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ORIGINAL ARTICLE

Agreement of infrared ear temperature with nasopharyngeal temperature and diagnostic performance on hypothermia in general anesthetized patients

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Abstract

Background: Infrared ear thermometry is widely used in clinical practice due to its noninvasive, convenient, and quick sampling. However, its accuracy and feasibility in anesthetized patients have not yet been established.

Methods: We conducted this cross-sectional study to evaluate the agreement between infrared ear temperature and nasopharyngeal temperature in general anesthetized patients and its performance in intraoperative hypothermia, defined as nasopharyngeal temperature <36°C. Adult female patients who underwent gynecological surgery under general anesthesia were enrolled in this study. Infrared ear temperature by Braun ThermoScan PRO 4000 (Braun GmbH, Kronberg, Germany) and nasopharyngeal temperature were measured simultaneously before, during, and after surgery. The agreement between the two temperatures was assessed using the intraclass correlation coefficient (ICC) and Bland-Altman analysis. The diagnostic performance of the infrared ear thermometer for hypothermia was evaluated using receiver operating characteristic (ROC) curve analysis.

Results: Fifty-six patients with 168 pairs of simultaneous infrared ear and nasopharyngeal temperatures were included in this analysis. The mean infrared ear temperature was consistently higher than the nasopharyngeal temperature throughout surgery, but the differences were small (0.22, 0.13, and 0.06°C before, during, and after surgery, respectively). The ICC between the two temperatures before, during, and after surgery was 0.70, 0.75, and 0.80, respectively, and 93.5% of the differences fell within the 95% limits of agreement of ±0.5°C. An infrared ear thermometer had high diagnostic accuracy for hypothermia, with an area under the ROC curve of 0.95 (95% confidence interval [CI], 0.92-0.98). The cutoff of infrared ear temperature for hypothermia was 36.2°C with a sensitivity of 0.89 (95% CI, 0.71-0.98) and a specificity of 0.87 (95% CI, 0.81-0.92).

Conclusion: The infrared ear temperature is in good agreement with the nasopharyngeal temperature in general anesthetized patients without hyperthermia and has high performance for detecting hypothermia. An infrared ear thermometer can be a diagnostic tool for intraoperative hypothermia.

Keywords: General anesthesia; Hypothermia; Infrared ear thermometer; Monitoring; Temperature

1. INTRODUCTION

Body temperature is maintained by a thermoregulatory system that involves afferent sensing, central control, and efferent defenses.[1] Anesthesia can impair central thermoregulatory control and peripheral responses to hypothermia, such as vasoconstriction and shivering, leading to thermal disturbances. The most common intraoperative thermal disturbance is inadvertent hypothermia due to a cold operating room environment and surgical exposure. There is ample clinical evidence showing that even mild hypothermia is associated with numerous perioperative complications, including coagulopathy, cardiac morbidity, wound infection, and delayed postoperative recovery.[1,2] Therefore, temperature monitoring and thermal management are important for anesthetized patients during the intraoperative period.

The core temperature is the best indicator of body temperature, and the recommended sites for the monitoring of the intraoperative core temperature are the pulmonary artery, esophagus, nasopharynx, and tympanic membrane.[1,2] However, these are limited or unfeasible in some situations. For example, pulmonary artery thermometry is considered the gold standard for core temperature, but is invasive, expensive, and therefore, unavailable to most surgical patients. The esophagus and nasopharynx are the most common temperature monitoring sites during general anesthesia, but the accuracy depends on the temperature probe being inserted in the correct position and are not suitable for

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esophageal or nasopharyngeal surgery. Tympanic thermometry requires the probe to be inserted in direct contact with the tympanic membrane and may be difficult because the aural canal is several centimeters long and not straight.[1–3] Furthermore, these temperature measurements are often performed by anesthesiologists with specialized thermometers and equipment and are not always available in resource-limited environments.[4]

Infrared ear thermometers detect thermal radiation from the tympanic membrane and the ear canal without the need for a probe in direct contact with the tympanic membrane.[5,6] Due to its noninvasive, convenient, and quick sampling, an infrared ear thermometer has been widely applied in clinical practice, including in outpatient clinics, general wards, and emergency departments.[6–8] However, little data on its accuracy and feasibility for intraoperative thermometry are available. Therefore, this study aimed to evaluate the agreement between infrared ear temperature and nasopharyngeal temperature and the diagnostic performance of infrared ear temperature on intraoperative hypothermia in patients under general anesthesia.

