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Conductive warming and insulation reduces perioperative hypothermia

Research Article

Thorsten Perl[1]*, Anke Rhenius[1], Christoph B Eich[2], Michael Quintel[1], Daniel Heise[1], Anselm Bräuer[1]

1 Department of Anaesthesiology, Emergency and Intensive Care Medicine, Georg-August University Göttingen, Robert-Koch-Str. 40, D-37075 Göttingen, Germany

2 Department of Paediatric Anaesthesia, Department of Anaesthesia, Paediatric Intensive Care and Emergency Medicine, Kinderkrankenhaus auf der Bult, Janusz-Korczak-Allee 12, D-30173 Hannover

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Abstract: Background: Perioperative hypothermia is rather common after head and neck surgery. Methods: In this prospective, randomised controlled study with 40 patients, we tested the hypothesis that the use of a new conductive warming system (PerfecTemp™, The Laryngeal Mask Company Limited, St. Helier, Jersey) in combination with insulation of 1.29 clo (treatment group) is better in reducing the incidence of hypothermia during and after head and neck surgery than insulation only (control group). Results: Repeated-measures analysis of variance (ANOVA) and post hoc Scheffé's test identified a significantly higher core temperature in the treatment group at 45, 60, 75, 90, 105 and 120 min ($p < 0.05$). Furthermore, Fisher's exact test confirmed a lower incidence of intraoperative (3 vs. 9 patients; $p = 0.03$) and postoperative hypothermia (0 vs. 6 patients; $p = 0.008$). Conclusion: In conclusion, the combination of good thermal insulation and conductive warming is effective in preventing perioperative hypothermia during head and neck surgery. Level of Evidence: 1b

Keywords: *Conductive warming • Insulation • Head and neck surgery • Perioperative hypothermia • oesophageal temperature • Randomised controlled trial*

1. Introduction

Perioperative hypothermia, defined as a core temperature below 36 °C, is one of the most common side effects of general anaesthesia [1;2]. It results from various factors, including low preoperative core temperatures [3]; anaesthesia-induced inhibition of thermoregulatory defences with a redistribution of heat after the induction of anaesthesia, combined with a cold surgical environment; administration of cold intravenous fluids and evaporation from surgical incisions [4].

Several prospective, randomised trials and retrospective studies have shown that perioperative hypothermia is associated with numerous adverse effects and outcomes [5]. Following head and neck surgery, perioperative hypothermia can cause delayed extubation and the development of early perioperative wound complications, such as neck seromas and flap dehiscence [6;7]. Although the authors of these studies recommend active warming for patients at risk for intraoperative hypothermia [6;7], most patients are not actively warmed during head and neck surgery.

The purpose of this prospective, randomised, controlled study was to test the hypothesis that the use of a new conductive warming system (PerfecTemp™, The Laryngeal Mask Company Limited, St. Helier, Jersey) in combination with insulation is better in reducing the incidence of hypothermia during and after head and neck surgery than insulation only.

* E-mail: tperl@gwdg.de

2. Methods

After formal approval of the protocol by our local research ethics committee, 40 patients were recruited. Written informed consent was obtained from all patients on the day prior to anaesthesia and surgery. All patients included in the study were required to be adults between 18 and 75 yrs, to have American Society of Anesthesiology (ASA) physical status I–III and to undergo elective head or neck surgery that was scheduled to last between 90 min and 180 min. The exclusion criteria were as follows: body mass index < 20 or > 30 kg/m²; preoperative temperature > 38°C or < 35°C; pregnancy or a history of thyroid disease; and operating time < 60 min or > 180 min.

All patients were premedicated with 7.5 mg oral midazolam. General anaesthesia was induced with propofol (2 to 2.5 mg per kg of body weight) and remifentanil (0.2-0.5 µg/kg) followed by rocuronium (0.4-0.6 mg/kg) to facilitate tracheal intubation. Anaesthesia was maintained with infusions of remifentanil (0.1-0.6 µg/kg/min) and propofol (3-6 mg/kg/h) titrated to maintain adequate anaesthetic depth and hemodynamic stability.

The ambient temperature of the operating theatre was 19 °C. Sublingual temperatures were measured preoperatively with an electronic thermometer (Geratherm rapid, Geratherm Medical AG, Geschwenda, Germany) and an accuracy of +/- 0.1°C. During all measurements, sublingual placement and mouth closure were ensured by a member of the study team (A.R.) experienced in the use of this device. From induction to the end of surgery, oesophageal temperatures were measured every 15 minutes using a temperature probe (TEMPRECISE #4-1512-A, Arizant International Corp. Eden Prairie, MN, USA) inserted 30 to 35 cm into the distal oesophagus and an accuracy of +/- 0.1°C.

