



## ORIGINAL ARTICLE

# A randomised single blinded study of the administration of pre-warmed fluid vs active fluid warming on the incidence of peri-operative hypothermia in short surgical procedures\*

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### Summary

We compared the effect of delivering fluid warmed using two methods in 76 adult patients having short duration surgery. All patients received a litre of crystalloid delivered either at room temperature, warmed using an in-line warming device or pre-warmed in a warming cabinet for at least 8 h. The tympanic temperature of those receiving fluid at room temperature was 0.4 °C lower on arrival in recovery when compared with those receiving fluid from a warming cabinet ( $p = 0.008$ ). Core temperature was below the hypothermic threshold of 36.0 °C in seven (14%) patients receiving either type of warm fluid, compared to eight (32%) patients receiving fluid at room temperature ( $p = 0.03$ ). The administration of 1 l warmed fluid to patients having short duration general anaesthesia results in higher postoperative temperatures. Pre-warmed fluid, administered within 30 min of its removal from a warming cabinet, is as efficient at preventing peri-operative hypothermia as that delivered through an in-line warming system.

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Unintended peri-operative hypothermia (defined as a peri-operative core temperature  $< 36.0$  °C) is a common problem [1, 2]. Known complications attributed to peri-operative hypothermia include an increased incidence of myocardial ischaemia, wound infections, and coagulopathies. Peri-operative hypothermia is also associated with prolonged hospital stay and increased hospital costs [3–5]. Thermal redistribution occurs following induction of anaesthesia and accounts for a drop in core temperature of up to 1.6 °C [2]. Although forced-air warming devices can effectively restore core temperature within 2 h [6, 7], the physiology of thermal redistribution often renders them inadequate for procedures of short duration [8]. The recently published National Institute for Health and Clinical Excellence (NICE) guidelines on prevention of peri-operative hypothermia advise that all fluid (and blood products) delivered to patients having anaesthesia of any duration should be warmed to 37.0 °C [9, 10].

Most fluid warming techniques involve the use of disposable equipment and hardware [11]. Fluid warming

cabinets are installed in many theatres. A bench study has demonstrated that fluid previously warmed in a warming cabinet has the potential to be as effective in limiting the effect of peri-operative hypothermia as 'in-line' warming systems [12].

The aims of this study were to examine the difference in core temperatures of patients following delivery of 1 l pre-warmed intravenous fluid taken from a warming cabinet compared with delivery of 1 l fluid via a commercial in-line warmer. We also wanted to observe the incidence of postoperative hypothermia following administration of 1 l warmed fluid, when compared with fluid administered at room temperature.

### Methods

The study was granted approval by the local research ethics committee. Written informed consent was obtained from 82 adult patients of ASA physical status 1–2 who were scheduled to undergo general anaesthesia for

day-case surgery estimated to last < 30 min. Patients were randomly assigned by computer into the following three groups: (1) 'room temperature'; (2) 'in-line warmer'; and (3) 'warming cabinet'. Patients were excluded if they were undergoing laparoscopic surgery, surgery involving irrigation fluid, or surgery with an estimated blood loss > 200 ml. Other exclusion criteria were medication with nitrates, ACE inhibitors or calcium channel blockers, as these might interfere with normal thermal homeostatic mechanisms.

Patients in the room temperature group received 1 l of Hartmann's solution stored at room temperature. Those in the in-line warmer group received 1 l of Hartmann's delivered via an in-line warmer at 39.0 °C (Astotherm®; Futuremed, Granada Hills, CA, USA) and those assigned to the warming cabinet group received 1 l of Hartmann's pre-warmed for at least 8 h to 41.0 °C in a warming cabinet.

Pre and postoperative temperatures were recorded using an indirect tympanic thermometer. Readings were taken from both ears and the highest reading used for analysis. The ambient pre-operative holding bay area and theatre temperature were recorded. All patients had a temperature probe inserted approximately 15 cm into the oesophagus under direct vision, following induction of anaesthesia with propofol. The core temperature was recorded at 10 min intervals for the duration of the surgery. General anaesthesia was maintained using a volatile agent, with patients breathing spontaneously via a laryngeal mask airway. No forced-air warming was used in these short cases (as per NICE guidelines). All exposed areas were kept covered with standard hospital blankets and surgical drapes.

