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## FEATURE

Temperature measurement during anaesthesia: the case for disposable thermometers

## CASE REPORT

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# Temperature measurement in anaesthetised patients

A disposable liquid crystal thermometer performs as well as a non-disposable temporal artery infra-red thermometer say **David Southern, Andrew Campbell, Stella Wright and Jim Turner**

The UK National Institute for Health and Care Excellence (NICE) has recently reported that perioperative hypothermia increases morbidity and mortality of surgical patients and mandates regular temperature measurement. The ideal thermometer would be able to estimate core temperature measurement without invading the body core, would be cheap and disposable. The Clinitrend strip approaches this ideal if its accuracy is at least as good as other thermometers currently in use. We therefore evaluated the accuracy of Clinitrend in estimating core temperature as measured by a nasopharyngeal temperature probe and compared the accuracy to a peripheral temperature thermometer in current clinical use (Exergen).

### Introduction

NICE prioritised peri-operative normothermia when it issued Clinical Guideline 65 in 2008 [1]. This guideline acknowledged that most thermometers inferred core temperature from a reading taken peripherally and that there were discrepancies between different thermometer designs. The Guideline promoted the use of thermometers that were maintained according to manufacturers guidelines and cleaned according to local infection control policy. A disposable design simplifies these requirements, provided that its performance is equivalent to a non-disposable thermometer.

In this study, we designated nasopharyngeal temperature as the means of measuring core temperature. We then assessed concordance between this technique and two techniques that measure temperature in the frontal region of the head and then deduce core temperature. One of the thermometers (Clinitrend [2]) is disposable.

### Methods

Following local research ethics committee approval and written informed consent from the individuals, we recruited 30 patients who were scheduled for elective surgery on a body region below the diaphragm. Operations were chosen that were anticipated to be of at least two hours duration; they included gynaecological, orthopaedic and abdominal procedures.

General anaesthesia was induced intravenously and maintained with a volatile agent. Following endotracheal intubation, a nasopharyngeal temperature probe [3] (temperature probe, Part no. 21090A, Philips Medical Systems) was inserted, a Clinitrend liquid



crystal thermometer was applied to the central forehead and the Exergen [4] thermometer was passed over the skin of the temporal region. Measurements were taken according to the manufacturers instructions and were designated as the temperature at time zero.

Patients were then transferred to the operating theatre where surgery was performed. Patients were warmed using a forced air convection heater device applied to an appropriate body region below the clavicles. Temperature measurements were taken every 30 minutes using all three thermometers – nasopharyngeal (NAPOP), Clinitrend (Clin) and Exergen (Ex) devices. When the operation was finished, the nasopharyngeal temperature probe was removed and no further measurements were taken for this study.

Temperature was measured by the three thermometers at time 0, 30, 60, 90 and 120 minutes. Mean and standard deviation were calculated and a One-Sample Kolmogorov-Smirnov test performed to assess for normal distribution.

“Patients are more tolerant of thermometers placed in peripheral body sites such as the mouth, axilla or forehead. These peripheral sites are not in temperature equilibrium with the body core and maintain a slightly lower temperature.”

**Table 1. Mean and standard deviation of patient temperatures as measured by NAPOP, Clinitrend and Exergen.**

Thermometer	Time in minutes				
	0	30	60	90	120
NAPOP	35.98(0.62)	35.94(0.52)	35.93(0.51)	35.95(0.49)	35.95(0.49)
Exergen	36.46(0.59)	36.90(1.07)	36.79(0.87)	36.95(1.18)	37.03(1.18)
Clinitrend	35.50(0.77)	35.80(0.72)	35.87(0.77)	35.76(0.83)	35.81(0.93)

**Results**

Thirty patients were enrolled. Temperatures were measured at 30-minute intervals for two hours in 23 patients. In seven patients, surgery finished prematurely and patients were studied for only 90 minutes. Temperatures were recorded with three thermometers at all timepoints within the study periods producing a data set of 429 measurements. Data were similar (mean and standard deviation) at 90 and 120 minutes despite the reduction in the size of the study sample (Table 1). A One-Sample Kolmogorov-Smirnov test confirmed normal distribution of data. The mean and standard deviation of the data are shown in Table 1.

