

Short interruptions between pre-warming and intraoperative warming are associated with low intraoperative hypothermia rates

Rolf Grote¹  | Anna Wetz² | Anselm Bräuer² | Matthias Menzel¹

¹Department of Anaesthesiology, Emergency Medicine, Intensive Care Medicine and Pain Therapy, Klinikum Wolfsburg, Wolfsburg, Germany

²Department of Anaesthesiology, University Hospital Göttingen, Göttingen, Germany

Correspondence

Rolf Grote, Department of Anesthesiology, Emergency Medicine, Intensive Care Medicine and Pain Therapy, Klinikum Wolfsburg, Sauerbruch Straße 7, 38442 Wolfsburg, Germany.
Email: rolf.grote@outlook.de

Background: Prevention of inadvertent hypothermia is recommended for procedures >30 minutes because hypothermia increases the risk of myocardial ischemia, intraoperative blood loss, transfusion and wound complications. Therefore, short warming interruptions between pre-warming and intraoperative warming might result in lower hypothermia rates. The aim of this retrospective investigation was to determine whether the incidence of inadvertent intraoperative hypothermia was affected by the warming interruption.

Methods: The lowest intraoperative body core temperature value and the warming interruption time were taken from anaesthesia records. Body core temperature was recorded continuously, and a patient was classified to be hypothermic if the lowest recorded temperature value was <36°C. Hypothermia rates and the correlation between warming interruption times and intraoperative hypothermia rates were calculated.

Results: Five thousand eighty-four patients were analysed. The intraoperative hypothermia rate was 15.3%. Nineteen patients (0.4%) had a recorded temperature of <35.0°C. An increase in forced-air warming interruption time was significantly associated with an increase in intraoperative hypothermia rates ($P < .0001$). Patients with interruptions in forced-air warming >20 minutes showed significantly higher hypothermia rates than those with interruptions of ≤ 20 minutes ($P < .0001$).

Conclusion: Intraoperative hypothermia rates increased significantly with longer forced-air warming interruptions between pre-warming and intraoperative warming. Short warming interruptions can preserve the effect of pre-warming and are associated with low intraoperative hypothermia rates.

1 | INTRODUCTION

Inadvertent perioperative hypothermia, defined as a core body temperature less than 36.0°C, increases the risk of myocardial ischemia, arrhythmia, intraoperative blood loss, transfusion and wound

complications in surgical patients.¹⁻³ The scientific evidence of measures to prevent inadvertent intraoperative hypothermia has been summarized in the NICE and the German and Austrian guidelines.^{2,3} Active pre-warming with forced-air combined with intraoperative forced-air warming was recommended with the highest level of evidence.³

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Pre-warming can be performed in general wards, in holding areas or in the operating room. When patients are exposed to a cold environment after pre-warming the warm body surface loses much heat.⁴ When pre-warming with forced-air was conducted in general wards, patients showed intraoperative hypothermia rates between 24%-42%.⁵⁻⁷ In comparison, when pre-warming with forced-air was performed directly before induction of anaesthesia lower intraoperative hypothermia rates of 15.8% could be achieved.⁸ A possible explanation could be that a long warming interruption between the end of pre-warming and the beginning of intraoperative warming reduces the effect of pre-warming and therefore results into higher hypothermia rates.

The aim of the present retrospective study was to determine whether the incidence of inadvertent intraoperative hypothermia was affected by the forced-air warming interruption time between end of pre-warming and initiation of intraoperative warming.

2 | MATERIALS AND METHODS

The Ethics Committee of the Medical School of the Martin Luther University Halle Wittenberg, Germany, approved the data collection procedures and the scientific evaluation of the data ("processing number" 2012-92).

2.1 | Primary outcome measure

The primary outcome measure was the incidence of intraoperative hypothermia depending on the warming interruption time between the end of pre-warming and the beginning of intraoperative warming. A patient was classified to be hypothermic, if the lowest core body temperature recorded was $<36^{\circ}\text{C}$.

2.2 | Anaesthesia records analysed

The retrospective study involved the analysis of anaesthesia records of patients from the departments of General Surgery, Trauma Surgery, Gynaecology, Urology and Spinal Surgery who underwent elective surgery between 1 July 2014 and 31 December 2014. The inclusion criteria for data analysis were as follows: age >18 years, American Society of Anaesthesiologists (ASA) grade 1-4, general anaesthesia with endotracheal intubation and without combined general-neuraxial anaesthesia, anaesthesia time of at least 30 minutes, pre-warming for at least 10 minutes and intraoperative warming until the end of surgery.

2.3 | Data analysis from the anaesthesia records

The total number of patients, the number of patients with intraoperative hypothermia and the warming interruption times were calculated from the anaesthesia records.