2. METHODS

The study protocol was approved by the research ethics committee of our hospital (approval no. [2020]14) and registered with the Chinese Clinical Trial Registry (www.chictr.org.cn/index.aspx) under the number ChiCT2000032620. Written informed consent was obtained from all patients before participating in the study. The report adhered to the Standards for the Reporting of Diagnostic Accuracy Studies statement.[9]

2.1. Study design, setting, and participants

This cross-sectional observational study was designed to assess the agreement between simultaneously measured infrared ear temperature and nasopharyngeal temperature in the same general anesthetized patients. Adult female patients with the American Society of Anesthesiology physical status I and II scheduled for elective gynecological surgery under general anesthesia at our hospital were recruited from consecutive operating room admissions between May 2020 and June 2020. Exclusion criteria were as follows: body temperature of >37.5 or <36.0°C before entering the operating room, preexisting ear or nasopharyngeal disease, infection or anomalies of the auditory canal, impacted cerumen, epistaxis, coagulopathy, and surgery duration <1 hour. Patients who refused to participate in the study were also excluded.

2.2. Temperature measurements

The operating room temperature was kept at 22 to 24°C, and humidity was 40% to 60%. After induction of general anesthesia, a disposable thermistor probe (CP-MQ-TQ; Copper Medical Technology Co., Ltd., Shenzhen, China) was placed in the patient's nasopharynx and connected to the same anesthetic monitor (B6 50; GE Healthcare, Helsinki, Finland) by the attending anesthesiologist. Nasopharyngeal probe placement was standardized to the distance between the nasal fold and tragus, approximately 10 to 12 cm beyond the nostrils. A 5-minute interval was allowed for probe stabilization before recording the temperature readings. Infrared ear temperature was measured by a circulating nurse who had received standardized training using a ThermoScan PRO 4000 (Braun GmbH, Kronberg, Germany). Briefly, the nurse gently pulled back the pinna to sufficiently straighten the external auditory meatus, inserted the thermometer probe into the ear canal to create a seal, and then pressed the start button until a long beep was heard and a temperature value was visible on the display. Before each measurement, the probe cover was replaced with a new cover (Braun ThermoScan Probe Cover PC 800). The infrared ear temperature was measured before (immediately before the beginning of surgery), during (1 hour after the beginning of surgery), and after surgery (immediately after the end of surgery). At each time point, triplicate measurements from the right ear were taken consecutively in equal mode, and the averaged value was used for analysis. The anesthesiologist recorded nasopharyngeal temperature readings during the third ear temperature measurement.

2.3. Statistical analysis

Assuming that a difference of <0.2°C between measurements of the two temperatures would be clinically insignificant,[7] with a sample size of 26 achieves 90% power to detect a mean of paired differences of 0.2°C with an estimated standard deviation (SD) of 0.3°C and with a significance level (α) of 0.05, using a two-sided paired *t* test. We recruited 50 patients to compensate for possible losses and protocol violations.

The primary outcome variables were infrared ear and nasopharyngeal temperatures before, during, and after surgery. The secondary outcome was the performance of the infrared ear thermometer in hypothermia, defined as the nasopharyngeal temperature <36°C. Results are presented as mean (SD) or number (%). The normal distribution for continuous variables was analyzed using the Shapiro-Wilk test. A two-tailed paired *t* test was used to compare the two temperatures at each time point. The agreement between two temperatures was evaluated using intraclass correlation coefficient (ICC) and Bland-Altman plots with mean difference and 95% limit of agreement, that is, mean difference ±1.96 SD.[10] We defined the clinically acceptable accuracy for the infrared ear thermometer as a 95% limit of agreement between −0.5 and 0.5°C.[1,2] The performance of the infrared ear thermometer to detect hypothermia was evaluated by receiver operating characteristic (ROC) curve analysis. The area under the ROC curve (AUC) and 95% confidence interval (CI) were calculated, and the optimal cutoff value for hypothermia was determined based on the Youden index (i.e., maximum [sensitivity + specificity] − 1). Data were analyzed using SPSS version 19.0 for Windows (IBM Corp., Armonk, NY). Bland-Altman plots were constructed using MedCalc software 15.2.2 (MedCalc Software Ltd, Ostend, Belgium). A two-sided $p < 0.05$ was considered statistically significant.