A Kernel density estimation (Figure 1) was calculated for temperature measured by NApOP, Clinitrend and Exergen. This estimation of probability density function provides a visual impression of the ‘goodness of fit’ between two distribution curves. It does not allow calculation of statistical differences. The goodness of fit of Clinitrend appears to be closer to NApOP than that of Exergen.

For each patient at each timepoint, we calculated the difference between the NApOP and the temperature measured by each test thermometer (temp-diff). The mean and standard deviation of temp-diff are shown for both test thermometers at 30-minute intervals (Figure 2). The mean Clinitrend reading was found to underestimate NApOP by 0.2°C whereas the mean Exergen overestimated NApOP by 0.8°C.

Bland-Altman plots (Figure 3) were performed to assess bias of measurement. The accuracy of both Clinitrend and Exergen changed over the NApOP temperature range. Clinitrend underestimated NApOP at lower temperatures and slightly overestimated at higher temperatures, in agreement

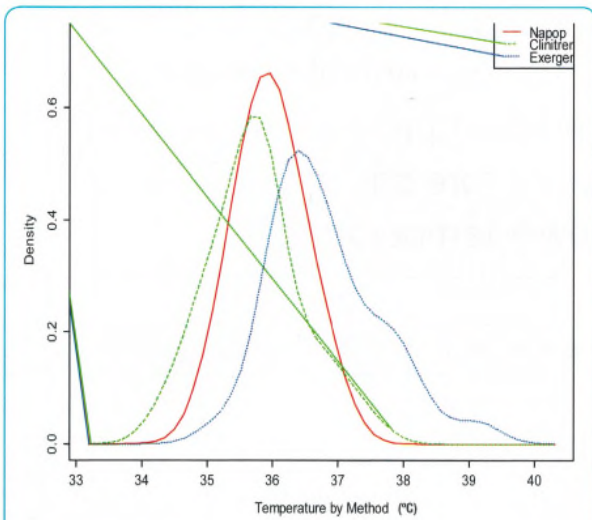
“NICE guidelines promoted the use of thermometers that were maintained according to manufacturers guidelines and cleaned according to local infection control policy.”

with Kimberger’s results [5]. However, Exergen overestimated temperature throughout the NApOP temperature range, this discrepancy increasing with NApOP temperature.

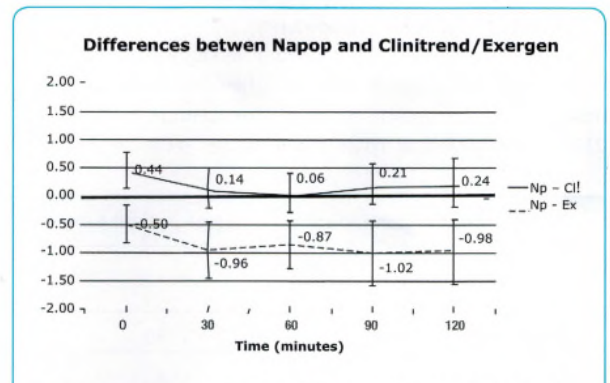
The standard deviation of both thermometers changed over the range of NApOP temperature (Figure 4). Both test thermometers had greater standard deviation at higher NApOP temperatures. This increase in variance appeared to be less for Clinitrend than it was for Exergen.