Editorial Comment

Unplanned intraoperative or post-operative hypothermia can increase risk for complications for patients. This investigation shows that short (rather than long) warming interruptions between pre-warming and intraoperative warming can reduce the rate of intraoperative hypothermia.

2.4 | Standard thermal management

The thermal management measures followed a standard operating procedure. After positioning on the operating table, the patients were covered with a forced-air warming blanket and pre-warming was started immediately after arrival in the anaesthesia induction area. Warming was continued during the induction of anaesthesia and stopped with the beginning of preparatory surgical measures. Forced-air warming was restarted at the beginning of the operation and continued until the end of surgery with the same forced-air warming blanket. Patients received forced-air warming with an air temperature of 43°C using an upper body blanket (Model 522; 3M Germany, Neuss) or a lower body blanket (Model 525; 3M Germany, Neuss, Germany). Intravenous fluids exceeding 2 L per patient and blood products were warmed using an infusion warmer (3M Ranger High Flow System; 3M Germany, Neuss, Germany).

2.5 | Measurement and documentation of core temperature

Body core temperature was continuously measured during anaesthesia either with an oesophageal probe (Assmuth D-0S4, Philips 21075A-compatible, Philips Healthcare, Germany), whose tip was positioned under laryngoscopic view with a Magill forceps 30 cm distal from the lower incisor teeth, or a bladder catheter thermometer (UROSID[®] sensor 400; Asid Bonz, Herrenberg, Germany), or an intraarterial temperature probe (PiCCO-Catheter; Pulsion, München, Germany). Temperature values were continuously recorded by the anaesthesia monitor. The lowest recorded intraoperative temperature value was entered into a special checkbox for digital data acquisition in the anaesthesia record by the attending anaesthesiologist.

2.6 | Statistical analysis

Statistical analysis was performed with the Excel software for Mac (version 15.20, Microsoft Inc, Redmond, WA, USA), MedCalc (version 12.4.0.0, MedCalc Software bvba. Avadialaan 22 8400 Ostend, Belgium), and Statistica (version 10, 1984-2011; StatSoft, Tulsa, OK, USA). Normal distribution was tested with the Kolmogorov-Smirnov test. Continuous parameters are presented as medians with interquartile ranges when they showed

no normal distribution. The Mann-Whitney *U* Test was used to analyse continuous parameters regarding significant differences between normo- and hypothermic patients; the chi-squared test was used to analyse significant differences between normo- and hypothermic patients in categorical parameters. A *P*-value of $<.05$ was considered statistically significant. Receiver operating characteristic (ROC) analysis was used to determine a cut-off value for the forced-air warming interruption time.

3 | RESULTS

During the analysed time period, 6471 patients fulfilled the inclusion criteria. In 1387 (21.4%) of the analysed anaesthesia records, documentation of temperature values or of the used temperature probe was insufficient, so that 5084 records could be used for retrospective analysis. Patient data and process times are shown in Table 1.

The main surgical procedures were:

General surgery: hernia repair, cholecystectomy, colorectal resection

Trauma surgery: hip replacement, knee arthroplasty, knee replacement

Gynaecology: hysterectomy, oophorectomy, breast surgery

Urology: prostatectomy, cystectomy, nephrectomy

Spinal surgery: spinal fusion, laminectomy

Seven hundred and seventy-six patients (15.3%) showed an intraoperative body core temperature of $<36.0^{\circ}\text{C}$ and 19 (0.4%) had a recorded temperature of $<35.0^{\circ}\text{C}$.

There was a negative correlation between the warming interruption time and the lowest intraoperative core body temperature (correlation coefficient, -0.2255 ; $P < .0001$) (Figure 1).

The duration of forced-air warming interruption was median (IQR) (range) 20 (15-30) (10-60). Hypothermia rates varied from 7.4%-40.0% depending on the warming interruption time ($P < .0001$) (Figure 2).

Receiver operating characteristic analysis revealed a cut-off value for forced-air warming interruption time of >20 minutes (AUC 0.652

with a specificity of 67.9% and a sensitivity of 54.4%; $P < .001$). The incidence of intraoperative hypothermia was significantly lower in patients with a forced-air warming interruption time of ≤ 20 minutes than those with an interruption of >20 minutes (9.6% vs 21.2%; $P < .0001$).

4 | DISCUSSION

This large retrospective analysis of more than 5000 patients undergoing general anaesthesia revealed that longer forced-air warming interruption times were associated with significantly higher intraoperative hypothermia rates. Patients with forced-air warming interruptions >20 minutes showed significantly higher intraoperative hypothermia rates than those with interruptions of ≤ 20 minutes (21.2% vs 9.6%; $P > .0001$).

