Core temperature monitoring: essential for an optimized perioperative care

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Background

Surgical patients are at risk of developing hypothermia at any stage of the perioperative pathway.

Inadvertent perioperative hypothermia is a common but preventable complication, which is associated with poor outcomes for patients.
PERIOPERATIVE NORMOTHERMIA TO REDUCE THE INCIDENCE OF SURGICAL-WOUND INFECTION AND SHORTEN HOSPITALIZATION

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Abstract Background. Mild perioperative hypothermia, which is common during major surgery, may promote surgical-wound infection by triggering thermoregulatory vasconstriction, which decreases subcutaneous oxygen tension. Reduced levels of oxygen in tissue impair oxidative killing by neutrophils and decrease the strength of the healing wound by reducing the deposition of collagen. Hypothermia also directly impairs immune function. We tested the hypothesis that hypothermia both increases susceptibility to surgical-wound infection and lengthens hospitalization.

Methods. Two hundred patients undergoing colorectal surgery were randomly assigned to routine intraoperative thermal care (the hypothermia group) or additional warming (the normothermia group). The patients’ anesthetic care was standardized, and they were all given cefamandole and metronidazole. In a double-blind protocol, their wounds were evaluated daily until discharge from the hospital and in the clinic after two weeks; wounds containing culture-positive pus were considered infected. The patients’ surgeons remained unaware of the patients’ group assignments.

Results. The mean (±SD) final intraoperative core temperature was 34.7±0.6°C in the hypothermia group and 36.6±0.5°C in the normothermia group (P<0.001). Surgical-wound infections were found in 18 of 96 patients assigned to hypothermia (19 percent) but in only 6 of 104 patients assigned to normothermia (6 percent, P=0.009). The sutures were removed one day later in the patients assigned to hypothermia than in those assigned to normothermia (P=0.002), and the duration of hospitalization was prolonged by 2.6 days (approximately 20 percent) in the hypothermia group (P=0.01).

Conclusions. Hypothermia itself may delay healing and predispose patients to wound infections. Maintaining normothermia intraoperatively is likely to decrease the incidence of infectious complications in patients undergoing colorectal resection and to shorten their hospitalizations. (N Engl J Med 1996;334:1209-15.)
Adverse outcomes of perioperative hypothermia

- Morbid myocardial outcomes
- Surgical site infection
- Coagulopathy
- Increased allgogeneic transfusions
- Negative nitrogen balance
- Delayed wound healing
- Delayed postanesthetic recovery
- Prolonged hospitalisation
- Shivering
- Patient discomfort
Preventing Inadvertent Perioperative Hypothermia

SUMMARY
Inadvertent perioperative hypothermia occurs in 25-50% of all patients undergoing elective surgery under general anaesthesia or regional anaesthesia. Many factors contribute to the development of hypothermia during surgery, including pre-operative factors (such as patient age, body mass index, and preoperative fasting time), surgical factors (such as the type of surgery, duration of surgery, and the use of drapes), and intra-operative factors (such as the type of anaesthetic, the use of surgical techniques, and the use of warm blankets). The most common cause of hypothermia during surgery is the use of cold fluids, which can cause a rapid decrease in core body temperature. The risk of hypothermia is increased in infants, children, and the elderly, and in patients with certain medical conditions such as hypothyroidism, diabetes, and obesity. The diagnosis of hypothermia can be challenging, as the core body temperature may not be accurately assessed in the operating room. The consequences of hypothermia include increased surgical site infections, prolonged postoperative recovery, and increased mortality. Therefore, it is important to prevent hypothermia during surgery to improve patient outcomes. The NICE clinical guideline 65 provides recommendations for the prevention of hypothermia during surgery, including the use of warm intravenous fluids, the use of warm blankets, and the use of warm water for irrigation. The guideline also recommends the use of warm air or water to humidify the inspired gases during general anaesthesia. The implementation of these recommendations can significantly reduce the incidence of hypothermia during surgery.
Patients at higher risk of perioperative hypothermia

Any two of the following:
- ASA grade II to V
- Preoperative temperature below 36.0°C
- Undergoing combined general and regional anaesthesia
- Undergoing major or intermediate surgery
- At risk of cardiovascular complications.
Definition of hypothermia

- **Hypothermia**: a patient core temperature of below 36,0°C
- **Preoperative**: 1 hour before induction of anaesthesia
- **Intraoperative**: the total anaesthesia time
- **Postoperative**: 24 hours after entry into the recovery area in the theatre suite

NICE
Preoperative phase

Each patient should be assessed for their risk of inadvertent perioperative hypothermia and potential adverse consequences before transfer to the theatre suite. = measurement of temperature
Preoperative warming

If the patient’s temperature is below 36.0°C in the hour before they leave the ward or emergency department

- Forced air warming should be started preoperatively on the ward or in the emergency department (unless there is a need to expedite surgery because of clinical urgency)

- Forced air warming should be maintained throughout the intraoperative phase

NICE
Intraoperative phase

- The patient’s temperature should be measured and documented before induction of anaesthesia and then every 30 minutes until the end of surgery.

