"Deep-forehead" temperature correlates well with blood temperature

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Purpose: To evaluate the accuracy and precision of "deep-forehead" temperature with rectal, esophageal, and tympanic membrane temperatures, compared with blood temperature.

Methods: We studied 41 ASA physical status 1 or 2 patients undergoing abdominal and thoracic surgery scheduled to require at least three hours. "Deep-forehead" temperature was measured using a Coretemp® thermometer (Terumo, Tokyo, Japan). Blood temperature was measured with a thermistor of a pulmonary artery. Rectal, tympanic membrane, and distal esophageal temperatures were measured with thermocouples. All temperatures were recorded at 20 min intervals after the induction of anesthesia. We considered blood temperature as the reference value. Temperatures at the other four sites were compared with blood temperature using correlation, regression, and Bland and Altman analyses. We determined accuracy (mean difference between reference and test temperatures) and precision (standard deviation of the difference) of 0.5°C to be clinically acceptable.

Results: "Deep-forehead" temperature correlated well with blood temperature as well as other temperatures, the determination coefficients (r^2) being 0.85 in each case. The bias for the "deep-forehead" temperature was 0.0°C, which was the same as tympanic membrane temperature and was smaller than rectal and esophageal temperatures. The standard deviation of the differences for the "deep-forehead" temperature was 0.3°C, which was the same as rectal temperature.

Conclusions: We have demonstrated that the "deep-forehead" temperature has excellent accuracy and clinically sufficient precision as well as other three core temperatures, compared with blood temperature.

Objectif : Évaluer l'exactitude et la précision de la température frontale «cutanée profonde» et les températures rectale, œsophagienne et tympanique, comparées à la température du sang.

Méthode : L'étude a porté sur 41 patients d'état physique ASA I ou II devant subir une intervention chirurgicale abdominale et thoracique d'au moins deux heures. La température «cutanée profonde» a été mesurée à l'aide du thermomètre Coretemp® (Terumo, Tokyo, Japon). Celle du sang a été prise avec une thermistance d'une artère pulmonaire et les températures rectale, tympanique et œsophagienne distale, avec des thermocouples. Elles ont toutes été enregistrées à 20 min d'intervalle après l'induction de l'anesthésie. La température du sang a servi de référence. Les températures des quatre autres sites ont été comparées avec celle du sang à l'aide d'analyses de corrélation, de régression et des analyses de Bland et Altman. Nous avons reconnu une exactitude (différence moyenne entre la température de référence et les autres) et une précision (écart type de la différence) de 0,5 °C près comme une différence acceptable en clinique.

Résultats : La température «cutanée profonde» était en corrélation avec celle du sang, et avec celle des autres sites, le coefficient de détermination (r^2) étant de 0,85 dans chaque cas. Le biais de la température «cutanée profonde» était de 0,0 °C, comme celui de la température tympanique, et plus faible que ceux des températures rectale et œsophagienne. L'écart type de la différence pour la température «cutanée profonde» était de 0,3 °C, comme pour la température rectale.

Conclusion : Nous avons démontré que la température frontale profonde présentait une grande exactitude et une précision utile suffisante, autant que les trois autres températures centrales, comparée à la température du sang.

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PERIOPERATIVE hypothermia is common because of the inhibition of thermoregulation induced by anesthesia and the exposure of the patient to a cool environment.[1] After induction of general anesthesia, the core temperature decreases approximately 1.5°C during the first hour mainly due to internal redistribution of heat inside the body.[2] Core hypothermia is also common during epidural and spinal anesthesia.[3]

Hypothermia produces several adverse effects such as decreased metabolism of the drugs, reduced platelet function, and postanesthetic shivering.[4–6] In addition, even mild intraoperative hypothermia has been shown to prolong hospitalization due to increased surgical wound infection and to increase postoperative myocardial ischemia.[7–8] Therefore, core temperature monitoring is essential for safe patient care during anesthesia.

The standard core temperature monitoring sites - distal esophagus, tympanic membrane, nasopharynx, and pulmonary artery - are accurate to ≈ 0.2°C and precise to ≈ 0.1°C.[9] Temperature at the rectum also correlates well with core temperature, but fails to follow the rapid change of the temperature.[10] In addition to these temperature monitoring sites, "deep-forehead" and "deep sternal" temperatures measured by the "deep-tissue" thermometer (Coretemp® CTM-205, Terumo corp., Tokyo, Japan) which was developed by Fox[11] and refined by Togawa[12] has been shown to have sufficient accuracy, compared with esophageal temperature.[13–15] In this study, we evaluated the accuracy and precision of "deep-forehead" temperature with rectal, esophageal, and tympanic membrane temperatures, compared with blood temperature, which is considered to be the most reliable estimate of core temperature.