3. RESULTS

3.1. Characteristics of the patients

Sixty-seven patients were recruited for the study. Of these, 11 patients were excluded due to surgery duration <1 hour. Consequently, 56 patients with 168 pairs of simultaneous infrared ear and nasopharyngeal temperatures were included in the final analysis. The mean age of the included patients was 51 years (range, 24-75 years), and the mean body mass index was 23.5 kg/m^2 (range, 16.8-31.6 kg/m^2). The types of surgery performed included hysterectomy, myomectomy, oophorectomy, and/or salpingectomy. Laparoscopic surgeries were performed in 40 (71.4%) patients and open surgeries in 16 (28.6%) patients, with a median surgical duration of 102 min (range, 81-262 min). Seven patients were warmed intraoperatively using a forced air heating system.

3.2. Difference between infrared ear and nasopharyngeal temperatures

A comparison of the two temperatures at each time point is presented in Table 1. In general, the mean infrared ear temperature was consistently higher than the nasopharyngeal temperature throughout surgery, but the differences were small, albeit

Table 1

Comparison and correlation of infrared ear temperature and nasopharyngeal temperature

Time point	Ear temperature (°C) Mean (SD)	Nasopharyngeal temperature (°C) Mean (SD)	Difference (°C) Mean (95% CI)	p	ICC (95% CI)
Before surgery (n = 56)	36.78 (0.38)	36.56 (0.35)	0.22 (0.16-0.27)	<0.001	0.70 (0.11-0.88)
During surgery (n = 56)	36.46 (0.36)	36.33 (0.36)	0.13 (0.07-0.19)	<0.001	0.75 (0.50-0.87)
After surgery (n = 56)	36.36 (0.39)	36.29 (0.40)	0.06 (0.01-0.13)	0.047	0.80 (0.67-0.88)

CI = confidence intervals; ICC = intraclass correlation coefficient; SD = standard deviation.

statistically significant. Except for the difference before surgery (0.22°C), the mean difference between the two temperatures during and after surgery was <0.20°C.

3.3. Agreement between infrared ear and nasopharyngeal temperatures

The ICCs between the two temperatures at the three time points were ≥0.70; moreover, a trend of decreasing difference and increasing ICC toward the end of surgery was observed (Table 1), indicating that the agreement between the two temperatures improved with time. Bland-Altman plots with mean differences and 95% limits of agreement are shown in Fig. 1. Overall, 157 (93.5%) of the 168 temperature measurements fell within 95% limits of agreement of ±0.5°C.

3.4. Performance of infrared ear thermometer for detecting hypothermia

Of the 168 nasopharyngeal temperatures, 27 (16%) measurements were <36°C (1 before, 12 during, and 14 after surgery), with the lowest nasopharyngeal temperature of 35.4°C. The AUC of the infrared ear temperature to detect hypothermia was 0.95 (95% CI, 0.92-0.98; $p < 0.001$) (Fig. 2). The cutoff value was 36.2°C with the best Youden index of 0.76. At this point, the sensitivity was 0.89 (95% CI, 0.71-0.98) and the specificity was 0.87 (95% CI, 0.81-0.92).

4. DISCUSSION

The main findings of this study are (1) the infrared ear temperature has a good agreement with nasopharyngeal temperature in general anesthetized patients without hyperthermia, (2) the infrared ear temperature has a high diagnostic performance for intraoperative hypothermia (defined as a nasopharyngeal temperature <36°C) when using a cut point of 36.2°C, and (3) both temperatures gradually decrease and maintain a similar behavior throughout the surgery.

