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®, Quicktherm™, and Thermopit®. We therefore tested the hypothesis that each is sufficiently accurate and precise for clinical use.

Methods: For the purpose of this investigation, we considered accuracy to be the mean difference between the test thermometers and the reference thermocouple. Precision was considered to be the standard deviation of the difference between the test and reference values. We evaluated ten patients undergoing cardiopulmonary bypass with moderate hypothermia (~30°C). Aural canal temperatures were measured in random order with each infrared thermometer, and compared with readings from a thermocouple positioned at the contralateral tympanic membrane.

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 Quicktherm™ 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 Quicktherm™ and a full 2.3°C with the Thermopit®. The precision (standard deviation) of the measurements, however, was ~0.8°C in each case.

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

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Perioperative thermal disturbances are common, and associated with serious physiological perturbations. Elevated temperatures, for example, may alert clinicians to malignant hyperthermia (1), overheating (2, 3), allergic reactions (4), drug toxicity (5), or infectious fever (6). Conversely, inadvertent hypothermia doubles the incidence of morbid myocardial outcomes (7), triples the incidence of surgical wound infections (8), increases blood loss and transfusion requirement (9), and prolongs postanesthetic recovery (10). Hypothermia may also be induced therapeutically because even small reductions in core temperature provide substantial protection against cerebral ischemia (11, 12) and malignant hyperthermia (13, 14).

Intraoperative core temperature monitoring is now routine for detection of temperature perturbations and to facilitate thermal management. Core temperature can reliably be measured at four sites: the tympanic membrane, distal esophagus, nasopharynx, and pulmonary artery (15, 16). Among these sites, only the tympanic membrane is non-invasive and can be used routinely in patients not given general anesthesia. The accuracy of tympanic membrane measurements, however, is only well established for well-insulated thermocouple probes carefully positioned adjacent to the membrane itself. Clinical use of measurements at this site is restricted by the technique's difficulty and associated patient discomfort. Consequently, infrared aural canal thermography has recently become popular.

Infrared thermometers are small, battery-operated units, with an otoscope-like probe (covered by disposable cellophane) that is introduced into the outer third of the auditory canal. The analog output from the sensor is converted to a digital signal for subsequent processing, and the resulting temperature is displayed on a liquid-crystal or diode screen. Unlike thermocouples, which directly contact the tympanic membrane, most infrared thermometers are subject to considerable environmental artifact because aural canal skin is cooled by ambient air.
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. For the purpose of this investigation, we considered accuracy to be the mean difference between the test thermometers and the reference thermocouple. Precision was considered to be the standard deviation of the difference between the test and reference values. As in our previous study (17), sufficient accuracy was considered to be an offset and standard deviation from the reference temperature of ≤0.5°C (i.e., a range of 1°C). This value was chosen because no adverse effects have been noted for intraoperative temperature deviations <1°C. Furthermore, normal circadian fluctuations are of this order (18), which suggests that similar perioperative changes are unlikely to prove harmful.

Methods

The study was approved by the Ethics Committee of the Yamanashi Medical University Hospital. Informed consent was obtained from 2 women and 8 men undergoing cardiac surgery with a target core temperature of 32°C. None of the patients had a history of problems with the aural canal, tympanic membrane, or middle ear.

Four aural canal thermometers were evaluated: Genius® (Sherwood IMS, Inc., CA, USA), Thermoscan® (Thermoscan, Inc., CA, USA), Quickthermo® (Omron, Inc., Mie, Japan), and Thermopit® (Nipro, Inc., Osaka, Japan). With each thermometer, temperature was measured, in random order, at the right tympanic membrane every 5 min throughout surgery. Individual measurements were separated by at least 1 min.

The reference temperature was measured simultaneously at the left tympanic membrane using a
Mon-a-Therm® thermocouple (Mallinckrodt Anesthesia Products, St. Louis, MO, USA). Visual inspection with an otoscope confirmed that the ear canals were free of wax in each patient. The aural probe was inserted by the patients until they felt the thermocouple touch the tympanic membrane: appropriate placement was confirmed when patients easily detected a gentle rubbing of the attached wire. The aural canal was then occluded with cotton wool, the probe securely taped in place, and a gauze bandage positioned over the external ear.

