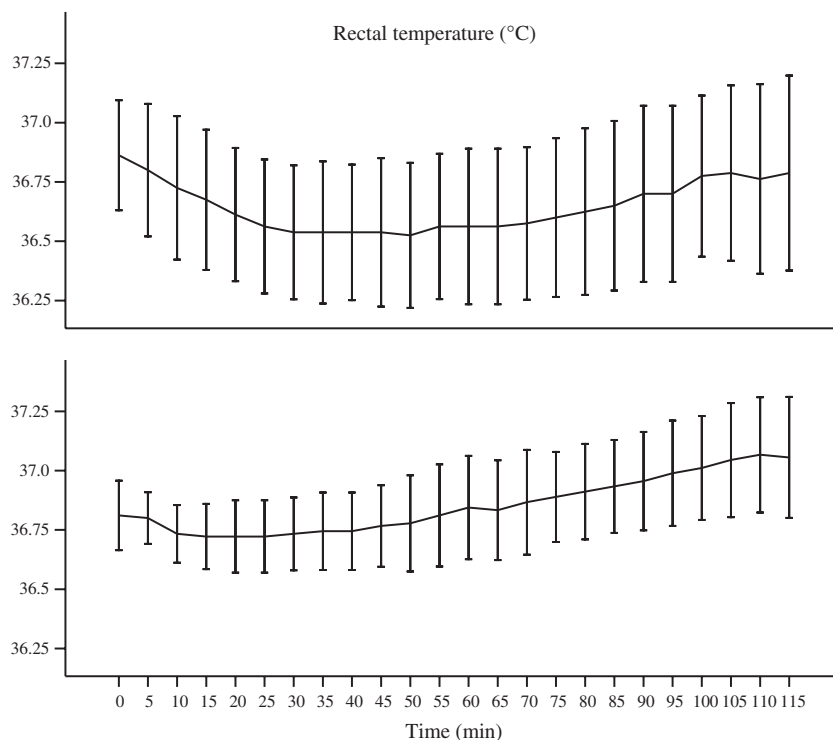
The efficacy of forced-air warming for maintaining normothermia has been well documented [8]. However,

**Table 1** Characteristics and anaesthetic/surgical details of patients warmed with either forced-air or heating pad during total knee replacement. Values are number (proportion) or mean (SD).

	Forced-air (n = 30)	Heating-pad (n = 30)
Sex; M : F	9 : 21	8 : 22
Age; years	67.3 (9.1)	67.4 (7.4)
Body mass index; kg.m <sup>-2</sup>	26.3 (4.4)	26.2 (4.5)
First tympanic temperature;* °C	36.6 (0.4)	36.6 (0.5)
First rectal temperature;* °C	36.8 (0.4)	36.9 (0.3)
Duration of anaesthesia; min	125.3 (15.1)	126.2 (17.2)
Duration of performance of CSE; min	15.8 (4.1)	15.6 (5.3)
Duration of surgery; min	89.3 (12.6)	90.9 (13.8)
Duration of tourniquet; min	96.3 (12.8)	97.7 (14.3)
Estimated blood loss; ml	100.0 (41.5)	103.3 (34.6)
Volume of local anaesthetics; ml	1.8 (0.1)	1.8 (0.1)
Level of sensory block:		
T9	2 (7%)	2 (7%)
T10	0	28 (93%)
T11	26 (87%)	0
T12	2 (7%)	0
Volume of crystalloid; ml	1357 (242)	1268 (228)

No significant differences between groups.

\*First tympanic temperature taken immediately after transfer to operating table; first rectal temperature recorded after initial equilibration.



**Figure 1** Rectal temperature in patients warmed with either forced-air (top) or heating pad (bottom) during total knee replacement. Values are mean (95% CI). Time 0 refers to the first rectal temperature after insertion and equilibration of the rectal temperature probe.

**Table 2** First and final temperatures and verbal analogue scale (VAS) for thermal comfort in patients warmed with either forced-air or heating pad during total knee replacement. Values are mean (SD).

