Accuracy of Temporal Artery Thermometry as an Indicator of Core Body Temperature in Patients Receiving General Anesthesia

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**Purpose:** To evaluate the agreement of temporal artery temperature (Tat) with esophageal temperature (Tes) and oral temperature (Tor), and explore potential factors associated with the level of agreement between the thermometry methods in different clinical settings.

**Design:** A prospective repeated measures (induction, emergence, and postanesthesia care unit) design was used.

**Methods:** Temperature data were collected for 54 patients receiving general anesthesia. Analyses included descriptive statistics, paired t tests for the within-patient comparison of temperature methods, Bland-Altman plots to examine agreement between methods, and multiple linear regression to identify factors associated with the agreement between methods.

**Findings:** Tat was significantly higher compared with Tes and Tor (P < .05) and was poor at detecting hypothermia. The use of a muscle relaxant and surgical site were suggested to be associated with the difference between Tat and Tes at emergence.

**Conclusions:** Tat is more convenient, but less accurate, than other thermometry methods. These inaccuracies are exacerbated by common anesthetic medications.

**Keywords:** temporal artery thermometer, esophageal temperature, oral temperature, agreement.

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**ANESTHETIC MEDICATIONS** and cold operating room (OR) environments decrease core body temperature in patients. These factors increase risk for hypothermia because of impaired thermoregulatory mechanisms. Vasodilation promotes heat loss by redistributing heat from the core to the...
periphery. General anesthetics decrease shivering thresholds by $2^\circ C$ to $3^\circ C$, further promoting hypothermia. Risk for unintended perioperative hypothermia is 26% to 90% and is associated with many untoward physiological responses, including augmented risks of blood loss and need for allogeneic transfusions, life-threatening cardiac complications, slowed drug metabolism, surgical site infections, scar formation, and mortality. Hence, proper temperature monitoring in the surgical patient population is vital in maintaining safety and promoting a full recovery.

Monitoring core body temperature of patients in the perioperative environment is required for early and accurate detection of hypothermia (ie, $36^\circ C$), a common problem of patients having surgery. Accurate thermometry monitoring is recommended to detect these temperature abnormalities before any complications can arise. Temperature can be measured either centrally, which represents temperatures of highly perfused organs such as the brain, abdominal, and thoracic cavities, or peripherally, which measures body temperature in less invasive places such as the ear, the skin over the forehead, rectum, axilla, and oral cavity. Selection of a perioperative temperature measurement device must balance accuracy and invasiveness as the most accurate indicators of core body temperature are also the most invasive and introduce additional risks. The multitude of methods to measure temperature varies greatly in efficiency and accuracy and noninvasive methods have questionable accuracy and reliability, particularly in the perioperative settings.

We set out to determine if temporal artery thermometry is an appropriate tool for surgical patients receiving general anesthesia and determine factors that are associated with the difference in temperature from induction to emergence. We hypothesize that because of factors from the cold OR environment and the effect of anesthetic medications, the temporal artery thermometer, which measures body surface temperature, will not correlate well with the temperatures obtained from an esophageal or oral thermometer. We also hypothesize that factors such as surgical site may decrease the accuracy of the temporal artery thermometer. The purpose of this study was to compare temporal artery temperature (Tat) with esophageal temperature (Tes) and oral temperature (Tor) during the perioperative period. The specific aims of this study were to (1) determine the level of agreement between Tat and Tes at the initiation of general anesthesia (ie, induction) and during emergence from general anesthesia in the OR, (2) determine the level of agreement between Tat and Tor in the postanesthesia care unit (PACU), and (3) explore variables that are associated with the difference between Tat and Tes measurements from induction and emergence.

Methods

The study took place in the ORs and PACU of a large university medical center, located in the Mid-Atlantic portion of the United States. The study was approved by the Internal Review Board. Informed consent was obtained from all participants in the preoperative holding area. STATA (version 14, StataCorp LP, College Station, TX) was used for all analyses.