Methods

With approval of the Ethics Committee of the Shimada Municipal Hospital and written informed consent, we studied 41 ASA physical status 1 or 2 patients undergoing abdominal and thoracic surgery under general anesthesia scheduled to last at least three hours. None was obese, was taking medication, or had a history of problems with the tympanic membrane or middle ear.

Protocol

Anesthesia was induced with thiopental, diazepam, fentanyl, and muscle relaxation with vecuronium. After tracheal intubation, anesthesia and relaxation were maintained with repeated doses of fentanyl and vecuronium, and was supplemented with lower concentration of volatile anesthetics (halothane, isoflurane, or sevoflurane, < 1.0 MAC) and nitrous oxide. Ventilation was mechanically controlled to keep $P_{ET}CO_2$ ≈ 35 mmHg and respiratory gases were warmed with a heat and moisture exchanger. During surgery, ambient temperature was maintained at 20 to 22°C. Patients were covered with surgical draping in the usual manner and a circulating-water mattress heated to 38°C was positioned under each patient. Intravenous fluids, except for blood, were not warmed.

Measurements

"Deep-forehead" temperature was measured using a Coretemp®. The sensor element, 4.5 cm in diameter, was fixed securely with tape 20 min before anesthesia induction. Blood temperature was measured with a thermistor of a pulmonary artery catheter (Baxter Inc., Deerfield, IL, USA), which was necessary for each patient's anesthetic management, inserted before induction. Rectal, tympanic membrane, and distal esophageal temperatures were measured using disposable thermocouples and Model 6500 digital thermometers (Mon-a-Therm®, Mallinckrodt Anesthesiology Products, Inc., St. Louis, MO, USA). These thermometers require no user calibration and have a precision of 0.1°C when used with Mon-a-Therm disposable thermocouples. Tympanic temperatures were measured at the right tympanic membrane. The aural probe was inserted until the patients felt the thermocouple touch the tympanic membrane; appropriate placement was confirmed when they easily detected a gentle rubbing of the attached wire. The probe was then securely taped in place and the aural canal occluded with cotton. The esophageal thermocouples were positioned at the point with maximal heart sound. All temperatures were recorded at 20 min intervals after the induction of anesthesia.

Data analysis

We considered blood temperature as the reference value. Temperatures at the other four sites were compared with blood temperature using correlation, regression, and Bland and Altman analyses.[16] Repeated measures analysis of variance (ANOVA) followed by a Tukey test was used to test for differences between blood temperature and the other temperatures. We determined an accuracy (mean difference between reference and test temperatures) and precision (standard deviation of the difference) of 0.5°C to be clinically acceptable as our previous studies.[14,15]

Results

The patients' height was 158 ± 8 cm (mean ± SD), weight 54 ± 10 kg, and age 66 ± 10 yr. Four hundreds and fifty one temperature sets were recorded. Blood temperatures ranged from 33.3°C to 37.7°C. "Deep-

TABLE Accuracy and precision of four core temperatures.

	Forehead	*Rectal*	*Tympanic*	*Esophageal*
r^2	0.85	0.85	0.93	0.95
Slope	0.84	1.02	0.96	0.97
Mean (°C)	0.0*†	0.3	0.0*†	0.1*
SD (°C)	0.3	0.3	0.2	0.2

Correlation coefficients, slopes, accuracy, and precision of the forehead, rectal, tympanic membrane, and esophageal temperatures, compared with blood temperature.

*$P < 0.01$ compared with rectal temperature.

†$P < 0.01$ compared with esophageal temperature.

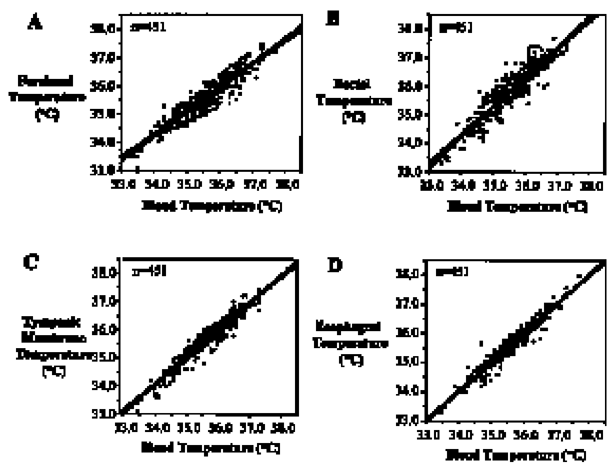

FIGURE 1 Correlation and linear regression analysis of blood temperature with "deep-forehead" (A), rectal (B), tympanic membrane (C), and esophageal (D) temperatures. The linear regression line and the 95% confidence intervals are shown. See table for regression slopes and determination coefficients.