Fluid was infused over approximately 25 min using a pressure bag where necessary. Total anaesthetic time was recorded on discontinuation of volatile agent. Intravenous paracetamol was given to all patients after the IV fluid infusion had been completed. On arrival in the recovery ward, indirect tympanic thermometer readings were again recorded. Patients were actively warmed using forced-air warming if their temperature was < 36.0 °C on arrival in recovery.

Study data were analysed using SPSS version 15 (SPSS UK, Woking, Surrey). Analysis of variance (ANOVA) compared the differences in core temperature measurement between the three groups with post hoc analysis where a difference was demonstrated. Chi-squared tests were used to assess the difference in the number of patients with peri-operative hypothermia on admission to recovery in those who had received warmed fluids compared with those who had received fluids at room temperature. 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 25.

## Results

Of the 82 patients recruited, six patients were excluded: two due to surgical cancellation; two because a regional anaesthetic technique was employed; and two because data collection sheets were missing. Data were therefore complete for 25 patients in the room temperature group, 25 in the in-line warmer group and 26 in the warming cabinet group. Patients' characteristics, holding bay and theatre environmental temperatures, core temperatures at induction and duration of anaesthesia were comparable between the groups (Table 1).

Using ANOVA on the data shown in Fig. 1, a significant difference was identified in indirect tympanic core temperature between the groups on arrival in the recovery ward ( $p = 0.008$ ); however, no difference was found in the oesophageal temperature at the end of anaesthesia between the groups ( $p = 0.073$ ). Tukey post hoc analysis demonstrated that the difference in recovery ward temperature was between the patients in the warming cabinet and room temperature groups ( $p = 0.006$ ). No statistical difference in temperature was found between the in-line warmer and warming cabinet groups ( $p = 0.769$ ), nor between the in-line warmer and room temperature groups ( $p = 0.15$ ).

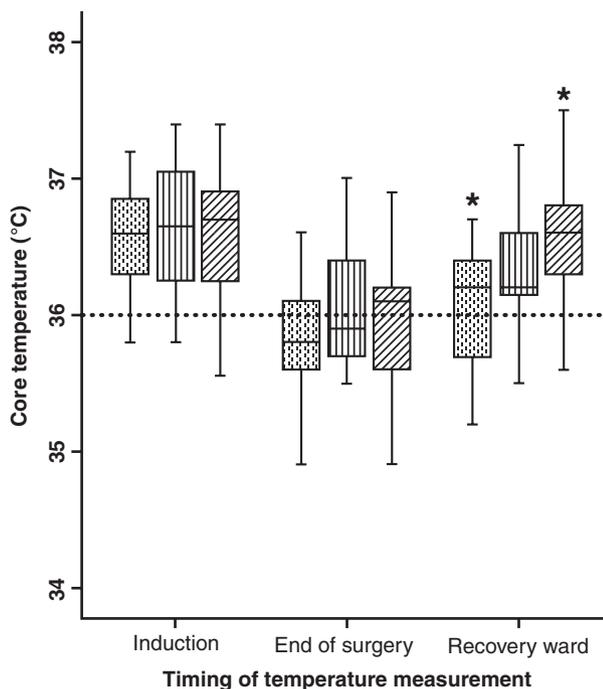
When considering postoperative hypothermia, the percentage of patients admitted to recovery with a temperature < 36.0 °C was lower in those who had received either type of warm fluid (in-line warmer group 4 patients (16%) and warming cabinet group 3 patients (12%)) than in those receiving fluid delivered at room temperature (eight patients (32%);  $p = 0.03$ ).

## Discussion

Fluid is frequently administered to patients undergoing day-case and short duration surgery since it has been

**Table 1** Characteristics of patients receiving fluids at room temperature or warmed with an in-line warmer or warming cabinet, and pre-operative, environmental air temperatures and mean core temperatures. Values are mean (SD).

	Room temperature	In-line warmer	Warming cabinet
Age; years	40 (15)	44 (15)	38 (17)
Male	36%	34%	32%
BMI; kg.m <sup>-2</sup>	27 (6)	27 (7)	27 (6)
Holding bay temp; °C	21.8 (1.0)	21.5 (1.9)	21.6 (1.7)
Theatre temp; °C	20.6 (1.6)	20.7 (1.7)	21.0 (1.4)
Pre-op temp; °C	36.5 (0.5)	36.6 (0.5)	36.6 (0.5)
Duration of anaesthesia; min	31 (10)	37 (15)	35 (13)