Study Design and Sample Selection

A prospective repeated measures design with a convenience sample of 54 participants aged at least 18 years receiving general anesthesia was used. Participants were included if they were receiving general anesthesia for a surgical procedure with planned Tes monitoring. Research participants were excluded if there was inability to access the patient’s forehead because of the nature of surgery. All participants had Tat measured by the study personnel at three time points: induction, emergence, and within 15 minutes of admission to the PACU. At induction and emergence, Tes was collected in addition to Tat. In the PACU, Tor was collected with Tat.

Procedure

Data were collected by seven nurse anesthesia students from the University of Pittsburgh, trained in the use of the temporal artery thermometer following the manufacturer’s recommendations. In the operative suite, subjects were connected to monitors, started on medications and fluids, and induced with general anesthetics. After anesthesia was induced, subjects were intubated and an esophageal probe was inserted. Convective
warmers were applied and set at 43°C during the operative procedure. Induction Tat and Tes measurements were obtained by study personnel shortly after the convective warmers were placed on the patient.

Anthropometric information (gender, race, age, weight, height, body mass index, and body surface area) was collected from the medical record. Intraoperative medication and dosages, American Society of Anesthesiologists physical risk score, surgical site, length of surgery, and OR temperature were recorded on data collection sheets.

During emergence, the Tat and Tes measurements were gathered. Once extubated and stabilized, the patient was moved into the PACU and both Tor and Tat were collected within 15 minutes of admission.

**Measures**

Tat was measured using an Exergen Temporal Scanner (Watertown, MA). The accuracy of the Exergen Temporal Scanner is reported to be ±0.1°C for temperatures between 16°C and 43°C.9

Tes was measured using the level 1 Acoustoscope Esophageal Stethoscope Model ES400-18 (Smiths Medical ASD, Inc, Rockland, MA). Accuracy of the Yellow Springs Instrument thermistor is ±0.05°C to ±0.2°C.10

Tor was measured using the Becton Dickinson Digital Thermometer. Accuracy of the Becton Dickinson Digital Thermometer (Franklin Lakes, NJ) is ±0.1°C.11

**Statistical Analysis**

Data were first screened for any anomalies (eg, outliers, missing data, non-normality, heteroscedasticity, multicollinearity, and so forth) that might invalidate analyses. Considering the variable’s level of measurement and observed data distribution, appropriate descriptive statistics (frequency distribution for categorical descriptors and means and standard deviations for continuous type normally distributed variables) were used to summarize the characteristics of the sample and temperature values at each time point. Paired t tests were compared with the temperatures obtained with different thermometry methods within each participant at each time point. Bland-Altman plots (or Tukey mean-difference plots) were generated to examine the variability in temperature agreement over the observed temperature range between Tat and Tes, and Tat and Tor.

To explore whether any factors were associated with the differences between Tat and Tes during induction and emergence, simple linear regression was first performed to obtain unadjusted estimated regression coefficients. Multiple linear regression was then applied to obtain adjusted estimated regression coefficients considering all patient characteristics and anesthetic factors of interest.

**Results**

The sample included 54 subjects, predominantly Caucasian (n = 45) and male (n = 27) with a mean age of 50.2 years (standard deviation [SD] = 15.9). Mean OR time was 115.8 minutes (SD = 97.5). Further sample descriptives are reported in Tables 1 and 2.

With Tes, there were 22 patients (41% of the sample) that were hypothermic, and the temporal artery thermometer only picked up that 1 patient was hypothermic at induction. During emergence, 11 patients were hypothermic according to the Tes measurement and the temporal artery thermometer found only 1 patient to be hypothermic during emergence. There were significant differences between the two temperature measurements (Table 3). At induction, Tat was higher than Tes with a mean difference of −0.67°C (P < .0001). At emergence, Tat also exceeded Tes with a mean difference of −0.66°C (P < .0001). In the PACU, the mean difference was −0.41°C (P < .0001) (Table 3).

The mean temperature difference at induction was −0.67°C with the 95% confidence interval between −1.83°C and 0.49°C for Tat and Tes (Figure 1). The difference between Tat and Tes at induction is greater when the patient is colder.