forehead" temperature correlated well with blood temperature as well as other temperatures, the determination coefficients (r^2) being 0.9 in each case (Table, Figure 1). The bias for the "deep-forehead" temperature was 0.0°C, which was the same as tympanic membrane temperature and was smaller than rectal and esophageal temperatures (Table, Figure 2). The standard deviation of the differences for the "deep-forehead" temperature was 0.3°C, which was the same as rectal temperature.

Discussion

The "deep-forehead" temperature showed good correlation with blood temperature and their determination coefficient was higher than the reported value

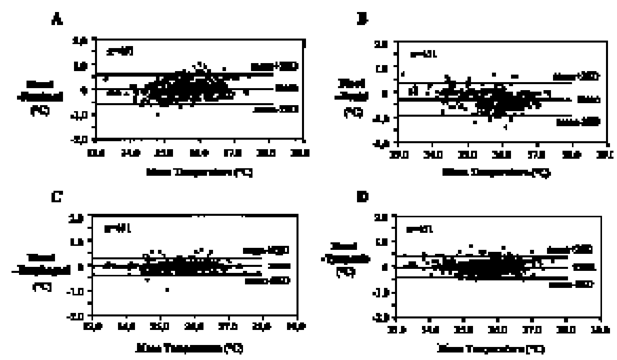

FIGURE 2 Bland and Altman bias analysis of blood temperature with "deep-forehead" (A), rectal (B), tympanic membrane (C), and esophageal (D) temperatures. The mean difference (bias) and limits of agreement (± 2SD of the difference values) are shown.

between the "deep-forehead" temperature and esophageal temperature.[14] Good accuracy and precision with this device, compared with esophageal temperature, has been reported previously.[14,17] Our study confirmed these results, and revealed that the accuracy was excellent, comparable to tympanic membrane temperature, and that the precision was clinically sufficient as good as rectal temperature, with reference to blood temperature.

The measurement principle of the Coretemp® "deep-tissue" thermometer is based on the zero-heat-flow method proposed by Fox and Solman.[11,12] The sensor element insulates the skin and is heated by the servo-controlled heater to null heat flux. Then, skin temperature is equilibrated both with the temperature of the sensor element and with the tissue temperature under the skin.[14] Since it takes approximately 15 min for the equilibration, we started the temperature measurements 20 min before the induction of anesthesia. Good correlation (r^2=0.87) has been shown between the temperature measured by the Coretemp and the temperature at 18-mm-depth from skin surface.[13]

The non-invasive nature of the "deep-tissue" thermometer offers some advantages over other thermometers that are used during anesthesia. Firstly, the "deep-tissue" thermometer may enable continuous monitoring of body temperature in awake or sedated patients. Although the liquid crystal skin-surface thermometer can also be used, its accuracy has been questioned.[18] Axillary temperature or oral temperature may also be suitable, but a probe must be carefully positioned and intermittent measurements are unpleasant in a sedated patient."Deep-tissue" thermometry is adequate in patients under neuroaxial anesthesia during which body temperature monitoring is necessary as well as during general anesthesia.[8,18]

The second advantage of the "deep-tissue" thermometer is that the sensor element is reusable. Almost all probes of other thermometers are fragile and disposable, because they may be injurious or infectious when inserted into the body.[19] In contrast, the sensor element of the "deep-tissue" thermometer is relatively durable and can be disinfected with isopropyl alcohol and glutaraldehyde. Thus, using "deep-tissue" thermometer may be cost saving in spite of the high initial cost (approximately US $4,000 in Japan, including two-sensor element US $300 each).

Easy manipulation is the third advantage of the "deep-tissue" thermometer. Only placing and affixing the sensor element on the skin surface is needed. The temperature is automatically measured, displayed, and recorded. The "deep-forehead" and "deep-sternum" temperatures have similar accuracy and precision, and either site can be used depending upon the position of the patient and the site of the surgery.[14]

In conclusion, we have demonstrated that"deep-forehead" temperature has excellent accuracy and has sufficient clinical precision as three other core temperature measurements, compared with blood temperature. The "deep-forehead" temperature is suitable to monitor body temperature non-invasively and continuously during anesthesia.

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