**Discussion**

In health and under normal circumstances, different parts of the human body core have slightly different temperatures. Core organs which generate heat, such as the liver and brain, are very slightly ‘hotter’ than the rest of the core. The continuous and large blood circulation of core organs minimises the temperature difference between different body regions. Thus the temperature of the liver, brain, oesophagus, nasopharynx and tympanic membrane are within 1°C of each other. However, inserting a temperature probe into these sites is invasive, causing patient discomfort and potentially tissue damage. Patients are more tolerant of thermometers placed in peripheral body sites such as the mouth, axilla or forehead. These peripheral sites are not in temperature



**Figure 1.** Kernel density plot of temperatures as measured by NApOP, Clinitrend and Exergen.



**Figure 2.** Mean temperature difference (temp-diff) between NApOP and test thermometers at times zero to 120 minutes. Standard deviation is shown by the vertical bar.

“There is a strong case for a thermometer that is disposable and simple to use which uses peripheral temperature to accurately predict and continuously display core body temperature.”

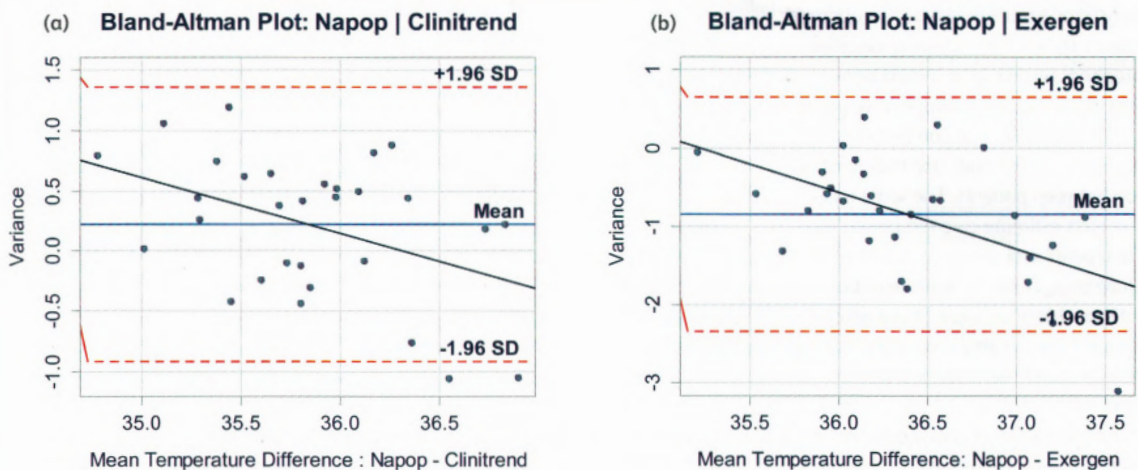
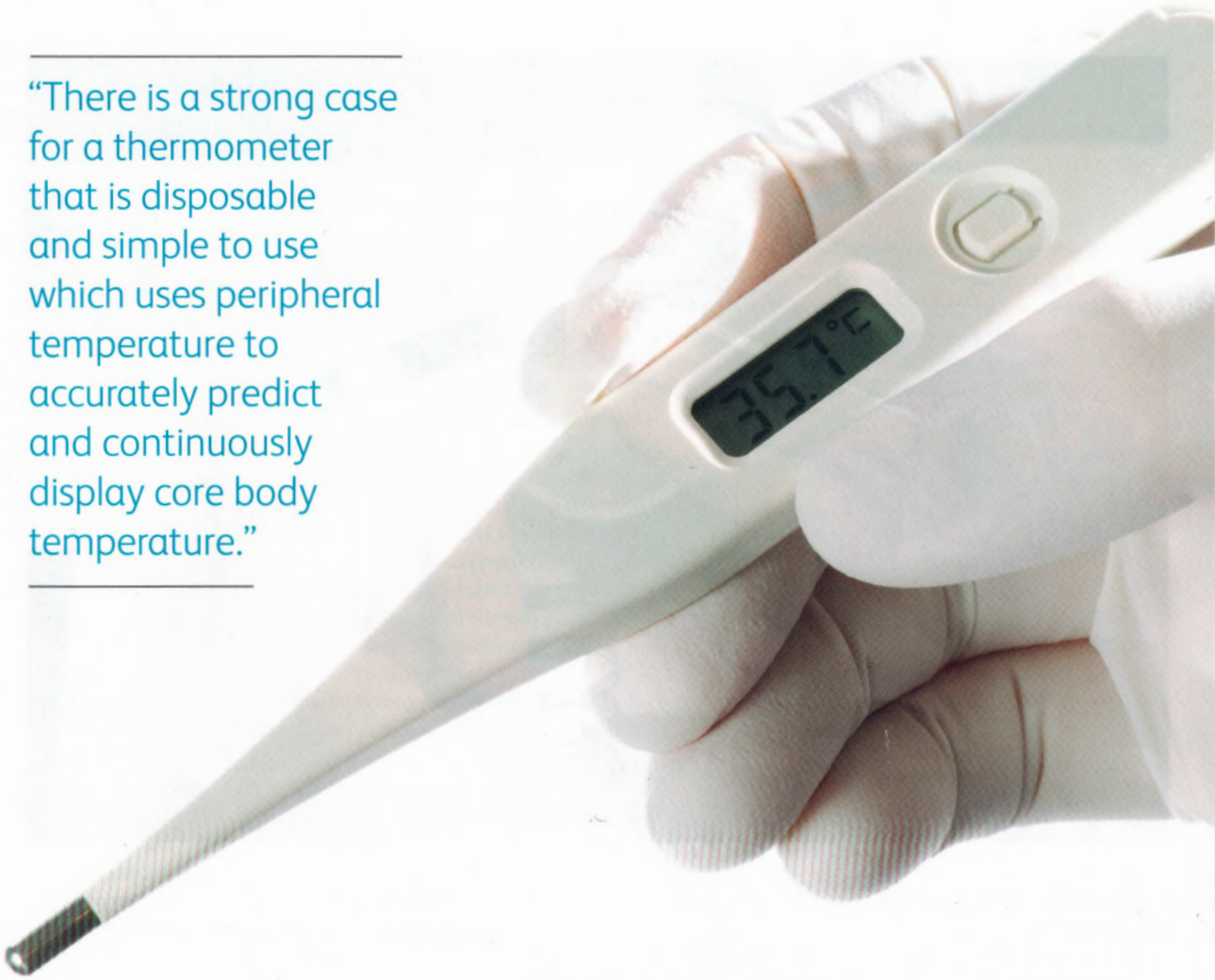