**Figure 1** Differences in core temperatures between the control group (room temperature □) and the active groups (in-line warmer ■ and warming cabinet ▨) at induction, end of surgery and in recovery. The box plots indicate median and IQR, the whiskers represent data within a multiple of 1.5 of the IQR. Core temperatures were measured using indirect tympanic or oesophageal thermometry. Core temperature 36.0 °C is indicated with a dotted line. \* $p = 0.006$  (warming cabinet vs room temperature).

shown that 1 l fluid results in an improved recovery profile with less nausea and vomiting [13]. A mathematical calculation (Appendix 1) demonstrates that the administration of a litre of crystalloid fluid at room temperature results in a drop in core temperature of approximately 0.25 °C in an average (70-kg) human [14]. The advent of NICE guidelines have drawn anaesthetists' attention to the fact that even low volume fluid administration can have deleterious effects on patients' peri-operative temperature. This study reinforces the advice that all intravenous fluids should be warmed before administration to minimise the incidence of peri-operative hypothermia.

The temperature recorded in the recovery ward was consistently higher than that recorded at the end of surgery in all groups. This could be due to the re-emergence of thermoregulatory control upon discontinuation of anaesthesia, with subsequent vasoconstriction and increase in core temperature. It might also reflect the fact that different thermometry and recording site was used at the end of surgery (oesophageal) and in recovery

(indirect tympanic). A temperature difference of 0.2 °C was defined by NICE as being of clinical significance in hypothermic patients [10]. Though indirect tympanic thermometry offers clear clinical advantages in performing quick, simple and non-invasive measurements of core temperature, the accuracy of the indirect tympanic thermometer (estimated as  $\pm 0.2$  °C within its operating range) may be compromised during clinical use [15]. Thus, although indirect tympanic temperature may not be a reliable estimate of absolute core temperature, its use to estimate trends within groups is acceptable. In this study, indirect tympanic recording was supplemented with the use of intra-operative oesophageal temperature measurements. Oesophageal temperature demonstrated similar changes of the trend in core temperature within the three groups when compared with indirect tympanic measurements.

Our results show a difference both at the end of surgery and on arrival in recovery between the groups given warm fluid, compared with the group given fluid at room temperature. However, only the difference of 0.4 °C between the room temperature group and the warming cabinet group reached statistical significance (Fig. 1). We used fluids warmed in a cabinet to 41 °C, since we have previously observed that the temperature of the fluid when delivered to the patient is about 37 °C when measured at the distal end of the infusion set [12]. The model of in-line warmer used only warms to 38 °C, and the temperature of fluids on reaching the patient is lower than 37 °C; this may explain why warming cabinet fluids may appear more effective at these infusion rates. Fluid should be pre-warmed for over 8 h to achieve the temperature of the warming cabinet. We have been given written confirmation from the manufacturers of the fluid (Fresenius Kabi, Bad Homburg, Germany) that it is safe to store crystalloids in industrial warmers for up to 1 month at temperatures of up to 41 °C. We recommend clear date labelling of all fluid stored in this way.

We studied a population that would, according to NICE guidelines, not usually receive any other form of active warming (such as forced-air warming), since the duration of anaesthesia was predicted to be < 30 min. The in-line warmer and warming cabinet groups had slightly longer anaesthetic durations, although this difference was not statistically significant. Since core to periphery redistribution of heat is ongoing at this time they might have been expected to be colder [2]; our results showed the opposite.

We have demonstrated that the administration of 1 l warmed fluid to patients having short duration general anaesthesia results in higher postoperative core temperatures, and a lower incidence of peri-operative hypothermia. In addition, we have shown that fluid

pre-warmed in a warming cabinet is comparable at preventing peri-operative hypothermia to that delivered using a commercial in-line warming system. The use of pre-warmed fluid in this way may increase the compliance with NICE guidelines for fluid warming, whilst simultaneously offering potential economic savings.

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## Appendix 1

Calculation to estimate change in core temperature ( $\Delta$ MBT) with the administration of fluid at any temperature ( $T_f$ ) [14]

$$\Delta\text{MBT} = \frac{(T_f - T_{bt}) * (S_f) * (\text{Volume})}{(S_{pt}) * (Wt)}$$

$\Delta$ MBT = Change in core body temperature

$T_f$  = Fluid temperature

$T_{bt}$  = Core body temperature

$S_f$  = Specific heat capacity of the fluid

Volume = Volume of fluid delivered

$S_{pt}$  = Specific heat capacity of human tissue

$Wt$  = Body weight (kg)