- Induction of anaesthesia should not begin unless the patient’s temperature is 36.0°C or above.
Postoperative phase

The patient’s temperature should be measured and documented on admission to the recovery room and then every 15 minutes.

- Ward transfer should not be arranged unless the patient’s temperature is 36.0°C or above.

- If the patient’s temperature is below 36.0°C, they should be actively warmed using forced air warming until they are discharged from the recovery room or until they are comfortably warm.

NICE
Why don’t just ask the anesthesiologist?

In fact, someone did ....

Temperature Monitoring and Management During Neuraxial Anesthesia: An Observational Study

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Are anaesthesiologists able to estimate patient thermal status?

Figure 3. All patients, divided by anaesthesiologists’ impression of thermal status. There was no difference in the number of hypothermic and normothermic patients ($P = 0.36$) when divided by anaesthesiologists’ impression. These data thus, indicate that anaesthesiologists were unable to reliably estimate patient thermal status.

October 13th 2004:

- 8081 patients in 316 hospitals in 16 European countries
- Temperature was monitored in 19.4 % of patients
- Active warming was used for 38.5 % of patients
So, where to measure ....?
And with what technology ....?
Methods for temperature measurement

- Expansion
  - Mercury, alcohol etc.
- Liquid crystal
- Infrared sensor
- Electronic
  - Thermistor
  - Thermocouple
- Heat flux (without active thermoelement)
- Zero heat flux (with active thermoelement)
Non-invasive methods (skin)

- Axilla
  - Usually 1-2 °C lower than actual core temperature
  - Measurement errors frequent
  - Slow

- Forehead
  1. Liquid crystal - thermochrome substance changing colour according to the temperature
     - Not accurate enough
  2. Thermistors and thermocouples
     - About 2 °C must be added, but still a rather inaccurate estimate of core temperature
Non-invasive methods (skin, contd)

- Temporal artery
  - Inaccuracy caused by environmental temperature and sweating
  - Generally not recommended for clinical needs
Temporal artery thermometry

Temporal Artery Versus Bladder Thermometry During Perioperative and Intensive Care Unit Monitoring

The sensitivity for detecting hypothermia (< 35.5°C) was 0.29, and the specificity was 0.93.

The positive predictive value for hypothermia was 0.31, and the negative predictive value was 0.95.

CONCLUSIONS:
The results of this study do not support the use of temporal artery thermometry for perioperative core temperature monitoring;
the temporal artery thermometer does not provide information that is an adequate substitute for core temperature measurement by a bladder thermometer.

Kimberger O et al. Anest Analg 2007;105:1042
Temporal artery thermometry

Comparison of temporal artery thermometer to standard temperature measurements in pediatric intensive care unit patients

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Conclusions: Temporal artery and axillary temperature measurements showed variability to rectal temperatures but had marked variability in febrile children. Neither was sufficiently accurate to recommend replacing rectal or other invasive methods. As temporal artery and axillary provide similar accuracy, temporal artery thermometers may serve as a suitable alternative for patients in whom invasive thermometry is contraindicated.

Minimally invasive methods

● Oral
  ➢ Dependent on patient compliance
  ➢ Not very reliable
  ➢ influenced by previous food intake, mucosal inflammation, air circulation in mouth
  ➢ Continuous measurement not feasible

● Tympanic
  1. Infrared/indirect
     ➢ Very inaccurate and artifact-prone (position cerumen etc.
  2. Direct
     ➢ Uncomfortable for patient
     ➢ Risk of tympanic perforation
Infrared aural canal thermometers

The accuracy and precision of four infrared aural canal thermometers during cardiac surgery

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Infrared aural canal thermometers

The accuracy and precision of four infrared aural canal thermometers during cardiac surgery

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Background: Four infrared aural canal thermometers are currently available in Japan: Genius®, Thermoscan®, Quickthermo®, and Thermopit®. We therefore tested the hypothesis that each is sufficiently accurate and precise for clinical use.

Method: Thermocouples were used to calibrate each thermometer in 36°C water bath and 28°C air. Thermocouples were also used to calibrate each thermometer against the tympanic membrane, with the ear to the microphone (Tympanic® Thermopit® Thermoscan®) and with the microphone to the ear (Genius®). Accuracy and precision were assessed by comparing all thermometers against several thermocouples in water baths of 30°C and 38°C.

Results: Compared to the thermocouple, the Genius® and Thermoscan® both had regression slopes >0.85 and correlation coefficients near 0.87; in contrast, slopes of the Quickthermo® and Thermopit® regressions were 0.68 and 0.53, respectively. The correlation coefficients for each were <0.65. The accuracy (offset, or bias) was near 0°C with both the Genius® and Thermoscan® thermometers. In contrast, it was 1.1°C with the Quickthermo® and Thermopit® instruments.

Conclusion: We conclude that none of the tested aural canal infrared thermometers was sufficiently accurate and precise for perioperative use.

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Key words: Anesthesia; surgery; cardiopulmonary bypass, open-heart; temperature: core, tympanic membrane, aural canal.