The mean temperature difference at emergence was −0.66°C with the 95% confidence interval between −2.55°C to 1.24°C between Tat and Tes (Figure 2). Temperatures were lower, in general, at induction compared with emergence.
The mean temperature difference in the PACU was 2.04°C with the 95% confidence interval between 2.15°C and 0.91°C (Figure 3). When the factors were jointly considered in a multiple linear regression, the significance of the regression coefficient for the use of a muscle relaxant was diminished once adjusted for other factors (b = −0.6842, P = .150); only the torso compared with neck surgical site operations remained statistically significant (b = −0.9716, P = .049).

Discussion

The level of agreement between central and peripheral indicators of temperature has been evaluated in many studies, and many conclude that the level of agreement between the two types of thermometers and the diagnostic accuracy of peripheral thermometers are poor. Hence, peripheral thermometry is often considered a marginal screening tool for temperature abnormalities, particularly in operative settings. In our study, we did not find that the temporal artery thermometer agreed well with other thermometer devices, be it central or peripheral devices. The temporal artery thermometer’s ability to detect fever and hypothermia has produced conflicting reports of accuracy and precision. At temperature extremes, the Tat measurements become affected by physiological factors such as shivering, vasoconstriction, and diaphoresis seen during the various phases of fevers, and in perioperative areas specifically, exposure to environmental temperature fluctuations and external heating devices can skew Tat measurements. Researchers have found that the infrared temporal artery thermometer is flawed because it does not provide sufficient accuracy and precision for body temperature measurements and has a poor ability to screen fever and hypothermia, in both adults and children. Some studies found Tat is accurate in operative settings. In colorectal and gynecological surgical patients, Tat and Tor both overestimated the Tes measurements, but with Tat being more accurate than Tor. The Tat and Tes measurements were within 0.4°C of the core esophageal measurement, which is clinically acceptable. However, this

### Table 1. Characteristics of Sample

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Descriptive Statistic</th>
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<tr>
<td>Age (y)</td>
<td>Mean (SD) 50.2 (15.93) (Min, max) (17, 84)</td>
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<tr>
<td>Gender, n (%)</td>
<td>Male 27 (50.0) Female 26 (48.1) Unknown 1 (1.9)</td>
</tr>
<tr>
<td>Race/ethnicity, n (%)</td>
<td>Caucasian 45 (83.3) African American 5 (9.3) Others 4 (7.4)</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>Mean (SD) 1.99 (0.31) (Min, max) (1.15, 2.72)</td>
</tr>
<tr>
<td>ASA, n (%)</td>
<td>1 5 (9.3) 2 20 (37.0) 3 28 (51.9) 4 1 (1.9)</td>
</tr>
<tr>
<td>Surgical site, n (%)</td>
<td>Neck 11 (20.4) Spinal 11 (20.4) Torso 21 (38.9) Extremities 8 (14.8) Unknown 3 (5.6)</td>
</tr>
<tr>
<td>Length of surgery (min)</td>
<td>Mean (SD) 116.1 (78.4) (Min, max) (9, 381)</td>
</tr>
<tr>
<td>Operating room temperature (°C)</td>
<td>Mean (SD) 19.3 (1.63) (Min, max) (14.4, 21.7)</td>
</tr>
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ASA, American Society of Anesthesiologists.
The study did not look at the temperature extremes, which may explain the differences in these findings compared with our study and other reported work.

Although temporal artery thermometers are more convenient than other methods of measuring temperature, we found wide variability between Tat compared with Tes and Tor, with greater differences at cooler temperatures. These results show that Tat may overestimate the temperature at colder temperatures, a concern because it is known that hypothermia is a common problem in patients receiving general anesthesia and there are many complications associated with a lower body temperature. Given the increased differences between Tat and Tes at colder temperatures and standard warming practices used intraoperatively, the cooler temperature at induction may be driving this relationship. The time that patients are left unwarmed and surgically prepped with alcoholic chlorhexidine and betadine sterilizing products will ultimately facilitate heat loss. Consequently, it is likely that the patient would be much colder in the OR at induction compared with emergence, when the patient has had time to warm up under convective warming devices. The difference between Tat and Tor in the PACU could be attributed to the fact that the oral thermometer eliminates the factor of peripheral vessel constriction, which can affect Tat measurements.