Values obtained from each of the infrared thermometers were compared with contralateral tympanic membrane temperature, as determined using the thermocouple. Regression and Bland and Altman analyses (19) established the reliability of each device. We a priori determined that an accuracy (mean difference between reference and test temperatures) and precision (standard deviation of the difference) of 0.5°C to be considered clinically adequate. The limit of 0.5°C was chosen because this variation is typical for other commonly used temperature measuring sites such as the axilla and mouth (16, 20), and because we have used this value previously (17). Results are expressed as means±SD.

Fig. 2. The differences between the tympanic membrane thermocouple and the aural canal temperature measured by Genius® (A), Thermoscan® (B), Quickthermo® (C), and Thermopit® (D). Mean differences were 0.0, -0.1, 1.1, and 2.3°C, respectively. SD=standard deviation.
Table 1

<table>
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<tr>
<th>Brand</th>
<th>Genius®</th>
<th>Thermoscan®</th>
<th>Quickthermo®</th>
<th>Thermopit®</th>
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<td>0.87</td>
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<td>0.88</td>
<td>0.53</td>
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<tr>
<td>Mean (°C)</td>
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<td>-0.1</td>
<td>1.1</td>
<td>2.3</td>
</tr>
<tr>
<td>SD (°C)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Correlation coefficients, slopes, accuracy, and precision of the Genius®, Thermoscan®, Quickthermo®, and Thermopit® thermometers, compared with a contralateral tympanic membrane thermocouple.

Results

The height of the patients was 162±10 cm, weight 59±12 kg, and age 69±7 yr. Compared to the thermocouple in the contralateral ear, the Genius® and Thermoscan® both had regression slopes >0.85 and correlation coefficients near 0.87 (Figs. 1A, 1B). In contrast, slopes of the Quickthermo® and Thermopit® regressions were 0.68 and 0.53, respectively. The correlation coefficients for each were <0.65 (Figs. 1C, 1D).

The accuracy (offset, or bias) was near 0°C with both the Genius® and Thermoscan® thermometers (Figs. 2A, 2B). In contrast, it was 1.1°C with the Quickthermo® and a full 2.3°C with the Thermopit® (Figs. 2C, 2D). The precision (standard deviation) of the measurements, however, was ≈0.8°C in each case (Table 1).

Discussion

Our major finding is that none of the tested infrared aural canal thermometers was sufficiently precise for routine clinical use. The precision (standard deviation) of each unit was ≈0.8°C. This is equivalent to saying that 67% of the measurements spanned a range of 1.6°C around the reference value. To encompass 97% of the values, a range exceeding 3°C would thus be required. Since clinically important outcomes have been documented with temperature differences near 1°C (7, 9), it is apparent that the precision we observed is inadequate.

Accuracy of two of the infrared thermometers was excellent (Genius® and Thermoscan®), with an offset near 0°C. The accuracy of a third (Quickthermo®) was poor, with an offset of 1.1 °C. The fourth infrared thermometer (Thermopit®) had an offset exceeding 2°C, indicating a major calibration error. Thus, even if the precision had been adequate, two of the tested thermometers were insufficiently accurate for routine use.

The tympanic membrane is considered a reliable core-temperature measurement site because it is relatively protected from the ambient environment, yet highly perfused with warm blood by a branch of the carotid artery (21). Numerous studies in the decades since the technique was proposed by Benzinger (22) have validated these assumptions (15, 23). Similar precision has also been observed with an infrared tympanic membrane thermometer (24-26). Our results thus emphasize the distinction between tympanic membrane and aural canal temperatures, with the latter being far less reliable. In this case, precision of the aural canal thermometers was no better than forehead skin temperature (17).

Our study was conducted in patients undergoing cardiac surgery. Cardiopulmonary bypass induces numerous and profound changes in body temperature and body heat distribution. However, there is no reason to believe that it alters temperatures at the right and left tympanic membranes differently. It thus seems likely that our results will apply comparably to other perioperative situations.

In summary, we evaluated the accuracy and precision of four infrared aural canal thermometers: Genius®, Thermoscan®, Quickthermo®, and Thermopit®. The precision of four infrared aural canal thermometers was insufficient for clinical use. Two were accurate, but the other two displayed substantial calibration errors. We thus conclude that none of these thermometers is suitable for perioperative use.

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References