Minimally invasive methods (contd)

- Rectal
  - Better than other minimally invasive methods
  - High temporal latency depending on the filling of the ampulla recti, with delays up to 1 h.
  - Still less accurate than aesophageal and bladder temperature measurement
Most non-invasive methods are unpresise
Temperature Measurement

• Core Sites
  – Pulmonary artery
  – Distal esophagus
  – Nasopharynx
  – Tympanic membrane by thermocouple

• Other generally-reliable sites
  – Bladder
All “core sites” are more or less invasive
Invasive methods for core temperature measurement

- Nasopharyngeal
  - Option primarily for the anaesthezised ventilated patient
  - Offers adequate accuracy (1)
  - Uncomfortable in non-anaesthezied patients
  - Not suitable for pre-operative measurement

Invasive methods for core temperature measurement (contd.)

- Esophageal
  - High accuracy
  - Easy to attach to patient
  - Not very prone to artifacts
  - Rather uncomfortable for the anaesthetised ventilated patient
  - Not suitable for pre-operative measurement
Invasive methods for core temperature measurement (contd.)

- **Bladder temperature**
  - High accuracy, but may produce false values with low urine output
  - Low risk of dislocation
  - Not suitable for pre-operative measurement
Urinary bladder and oesophageal temperatures correlate better in patients with high rather than low urinary flow rates during non-cardiac surgery

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Urinary bladder temperature

Urinary bladder temperature

Bland and Altman comparison:

Offset (oesophageal – urinary bladder):

- High urinary volume group: $-0.13 \pm 0.32$
- Low urinary volume group: $-0.46 \pm 0.45$

The gold standard core temperature

- The temperature measured next to the heart (e.g. pulmonary artery)
- Brain temperature

Both methods are extremely invasive
Non-invasive measurement of core temperature
Zero Heat Flux

Based on **thermic isolation** of an area of the skin and an **actively warming thermoelement** that is heated until there is **no more heat transfer** between the patient and the environment.
Noninvasive Determination of Core Temperature During Anesthesia*

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ABSTRACT: A noninvasive, zero heat flux method of determining core (intracardiac blood) temperature was studied in ten anesthetized patients having whole body hyperthermia for the treatment of cancer. True intracardiac blood temperature was determined by a calibrated pulmonary artery thermistor. Accuracy, precision, and responsivity for the noninvasive system were comparable to conventional esophageal thermometry in reflecting intracardiac blood temperatures. This method of contact thermometry is convenient and independent of environmental influence, and it rapidly reflects the small changes in arterial blood temperature which evoke vasomotor responses.

Zero-heat flux thermometry

Cool Environment

This point is the same temperature...

...as this point

Skin

Isothermal tunnel

Warm Core
Bringing the core to the surface

30 seconds

1 minute

3 minutes
Zero Heat Flux

**FIGURE 2.** Esophageal thermistor temperatures vs intracardiac blood temperature. Slope 0.94, Y intercept 2.1, $r^2$ 0.99, $P < .05$.

**FIGURE 3.** Zero heat flux probe temperatures vs intracardiac blood temperatures. Slope 0.98, Y intercept 0.93, $r^2$ 0.98, $P < .05$.

Accuracy and precision of a novel non-invasive core thermometer

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Background. Accurate measurement of core temperature is a standard component of peri-operative and intensive care patient management. However, core temperature measurements are difficult to obtain in awake patients. A new non-invasive thermometer has been developed,

Results:

98 % of all values were within + 0.5 °C of oesophageal temperature. Sensitivity and specificity for detection of hypothermia were 0.77 and 0.93 respectively.

Conclusions:

The new double-sensor thermometer is sufficiently accurate to be considered an alternative to distal oesophageal core temperature measurement, and may be particularly useful in patients undergoing regional anaesthesia.

Non-invasive continuous core temperature measurement by zero heat flux

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Zero Heat Flux

Figure 1. Oesophageal temperature ($T_{es}$), rectal temperature ($T_{re}$), zero heat flux temperature ($T_{zhf}$) and forehead skin temperature ($T_{fh}$) patterns during the complete experimental trial.

Teunissen LPJ et al. Physiol Measurement 2011;32:559
Zero Heat Flux

Figure 3. Bland–Altman diagrams showing the differences of (A) the zero heat flux and oesophageal temperatures ($\Delta T_{zhf-T_es}$) and (B) the rectal and oesophageal temperatures ($\Delta T_{re-T_es}$). Both figures consist of all individual 5 min values for the rest phase (circles), the exercise phase (squares) and the recovery phase (triangles).

Teunissen LPJ et al. Physiol Measurement 2011;32:559
Continuous monitoring by zero heat flux methodology during 30 whipple operations

![Graph showing temperature changes over time during 30 Whipple operations](image.png)
Conclusions

The use of temperature monitoring for control of core temperature is important for patient safety during surgery.

Monitoring should start before surgery (at the ward), and continue throughout the perioperative phase.

Zero heat flux technology eliminates the need for invasive monitoring, is monitoring core temperature and facilitates continuous monitoring throughout the perioperative period.