The general consensus is that body temperature should be monitored for patients undergoing general or neuraxial anesthesia for more than 30 minutes, as anesthesia-induced thermoregulatory impairment, combined with a cool operating room environment and surgical exposure, can make nearly all unwarmed surgical patients hypothermic.[1,2] Ideally, the temperature measurement should accurately reflect the core temperature, be easy, noninvasive, harmless, and technique independent.[3] Tympanic temperature is believed to be a reliable surrogate reading of core temperature as the tympanic membrane and hypothalamus share an arterial blood supply originating from the carotid artery.[8] Infrared ear thermometer uses an infrared sensor probe oriented toward, but not in contact with, the tympanic membrane.[5] Due to its noninvasive, convenient, hygienic, and quick nature, the infrared ear thermometer has been widely applied in clinical practice.[6–8] However, it is rarely used for intraoperative temperature monitoring, as its accuracy remains controversial.[11–13] Recently, Mah et al.[7] compared seven different commercially available thermometers and found that the infrared ear thermometer was the most accurate device for the regular measurement of body temperature; conversely, Mogensen et al.[14] found that although the infrared ear thermometer was able to detect fever (defined as ≥38°C rectally) using a cut point of 37.5°C, it was not accurate enough to measure the exact temperature in an adult emergency department population.

The current study showed a good agreement between infrared ear temperature and nasopharyngeal temperature in general anesthetized patients, with the difference and 95% limits of agreement between the two temperatures being mostly <0.2°C and within ±0.5°C, which have been considered clinically insignificant.[1,2] Furthermore, we noted that the agreement between the two temperatures improved with surgery time, possibly due to the patient's temperature gradually becoming more stable over time. Our findings are consistent with those of the previous studies showing that infrared ear temperature was able to estimate core temperature with low bias.[6,15,16] In contrast to previous studies, we further assessed the diagnostic performance of an infrared ear thermometer for hypothermia using ROC curve analysis. Our results showed that infrared ear temperature had high accuracy in detecting hypothermia

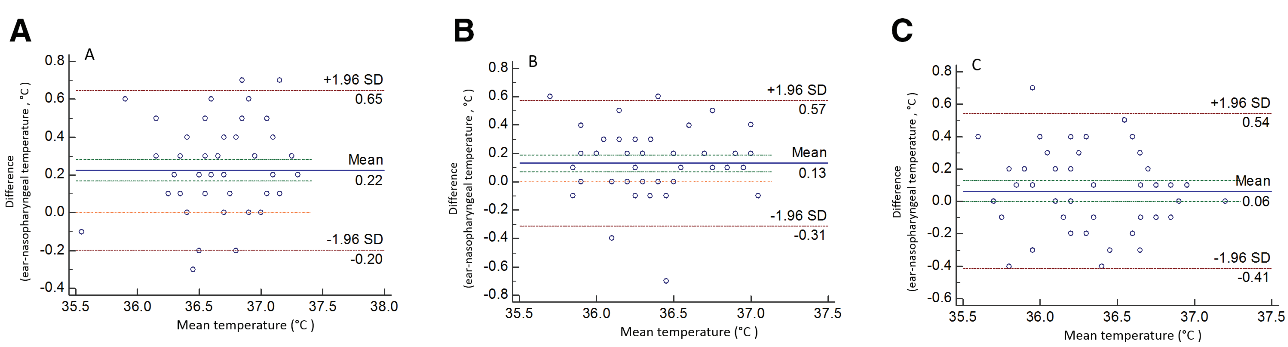

Fig. 1 Bland-Altman plots of the differences between infrared ear temperature and nasopharyngeal temperature. A, Before surgery, (B) during surgery, and (C) after surgery. SD = standard deviation.