Figure 3. Bland-Altman plots of (a) Clinitrend and (b) Exergen test thermometers compared with reference thermometer NAPOP.



equilibrium with the body core and maintain a slightly lower temperature.

There is substantial evidence that perioperative hypothermia increases morbidity and mortality of surgical patients. In the UK, NICE Clinical Guideline 65 emphasised the importance of keeping core body temperature above 36°C – apparent hypothermia mandated interventions including cancelling surgery [1]. NICE stipulated that temperature should be measured every 30 minutes throughout the intraoperative period using a device that is easy for staff to use, that can be maintained according to the manufacturer's instructions and that minimises the risk of cross-infection between patients. The same guideline noted that most thermometers estimate core temperature from measurements made at a peripheral site and that there are inaccuracies inherent in this inference. There is therefore a strong case for a thermometer that is disposable and simple to use which uses peripheral temperature to accurately predict and continuously display core body temperature. The Clinitrend strip approximates this ideal thermometer.

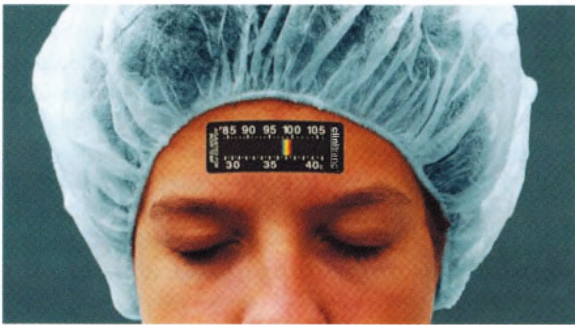
Early forms of liquid-crystal thermometer measured forehead skin temperature which was found to be typically 2°C lower than core temperature [6]. A clinically useful compromise is to use a peripherally sited thermometer to measure temperature and then

to add a correction factor to accurately estimate core temperature (as is done by Clinitrend). The purpose of this study is to compare the performance of Exergen and Clinitrend in estimating core temperature as measured by an indwelling nasopharyngeal temperature probe.

The trial assessed the feasibility of using Clinitrend as a continuously reading thermometer in anaesthetised patients undergoing orthopaedic, general and gynaecological surgery of two hours duration. All patients had their temperature measured with Clinitrend with no adverse effect.

The trial also assessed equivalence of performance of Clinitrend compared with an established perioperative thermometer, Exergen. We sought to determine whether the accuracy and precision of Clinitrend was comparable with that of Exergen in order to assess the clinical utility of a liquid crystal thermometer. We did not attempt to demonstrate statistical 'superiority' of one device compared with the other. 'Core' temperature varies between different parts of the body core and according to the thermometer site. Forehead skin temperature (as measured by Clinitrend) may be closer to nasopharyngeal temperature than is temporal artery temperature (as measured by Exergen). Similar results have recently been reported in non-anaesthetised subjects [7].

The concordance between nasopharyngeal temperature and



core temperature as measured by Clinitrend is similar to the concordance of a more sophisticated, novel 'double-sensor' thermometer [6].

One difference was found in the performance of Clinitrend compared with Exergen at higher core temperatures. The 'frequency power curve' shows a positive skew for both Exergen and Clinitrend that is not present in the curve for nasopharyngeal temperature. This skew appears greater for Exergen than it is for Clinitrend. This appearance is confirmed in the Bland-Altman plots. Both Exergen and Clinitrend over-read at high core temperature: this error is greater for Exergen.

The value of the difference between Clinitrend and NAPOP at zero minutes was statistically different to this value at all other times. This suggests a systematic difference in the performance of Clinitrend at zero minutes. We suspect that this difference occurred because the Clinitrend device is slow to equilibrate with forehead skin temperature. The manufacturer recommends an equilibration time of 15 seconds [8]. We suggest that this equilibration time

should be extended. Pragmatically, we suggest a period of 5 minutes but this study was not designed to estimate this duration.

**This study was sponsored by Clinitrend.**

### Contributions

David Southern & Andrew Campbell designed the trial; obtained ethical approval; obtained permission from the Research & Development Committee; and enrolled patients in the trial. David Southern wrote the draft submission paper.

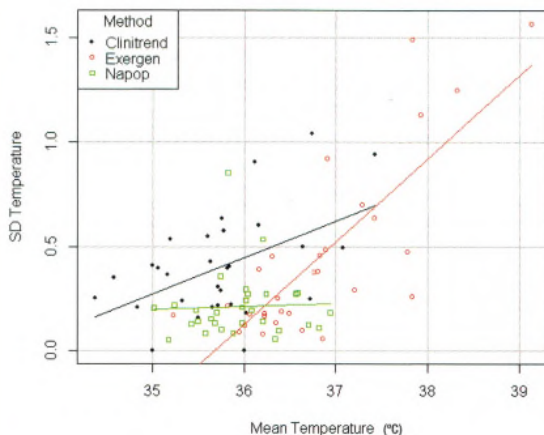
Stella Wright obtained and collated patient data.

Jim Turner performed statistical analysis.

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**Scatter Plot: napop, Clinitrend, Exergen**



**Figure 4.** The standard deviation of temperature measurement changed with mean temperature for all three thermometers. This bias was small for NAPOP, intermediate for Clinitrend and greatest for Exergen.

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