The effect that long interruption times between pre-warming and intraoperative warming can increase the risk of hypothermia has recently been shown for the first time in a prospective randomized-controlled trial with 200 patients.⁹ In contrast to the present analysis, where a standard warming blanket was used for pre-warming in the operating room, in the study of Lau et al⁹ a patient controlled pre-warming gown was used in the preoperative unit. A pre-warming gown is specially designed for the purpose of pre-warming awake patients in holding areas or general wards. Patient-controlled pre-warming with a pre-warming gown has already been shown to be effective in preventing perioperative hypothermia, but when conducted outside the operating room, longer warming interruptions occurred and hypothermia rates were higher than in the present investigation (25.2% vs 15.3%).⁵ Compared to the present results, Lau et al⁹ observed an intraoperative hypothermia rate of 46.5% despite a pre-warming time of at least 30 minutes. This result could be explained by the longer warming interruption time of the prewarmed patients in that investigation (median 33 min [IQR 26-51]) compared to the present data (median 20 min [IQR 15-30]).

Despite the different methods and results of the investigations, the effect of warming interruptions on the incidence of intraoperative hypothermia was the same. The effect was not only true under very controlled conditions of a randomized controlled trial but was also detectable in clinical practice. This effect is real, relevant and has an impact on the incidence of intraoperative hypothermia.

In previous studies it has been shown that the intraoperative hypothermia rates varied between 30.4%-69% with no pre-warming at all, 24%-42% with pre-warming in general wards or holding areas and 15.3% with pre-warming in the operating room directly before and during induction of anaesthesia.^{5-8,10} The different hypothermia rates of pre-warmed patients might now be explained by higher amounts of heat loss during longer forced-air warming interruption times. In addition, the presented analysis showed, that forced-air warming interruptions of more than 40 minutes were associated with hypothermia rates of $\geq 30\%$ that have also been described in patients without pre-warming.⁵⁻⁸ As a consequence, during longer

TABLE 1 Patient data and process times

Age (median [IQR]; y)	63 (49-76)
Sex (male/female) (%)	50/50
Number of patients with ASA 1 grade, n (%)	741 (14.6)
Number of patients with ASA 2 grade, n (%)	2272 (44.7)
Number of patients with ASA 3 grade, n (%)	1917 (37.7)
Number of patients with ASA 4 grade, n (%)	154 (3.0)
Duration of pre-warming (median [IQR]; min)	25 (15-30)
Duration of warming interruption (median [IQR]; min)	20 (15-30)
Duration of anaesthesia (median [IQR]; min)	110 (80-160)

Abbreviations: y, years; %, percent; min, minute; IQR, interquartile range; n, number; ASA, American Society of Anesthesiologists.

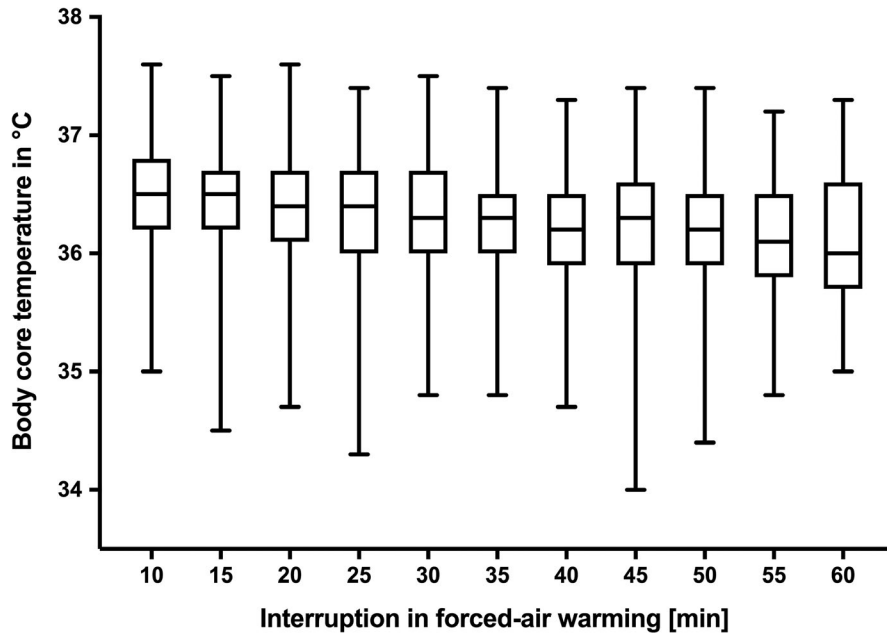


FIGURE 1 Lowest intraoperative core body temperature depending on the interruption in forced-air warming. The interruption in forced-air warming lasted from 10 to a maximum of 60 min. Lowest intraoperative core body temperature values varied from 36.0 to 36.5°C (medians) depending on the interruption in forced air warming. A significant decrease could be observed in the lowest intraoperative core body temperature ($P < .0001$)

