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Clinical Practice

Comparison of resistive heating and forced-air warming to prevent inadvertent perioperative hypothermia

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Abstract

Background: Forced-air warming is a commonly used warming modality, which has been shown to reduce the incidence of inadvertent perioperative hypothermia (<36°C). The reusable resistive heating mattresses offer a potentially cheaper alternative, however, and one of the research recommendations from the National Institute for Health and Care Excellence was to evaluate such devices formally. We conducted a randomized single-blinded study comparing perioperative hypothermia in patients receiving resistive heating or forced-air warming.

Methods: A total of 160 patients undergoing non-emergency surgery were recruited and randomly allocated to receive either forced-air warming (n=78) or resistive heating (n=82) in the perioperative period. Patient core temperatures were monitored after induction of anaesthesia until the end of surgery and in the recovery room. Our primary outcome measures included the final intraoperative temperature and incidence of hypothermia at the end of surgery.

Results: There was a significantly higher rate of hypothermia at the end of surgery in the resistive heating group compared with the forced-air warming group (P=0.017). Final intraoperative temperatures were also significantly lower in the resistive heating group (35.9 compared with 36.1°C, P=0.029). Hypothermia at the end of surgery in both warming groups was common (36% forced air warming, 54% resistive heating).

Conclusions: Our results suggest that forced-air warming is more effective than resistive heating in preventing postoperative hypothermia.

Clinical trial registration: NCT01056991.

Key words: equipment; hypothermia; temperature; warming devices

Inadvertent perioperative hypothermia (IPH), defined as a core temperature <36°C,[1] is associated with numerous adverse patient events, including greater intraoperative blood losses,[2] increased postoperative wound infection rates,[3 4] pressure ulcers,[5] cardiac events,[6] hospital costs, and lengths of stay.[7] A plethora of warming devices and techniques[8] have been developed to protect patients, including prewarming[9] and the use of fluid warmers,[10] water mattresses,[11] negative pressure devices,[12] forced-air warming,[13] and resistive heating.[14] Of these, the most commonly used modality is the forced-air warming blanket (FAWB). Use of a FAWB has been recommended by the National Institute for Health and Care Excellence (NICE) for all patients at high risk of IPH and those undergoing surgeries lasting >30 min.[1] However, they are single-use and therefore have ongoing, cumulative costs, which have been recognized in the NICE technology guidance on the Inditherm mattress.[15] They can also be difficult to

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Editor's key points

- Many methods and devices are available to prevent perioperative hypothermia, but their relative effectiveness is uncertain.
- This study compared a forced-air warming device (Bair Hugger™) with a resistive heat mattress (Inditherm) in patients undergoing surgery of >30 min duration.
- Body temperatures were very slightly higher after surgery in patients receiving forced-air warming.
- Although statistically significant, the clinical relevance of this is not established; perioperative hypothermia occurred in a high proportion of patients in both groups.

position in such a way that satisfies both anaesthetist and surgeon. Carbon-polymer resistive heating mattresses (RHMs) provide a silent, reusable warming system, which does not interfere with the surgical field and could provide a solution to the aforementioned problems. The mattress uses resistive heating, whereby a low-voltage electric current passes through a carbon-based conductive polymer to generate a uniform heating surface.[15]

A review of the literature comparing the efficacy of resistive heating with forced-air warming shows mixed results, with one non-clinical study favouring resistive heating,[16] six showing equivalence in performance,[17–22] and three clinical studies favouring forced-air warming.[23–25] The aim of our study was to compare the efficacy of the carbon-polymer mattress (posterior resistive heating) with the forced-air warming blanket (anterior forced-air warming) in preventing IPH in patients undergoing non-emergency surgery. Our study was a response to the NICE CG65 research recommendations calling for further assessments to compare the warming capacity of forced-air warming (FAW) with alternative devices.[1] This was a pragmatic study insofar as the use of warming and the mix of operations were intended to reflect everyday clinical practice.