### Table 3. Summary of Temperature Measurements by Time Points With Paired t Test Results

<table>
<thead>
<tr>
<th></th>
<th>Esophageal/Oral Mean ± SD (Min, Max)</th>
<th>Temporal Artery Mean ± SD (Min, Max)</th>
<th>Mean of Difference Mean ± SD (95% CI)</th>
<th>t Value (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Induction</strong></td>
<td>36.05 ± 0.62 (34.7, 37.5)</td>
<td>36.72 ± 0.33 (35.9, 37.7)</td>
<td>−0.67 ± 0.59 (−0.83, −0.51)</td>
<td>8.33 (&lt;.0001)</td>
</tr>
<tr>
<td>W/o 2 outliers</td>
<td></td>
<td></td>
<td>−0.67 ± 0.60 (−0.83, −0.50)</td>
<td>8.01 (&lt;.0001)</td>
</tr>
<tr>
<td><strong>Emergence</strong></td>
<td>36.53 ± 0.67 (35.1, 37.7)</td>
<td>37.2 ± 0.90 (35.8, 40.3)</td>
<td>−0.66 ± 0.97 (−0.93, −0.39)</td>
<td>4.90 (&lt;.0001)</td>
</tr>
<tr>
<td>W/o 2 outliers</td>
<td></td>
<td></td>
<td>−0.55 ± 0.79 (−0.77, −0.32)</td>
<td>4.86 (&lt;.0001)</td>
</tr>
<tr>
<td><strong>PACU</strong></td>
<td>36.34 ± 0.67 (34.6, 37.6)</td>
<td>36.75 ± 0.55 (35.4, 38.0)</td>
<td>−0.41 ± 0.57 (−0.57, −0.26)</td>
<td>5.33 (&lt;.0001)</td>
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</table>

PACU, postanesthesia care unit.
The influence of muscle relaxant use on the difference in Tes and Tat was seen at the time of emergence from anesthesia and may be because of thermogenesis. At emergence, muscle relaxants have reached peak therapeutic effects, but there is also decreased shivering and ability to generate heat. Duration of surgery is also an important consideration. More time with convective cooling helps core temperatures to adjust and return to normothermia in a longer surgery. In addition, larger surgical sites at a central body location were associated with poor correlation between measures. The decreased available body surface area for convective warming and increased body surface surgical prep area exposed to the cold temperatures of the OR may contribute to this finding.

Clinical Implications

In summary, we found the temporal artery thermometer consistently overestimated core temperature, particularly at lower temperatures. Generally, the study showed that at temperatures less than 37°C to 38°C, temporal artery thermometers showed a greater difference from a standard core temperature measurement at lower temperatures. The use of muscle relaxants and the surgical site (torso compared with neck) were found to be significant factors decreasing accuracy.

Our findings do not support the use of temporal artery thermometry in the perioperative setting. The benefit of a noninvasive thermometer may be acceptable in healthy individuals, short surgical cases with small, distal surgical sites, and emergent situations. If providers must use a temporal artery thermometer in these settings, proper use of the
device, as per the manufacturers’ instructions, is vital. Improper use, hair or bandages over the forehead, and sweating may skew results.

Limitations

There are some limitations to this study. The distance of the esophageal probe inserted into the subject was not standardized, but rather was dependent on the specific clinician performing the procedure. Oral thermometers, used in the PACU setting, are difficult for the patient to hold in their mouth during recovery and may underestimate temperature. There were also no febrile patients in the sample, limiting our analysis and interpretation. Although an exploratory investigation, the sample size when fitting regression models was somewhat limited and thus may have negatively impacted our ability to detect clinically meaningful associations between the differences in thermometry methods with patient characteristics and anesthesia factors.

Conclusions

Although temporal artery thermometer is a quick and convenient tool, it is not accurate during the perioperative period. Considering the potential risks of obtaining inaccurate temperatures in a surgical patient, such as perioperative
hypothermia and malignant hyperthermia, the use of a central body temperature monitoring device like an esophageal probe should be emphasized as a priority, especially in operations that use larger surgical sites and require the use of muscle relaxants.

References