All patients were identified through the daily surgical schedule. A computer generated randomisation list with four randomly permuted blocks of ten patients was used to allocate patients to either the treatment group (conductive warming and insulation) or the control group (insulation only).

In the treatment group, the patients were positioned supine on the conductive warming mattress (190.5 cm x 50.8 cm) (LMA PerfecTemp™) and placed on the operating table, as suggested by the manufacturer. The patients were then insulated immediately with a standard hospital duvet (188 cm x 122 cm), filled with Trevira (100% polyester) (Brinkhaus GmbH & Co. KG, Warendorf, Germany) with an insulation value of 1.29 clo [8], while one clo is defined as the amount of insulation, that provides thermal comfort for a resting person at a room temperature of 21°C. The conductive patient warming system was set to a temperature of 40.5°C throughout the study, and warming was stopped when the oesophageal temperature was > 37.5°C.

Patients in the control group were positioned supine on the operating table and were immediately insulated with the standard hospital duvet.

All intravenous fluids were infused at room temperature. The duration of anaesthesia and surgery (i.e., time from skin incision to last suture) were recorded.

Power analysis, assuming a clinically important reduction in the incidence of intraoperative and postoperative hypothermia from 50% to 90%, suggested that eleven patients were required in each group ($\alpha = 0.05$; $\beta = 0.2$). To compensate for the unexpected exclusion of patients with a shorter or longer duration of surgery than planned, the initial total number of recruited patients was increased to 20 patients in each group.

Comparisons of nominal data were made using Fisher's exact test. A Kolmogorov-Smirnov test was used prior to parametric testing to ascertain whether values came from a normal distribution. Comparisons of normally distributed data were made using Student's t-test. Comparisons of not normally distributed data were made using the Mann-Whitney U-test. Time-dependent changes in core temperature were evaluated using repeated-measures analysis of variance (ANOVA) and post hoc Scheffé's test. Results are expressed as means ± SD or as median and interquartile range (IQR) as appropriate. A $p < 0.05$ was considered statistically significant. STATISTICA for Windows 9.0 (StatSoft Inc., Tulsa, OK, USA) was used for all analyses.

3. Results

A total of 86 patients were assessed for eligibility, and 25 patients could not be asked to participate because they came to the hospital on the day of the operation. Twenty-one patients refused to participate. Of the 40 patients recruited, 10 patients had to be excluded because their operating times were unexpectedly below 60 minutes (five patients in the treatment and four in the control group) or above 180 minutes (one patient in the control group) (Figure 1).

In three patients, the conductive warming mattress did not fully heat to 40.5°C for unknown technical reasons. The temperature reached with the conductive warming mattress was 38°C, 38.5°C and 38.7°C in these three cases. These patients were still included in the analysis. Data were complete for 15 patients in each group. Patient characteristics, the ambient temperature of the operating theatre, core temperatures