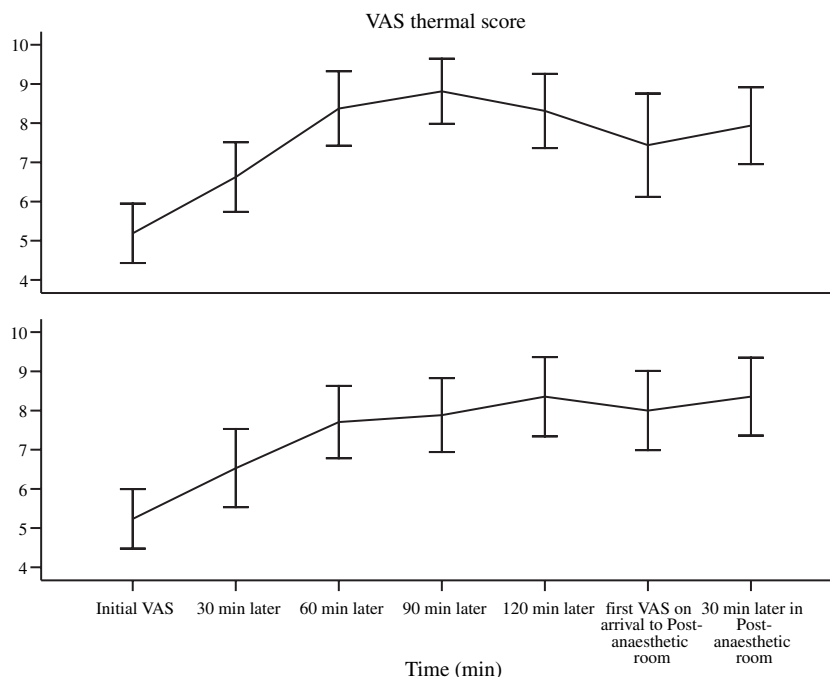
	Forced-air (n = 30)	Heating-pad (n = 30)
First rectal temperature; °C	36.8 (0.4)	36.9 (0.3)
First tympanic temperature; °C	36.6 (0.4)	36.6 (0.5)
First VAS thermal comfort score; mm	5.5 (1.5)	5.4 (0.6)
Mean ambient temperature; °C	20.2 (0.3)	20.1 (0.3)
Final rectal temperature; °C	36.8 (0.4)	36.9 (0.4)
Final tympanic temperature; °C	36.3 (0.5)	36.1 (0.7)
Final VAS thermal comfort score; mm	8.3 (1.8)	8.4 (1.9)

No significant differences between groups.

cost is a concern: the disposable blankets available costs more than UK£15 (€21; US\$20) each and are not recommended for re-use on another patient, the frequency of bacterial contamination tripling after single use [5]. Even if a brand new blanket is used on each patient, the problem is not eliminated. Avidan *et al.* sampled the air stream from nine forced-air warming units and found potentially pathogenic organisms in four [4]. In another study, heavy growth of bacteria was found in swab samples taken from the exterior and interior of the warming unit and from the distal end of the hose [6]. These studies demonstrate that the hose and the warming

units are potential sites for bacterial colonisation, probably due to difficulty in cleaning. This is of particular concern as resistant viruses such as the SARS coronavirus can live on inanimate surfaces for up to 24 h [9]. The electric heating pad used in the current study consists of a warming unit, an electric cable and a heating pad. The heating pad is water sealed and can be disinfected with alcohol or any other disinfectant, as suggested by the manufacturer. There is no hose or hidden space, and theoretically it is easier to clean and disinfect than forced-air warming devices.

We found that the electric heating pad was as effective as forced-air warming for maintaining intra-operative body temperature. The drop in mean rectal temperature over the first 30 min of surgery in the forced-air group, from 36.8 °C to 36.6 °C, could be explained by the redistribution of body heat from the core thermal compartment to the distal legs after induction of CSE anaesthesia [10]. The corresponding drop was slightly less in the heating pad group, from 36.9 °C to 36.8 °C. This might be because active warming had already started in the heating pad group once the patients were transferred to the operating table, and continued throughout the performance of the CSE. It is known that prewarming before induction of anaesthesia reduces the core-to-peripheral temperature gradient and reduces redistribution hypothermia [11]. Rectal temperature in the forced-air group gradually increased from its nadir at



**Figure 2** Verbal analogue score (VAS) for thermal comfort in patients warmed with either forced-air (top) or heating pad (bottom) during total knee replacement. Values are mean (95% CI). Initial VAS refers to that on transfer to the operating table.

30 min. This gradual increase might be due to persistent vasoconstriction in the upper limbs [10], making forced-air warming with an upper body blanket relatively less efficient. Rectal temperature was relatively stable in the heating pad group during the first hour of surgery and gradually increased above the baseline thereafter. Another factor to be considered is the body surface area available for warming. The upper body forced-air warming blanket only covered the anterior chest and both arms. The electric heating pad used was 104 cm long and 45 cm wide, resulting in the entire back of the patient being warmed by the pad. In addition, the air under the surgical drape was being warmed, resulting in a tent-like effect.

There are some limitations to our study. First, there was no control group (no active warming) to compare with the two warming strategies. However, we considered this unethical. In addition, we believe that active warming was achieved in both groups, as otherwise we would have expected the temperature drop in the forced-air group to persist for 3 h and the rectal temperature to drop by about 1 °C [10], whereas in the heating pad group the rectal temperature would have been less stable. Second, there was a difference in the time at which the two warming devices were applied: the heating pad was switched on before the patient was transferred to the operating table, whereas the forced-air warming blanket was applied only after induction of anaesthesia. We are not sure whether the temperature changes might have been different had the forced-air warming started once the patients were transferred to the operating table and

been continued throughout the performance of the CSE, but this would be difficult to achieve practically. Third, our study was limited to total knee replacement and we are uncertain whether the results can be extrapolated to other types of surgery. However, our results suggest that active warming with the electric heating pad should at least be considered as an alternative to forced-air warming for maintenance of intra-operative body temperature.

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