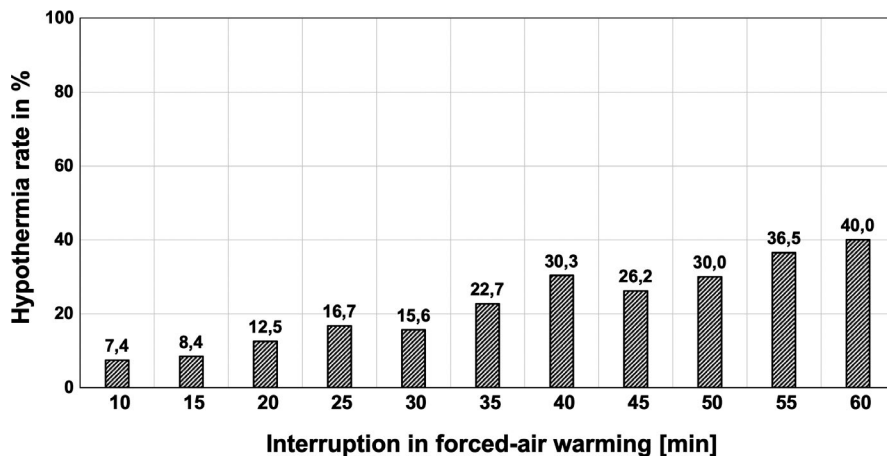


FIGURE 2 Intraoperative hypothermia rates depending on the interruption in forced-air warming. An increase in the length in forced-air warming interruption time was associated with a significant increase of the intraoperative hypothermia rate ($P < .0001$)

warming interruptions, the effort to prevent intraoperative hypothermia through conducting pre-warming can obviously be reduced dramatically.

The physiology of heat exchange and the clear association of short warming interruption times with low intraoperative hypothermia rates suggest that short warming interruption times are important to prevent perioperative hypothermia. The present analysis shows that a warming interruption time shorter than 20 minutes is desirable.

4.1 | Limitations of the study

As this investigation was based on a retrospective analysis of anaesthesia records, it is methodologically inferior to prospective randomized studies. However, a prospective investigation with scheduled withholding of active warming would have been ethically inappropriate in our institution considering the existing recommendations of the guidelines in Europe.^{2,3}

This study was merely performed at one anaesthesia department with standardized hypothermia prevention procedures, where pre-warming was performed on a routine basis in the operating room directly before and during the induction of anaesthesia. Due to this, low hypothermia rates were already achieved and only small differences between the temperature values of the normo- and hypothermic patients could be observed. This might raise doubts about the effectiveness of further measures to prevent intraoperative hypothermia. On the other hand, a hypothermia rate of 15.8% and only 0.4% of patients showing $<35.0^{\circ}\text{C}$ prove the success of combining pre-warming, intraoperative warming and short warming interruptions.

A very heterogeneous number of elective patients and surgeries was analysed and no subgroups of procedures and patients were created. Differences in the patient population and the surgical procedures would therefore probably result in different hypothermia rates in other hospitals. This would certainly be the case with special patient groups such as neonates, severely adipose patients, seriously injured trauma patients, burn patients and patients requiring

special surgeries such as in thoracic surgery.¹¹ Whether the effects of pre-warming time and forced-air warming interruption time on intraoperative hypothermia rate are different in special subgroups of patients has not been investigated yet.

Forced-air warming was the only heat-supply method in this study. Alternatives like conductive heat supply systems or combinations of convective and conductive warming devices which have also shown effectiveness were not analysed.¹²⁻¹⁴

The concept of focusing on the dichotomous outcome value hypothermia (body core temperature <36.0°C) is recommended in the NICE and German and Austrian guidelines.^{2,3} Alternatively, it could be discussed to use the combination of temporal duration and low core temperature (area under the curve for body core temperature <36°C).⁴ However, as the extent to which the degree of hypothermia experienced by the patients determines the occurrence and extent of complications, has not been evaluated yet, such an analysis was not intended nor possible with the present data. Furthermore, in clinical practice, the same measures will be necessary to avoid intraoperative hypothermia no matter whether hypothermia AUC curves or a dichotomous value (core body temperature <36°C) are the objectives.

5 | CONCLUSION

Intraoperative hypothermia rates increased significantly with longer forced-air warming interruptions between pre-warming and intraoperative warming. Short warming interruptions can preserve the effect of pre-warming and are associated with low intraoperative hypothermia rates.

CONFLICTS OF INTEREST

Rolf Grote received lecturing fees from 3M Germany and Fresenius Germany. Anselm Bräuer is a member of the advisory board of 3M Europe and has received consulting fees from 3M, 37 Company Netherlands, Seiratherm GmbH Germany, and CSL Behring Germany. Matthias Menzel is a member of the advisory board of 3M Europe and has received consulting fees from 3M and MSD Germany. Anna Wetz: none.

ORCID

Rolf Grote  <https://orcid.org/0000-0001-9465-1055>

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