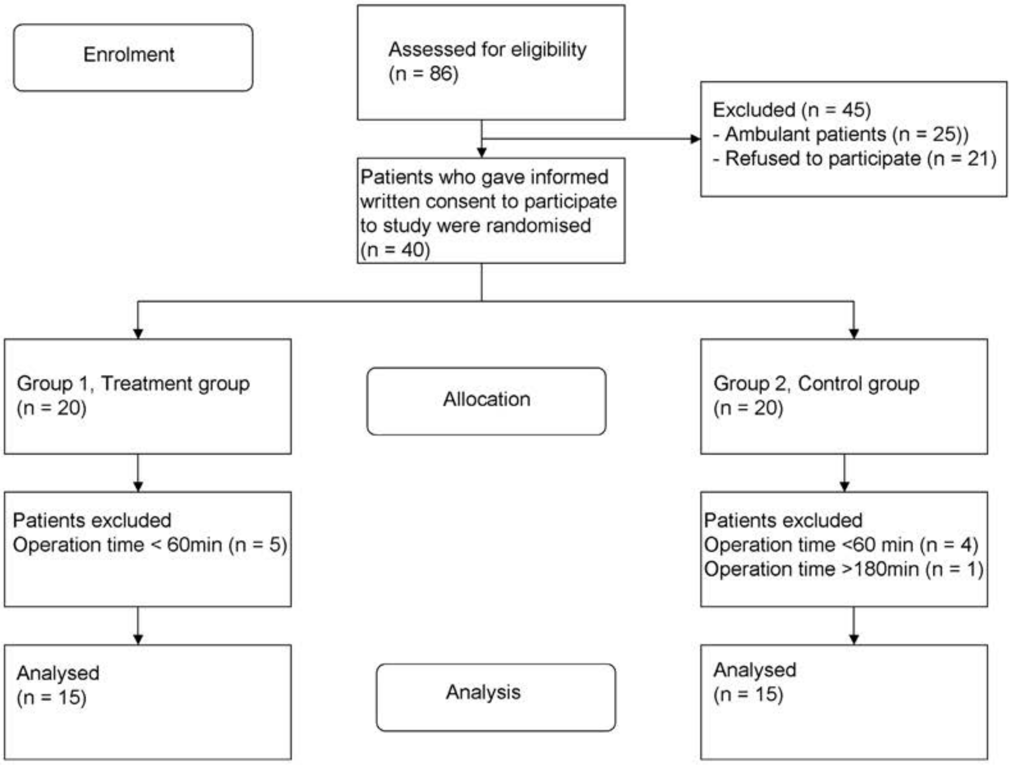

Figure 1 Flow diagram of the study

Table 1 Patient characteristics and perioperative variables. Values are presented as mean (SD), median, interquartile range and range (IQR [range]) or numbers of patients.

Variable	Treatment group (n = 15)	Control group (n = 15)	P-value
Age; yr	51 ± 18	51 ± 15	0.99
Sex; m/f	7/8	10/5	0.46
Height; cm	173 ± 11	175 ± 10	0.64
Weight; kg	74 ± 16	80 ± 9	0.21
ASA-Status	2 (1–2 [1–2])	2 (1–2 [1–3])	0.79
Temperature of the O.R.; °C	19 ± 1	19 ± 1	0.3
Core temperature before induction of anaesthesia; (°C)	36.1 ± 0.4	35.9 ± 0.5	0.33
Duration from positioning on the conductive warming mattress to induction of anaesthesia; min	7 (5–9 [4–25])	-	-
Duration of anaesthesia; min	118 ± 28	122 ± 38	0.74
Duration of surgery; min	97 ± 25	103 ± 37	0.61

before induction of anaesthesia and the duration of surgery were not different across the groups (Table 1). The types of surgery (control group / intervention group) were middle ear operations (5/6), endoscopic sinus surgery (6/5), rhinoplastic (2/1), paroidectomia (2/2) and neck dissection (0/1). The ANOVA identified a significantly higher core temperature in the treatment group at 45, 60, 75, 90, 105 and 120 min (Figure 2). Further testing was not necessary as there were only three patients with a longer duration of surgery included. Furthermore, Fisher's exact test confirmed a lower incidence of intraoperative (3 vs. 9 patients; $p = 0.03$) and postoperative hypothermia (0 vs. 6 patients; $p = 0.008$) in the treatment group. No adverse effects were observed.

4. Discussion

This prospective, randomised, controlled study demonstrates that a conductive warming mattress combined with insulation significantly reduces the incidence of hypothermia during and after head and neck surgery under general anaesthesia compared to insulation only.

Redistribution of body heat from the core to the periphery was unusually small in this study and similar

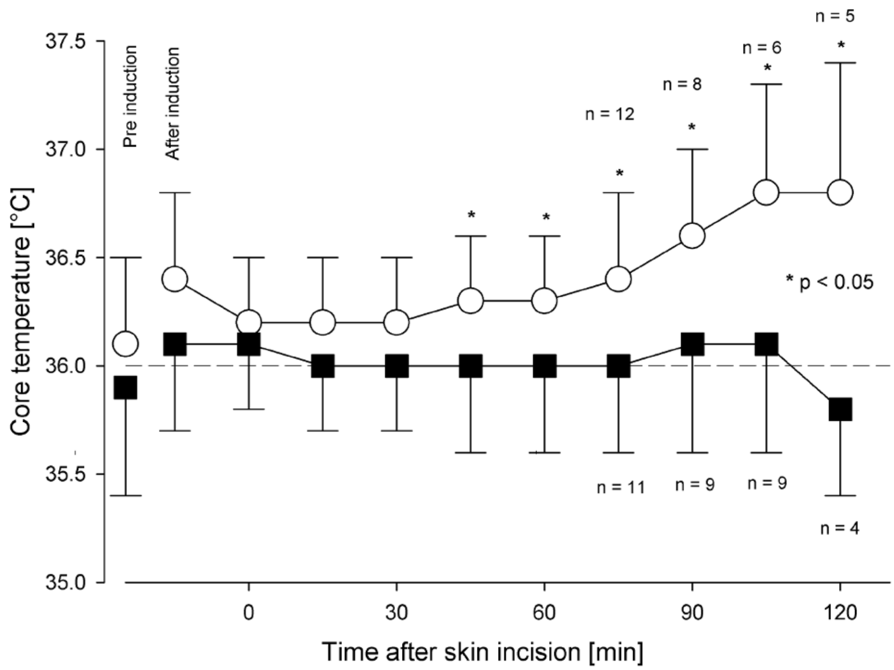

Figure 2. Mean pre- and intraoperative temperatures of the treatment group (o) and control group ([]). Error bars represent SD. In each group, data were complete for at least sixty minutes (n = 15).