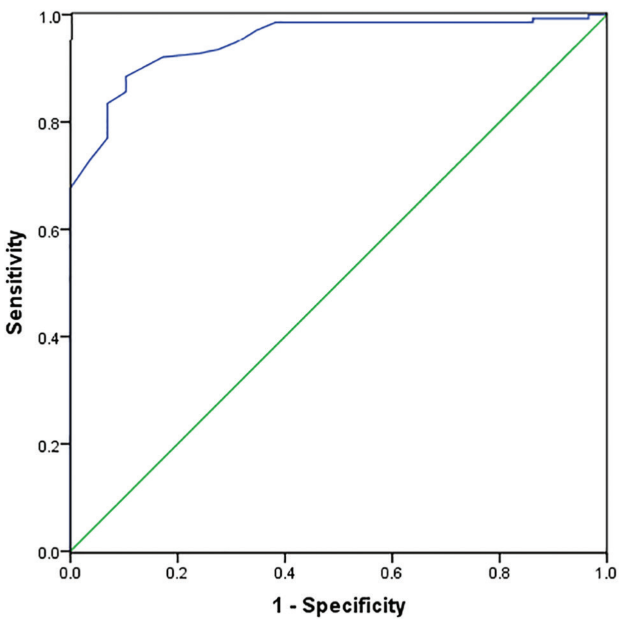

Fig. 2 The receiver operating characteristic curve for infrared ear temperature in detecting intraoperative hypothermia, as defined by nasopharyngeal temperature <36°C.

(defined as nasopharyngeal temperature <36°C) with a sensitivity of 0.89 and a specificity of 0.87 if the cutoff value of infrared ear temperature was set to 36.2°C. Considering that hypothermia is the most common thermal disturbance and a matter of concern during anesthesia,[1,2] our findings may have clinical implications for the intraoperative use of infrared ear thermometers. An infrared ear thermometer could be used as a diagnostic tool for intraoperative hypothermia if surgical patients do not receive temperature monitoring, but hypothermia is clinically suspected, or as an alternative to temperature measurement if traditional core temperature measurements are not easily available, such as in resource-limited environments. It is worth noting that although rare intraoperatively, hyperthermia can still occur during anesthesia, for example, in patients with infection or malignant hyperthermia, which is more dangerous than a comparable degree of hypothermia.[1] However, the performance of the infrared ear thermometer in the hyperthermia setting is unclear as none of our patients developed hyperthermia (≥38°C). Therefore, we do not know whether an infrared ear thermometer is suitable for febrile surgical patients, and we suggest that if the infrared ear temperature exceeds a certain value, for example, 37.5°C,[14,17] other temperature measurements should be used to obtain the exact temperature and determine whether hyperthermia occurs. Another point to note is that a major disadvantage of an infrared ear thermometer for intraoperative use is that it is discontinuous.

The accuracy of infrared ear temperature can be affected by several factors, especially the operator technique.[5,18] Therefore, it is essential that the operator is trained to use the thermometer correctly to obtain reliable measurements. An earlier study also recommended measuring both ears and taking the highest of the readings,[19] but another study did not find statistically significant differences between the right and left ears, and both ears were equally suitable for measurement.[6] Additionally, we took triplicate measurements of ear temperature and used the averaged value for analysis mainly for research purposes to reduce the potential measurement bias, but we observed a low-level variation in the triplicate measurements, indicating good reproducibility by the same operator. Therefore, in actual clinical practice, infrared ear temperature can be measured once the operator is proficient in the technique.

This study has several limitations. First, we recruited only adult female patients who underwent elective gynecological surgery, which could limit the generalizability of this study. Second, we measured the infrared ear temperature using only one brand/model of the thermometer. There may be differences in temperature readings between different brand/model infrared thermometers.[6,16,19] Therefore, we do not know whether other infrared ear thermometers have similar results. Third, we used the nasopharyngeal temperature as a reference rather than the pulmonary artery temperature, which was not possible in this study. Finally, as mentioned above, we cannot comment on the performance of the infrared ear thermometer in hyperthermia settings.

In conclusion, this study demonstrates that infrared ear temperature is in good agreement with nasopharyngeal temperature in general anesthetized patients without fever and has high performance in detecting intraoperative hypothermia. Therefore, infrared ear temperature may provide clinicians with an option to measure temperature in surgical patients without hyperthermia, particularly as a diagnostic tool for intraoperative hypothermia. However, the performance of infrared ear thermometers in the setting of hyperthermia is unclear and worthy of further study.

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