Methods

We initially performed a pilot study to assess larger scale feasibility by recruiting 40 patients undergoing elective surgery under general anaesthesia, where the anaesthetist judged that warming during the operation was appropriate. The only exclusion criteria were patients less than the age of 18 yr or presenting as an emergency. In the pilot study, 5% of patients were hypothermic on admission to the recovery room. Using the online calculator (http://www.cct.cuhk.edu.hk/stat/proportion/tspp_sup.htm) set to an α of 0.05 and a power of 0.8, we calculated that 59 patients in each arm or a total of 118 would be needed to show the RWM to be non-inferior. Taking the results for the incidence of IPH at the end of surgery, from the pilot phase, a total sample size of 120 patients would be required to show non-inferiority.

We therefore recruited a further 120 patients using exactly the same criteria and methods as the pilot before pooling all of the results for final analysis[26] (Fig. 1).

The study received local research ethics committee approval (REC reference 05/Q1907/166) and was registered with ClinicalTrials.gov (Identifier NCT01056991). Written informed consent was obtained from all patients.

Patients were randomized via computer-generated codes to receive warming using either a FAWB (Bair Hugger 750; Actamed, Wakefield, UK) or RHM (Inditherm; Inspiration Healthcare, Rotherham, UK).

General anaesthesia was induced i.v. and maintained with inhaled volatile agents in all patients. If indicated, tracheal intubation was facilitated with a non-depolarizing muscle blocker. Fresh gas flows were reduced to ≤1 litre min^{-1} within 15 min of inducing anaesthesia. All patients received warmed fluids (Ranger; Actamed, Wakefield, UK), and the operating theatre temperature was maintained between 20 and 22°C. The patients who were allocated to the FAWB group received forced-air warming via the Bair Hugger 750 Warming Unit set to the maximal setting (43°C). The most appropriate style of blanket was used for each patient. Patients allocated to the RHM group received resistive heating from lying supine on the mattress in theatre set to the maximal setting of 40°C. Patient warming in the RHM group commenced as soon as the patient was positioned on the operating table; in the FAWB group, it was started immediately after surgical draping. In both groups, it was maintained until the end of the operation.

Pre-induction and recovery room temperature measurements were obtained from all patients using a temporal artery thermometer (TAT 5000; Exergen, Watertown, MA, USA). After induction of anaesthesia, an oesophageal probe (Thermistor 400; Mallinckrodt, Cornamaddy, Ireland) was inserted to measure patient core temperature immediately after induction, at the start of surgery, every 15 min for the first hour, and then every 30 min thereafter until the end of surgery. The probes were maintained and calibrated according to the manufacturer's instructions. Primary outcomes included the postoperative core temperature and the incidence of IPH at the end of the operation. The secondary outcome measure was the estimated blood loss based on suction volume, swab weight, and surgical opinion.

Data analysis was performed using SPSS 16.0 for Mac (SPSS Inc., Chicago, IL, USA). Continuous data distributions were examined for normality by visual inspection of frequency histograms. Normally distributed data are presented as mean (SD) and were compared using Student's unpaired *t*-test. Where data distributions were skewed, we used medians, ranges and interquartile ranges (IQRs) and the Mann–Whitney *U*-test. Categorical data were analysed using the χ^2 test or Fisher's exact test as appropriate. Owing to the limited number of planned comparisons, no adjustment for multiple testing was made. A value of $P<0.05$ was considered statistically significant.

Results

Overall, 160 patients were randomized to receive intraoperative warming from either FAWB (n=78) or RHM (n=82). One patient allocated to the RHM group in whom a clear surgical cause of bleeding resulted in an excess of 5 litre blood loss was excluded from the final analysis. There were no reports of burns or other intraoperative complications related to the warming devices used. The groups were well matched (Table 1), and the rates of pre-induction hypothermia were low (RHM=6%, FAWB=1%). There was no significant difference in pre-induction starting temperatures between the RWM and FAWB groups (P=0.133). The mean (SD) patient core temperature before knife to skin was 36.0 (0.4)°C for the RHM group and 36.0 (0.5)°C for the FAWB group.

Mean, final intraoperative temperatures were significantly (P=0.029) higher in the patients warmed with forced-air warming (36.1°C) compared with resistive heating (35.9°C; Table 2). In keeping with the core temperature results, the incidence of hypothermia (defined as core temperature <36°C) at the end of surgery was significantly (P=0.017) lower in patients warmed with FAWB (36%)