in both groups, as core temperature decreased only 0.1°C in the control group and 0.2°C in the study group. In most clinical studies, the redistribution of heat after the induction of anaesthesia leads to a reduction in core temperature of about 0.3°C to 0.8°C [9-12] in the first hour, whereas under experimental conditions it can reach up to 1.7°C [13]. This small decrease in core temperature may be explained by the fact that patients were kept comfortably warm during the entire preoperative period (i.e., from the ward, during transport to the operating theatre and at the induction of anaesthesia) with the same effective insulating hospital blanket as was used during the operation. This approach refers to the recent NICE guideline [14].

Patients during head and neck surgery are often thought to have a relatively low risk for perioperative hypothermia because, in most cases, no body cavity is opened and because the surgical incisions as well as blood losses are small. Therefore, head and neck surgery is thought to be one of the easiest sub-specialities in which patients can be kept warm. This low risk may explain why there are no prospective studies about perioperative hypothermia and its prevention during head and neck surgery. However, many patients undergoing head and neck surgery are prone to hypothermia due to advanced age [6;15;16] and cancers with associated malnutrition and low body weight [6;17]. According to their preoperative risk profile (e.g., ischemic heart disease, diabetes mellitus, chronic obstructive pulmonary disease, preoperative radiotherapy, preoperative chemotherapy) [7;18], they are often vulnerable to hypothermia associated complications. These complications include the following: an increasing incidence of myocardial ischemia [19;20], which is also a relevant complication after reconstructive head and neck surgery [21]; an augmenting of blood loss [22]; a decreasing of resistance to surgical wound infections; or an increasing of local wound complications [6;7;23;24], thus prolonging hospitalisation.

The few existing studies were particularly focused on longer operations like parotidectomies, neck dissections [6] and reconstructive surgery with free tissue or regional flaps [7;25]. In the study of Agrawal et al. [6], the incidence of perioperative hypothermia was 65% in the unwarmed group, clearly showing the high risk of perioperative hypothermia in patients during head and neck surgery. In our study, which analysed relatively short operations, we observed an incidence of perioperative hypothermia of more than 40% in the control group. In contrast to the study of Agrawal et al. [6], we used a high level of insulation (1.29 clo for these patients), which is much higher than the insulation value of most commercially available materials designed for use in the operating room. With this insulation, heat losses from the covered skin can be reduced about 70%. [8]. In most of our patients, this insulation was able to maintain a stable thermal steady state with a relatively constant core temperature. However, this thermal steady state was at a core temperature of about 36.0 °C, with many patients being hypothermic.

In general, the efficacy of posterior patient-warming systems is limited [25-28]. These devices have a disadvantage because warming the back of the patient in the supine position is suboptimal. During surgery, little heat is lost from the back [28], and heat gain from the back is also limited [27;28], resulting in a small change in heat balance. However, in this special setting, the additional heat generated by the conductive warming system leads to a positive thermal balance and an increase in core temperature after 30 minutes. In contrast to conventional circulating water mattresses, the new conductive system is made of thick viscoelastic foam. This material enhances contact between the mattress and the back, thereby reducing thermal contact resistance and increasing the efficacy of heat exchange.

In contrast to forced-air warming, the combination of good insulation and conductive warming has several advantages. There are no expensive disposable elements or relevant noise emissions [12], and there are low costs for maintenance and low power consumption. The costs per use are probably the most important reason to explain why in Europe only about 43% of the surgical patients are actively warmed under general anaesthesia [29].

Another advantage is that the system can be used for pre-warming as soon as the patient can be placed on the operating table when the controller unit is mounted at the operating table.

Our study has several limitations. First, two different anatomic locations were used to measure core temperature (oral temperature before induction of anaesthesia and oesophageal during general anaesthesia). However, both methods are reasonable methods for core temperature measurements, and we could record the first reliable oesophageal temperature five minutes after induction of anaesthesia, allowing this temperature to serve as a reliable starting temperature.

Second, five patients per group had to be excluded from the analyses because the operating time was shorter or longer than planned. Nevertheless, we had to exclude these patients because it is not advisable to compare operations with durations of 30 minutes with operations of more than three hours.

Finally, we did not take full advantage of the option to pre-warm our patients with the conductive system. On average, the time from the beginning of warming to the induction of anaesthesia was only seven minutes. It seems likely that longer pre-warming periods would enhance the efficacy of the conductive warming mattress.

In conclusion, our study shows that the combination of good thermal insulation and conductive warming is effective to prevent perioperative hypothermia during and after head and neck surgery.

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