Insufficiency in a New Temporal-Artery Thermometer for Adult and Pediatric Patients

Mohammad-Irfan Suleman, MD*, Anthony G. Doufas, MD, PhD*, Ozan Akça, MD*, Michel Ducharme, PhD†, and Daniel I. Sessler, MD‡

*Outcomes Research™ Institute and Department of Anesthesiology, University of Louisville, Kentucky; †Defence R&D Canada-Toronto, Canada; and ‡Ludwig Boltzmann Institute, University of Vienna, Austria

SensorTouch™ is a new noninvasive temperature monitor and consists of an infrared scanner that detects the highest temperature on the skin of the forehead, presumably over the temporal artery. The device estimates core temperature ($T_{core}$). We tested the hypothesis that the SensorTouch™ is sufficiently precise and accurate for routine clinical use. We studied adults ($n = 15$) and children ($n = 16$) who developed mild fever, a core temperature of at least 37.8°C, after cardiopulmonary bypass. Temperature was recorded at 15-min intervals throughout recovery with the SensorTouch™ thermometer and from the pulmonary artery (adults) or bladder (children). Pulmonary artery ($T_{pa}$) and SensorTouch™ ($T_{st}$) temperatures correlated poorly in adults: $T_{core} = 0.7 \cdot T_{st} + 13, r^2 = 0.3$. Infrared and pulmonary artery temperatures differed by 1.3 ± 0.6°C; 89% of the adult temperatures thus differed by more than 0.5°C. Bladder and infrared temperatures correlated somewhat better in pediatric patients: $T_{core} = 0.9 \cdot T_{st} + 12, r^2 = 0.6$. Infrared and bladder temperatures in children differed by only 0.3°C, but the sd of the difference was 0.5°C. Thus, 31% of the values in the infants and children differed by more than 0.5°C.

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Mild hypothermia causes numerous serious postoperative complications. Major adverse outcomes of perioperative hypothermia include morbid myocardial outcomes (1), coagulopathy (2), surgical wound infections (3), and prolonged postanesthetic recovery (4) and hospitalization (3). Effective methods of preventing and treating hypothermia are readily available (5) but remain underused (6), partly because perioperative temperature monitoring is difficult in certain patients.

Core temperature ($T_{core}$) is easily measured in the distal esophagus in intubated patients. However, $T_{core}$ is more difficult in patients ventilated with a face mask or laryngeal mask airway. Accurate measurement of $T_{core}$ is similarly difficult during neuraxial anesthesia.

There is clinical need for a noninvasive and accurate $T_{core}$ monitor that can be used in the perioperative period. A potential system is the SensorTouch™ thermometer from Philips, Inc. (Rotterdam, The Netherlands), which consists of an infrared scanner that detects the highest temperature on the skin of the forehead and temporal region. From this value, the device estimates $T_{core}$ using a proprietary algorithm that incorporates a compensation for ambient temperature ($T_{st}$). This system thus differs from conventional skin-temperature measurements (i.e., liquid crystal strips) in searching for the highest forehead temperature and compensating for ambient temperature. We therefore tested the hypothesis that the SensorTouch™ thermometer is sufficiently precise and accurate for routine clinical use.

An important aspect of routine temperature measurement is detection of fever. We therefore tested the system in adult and pediatric patients recovering from cardiopulmonary bypass (CPB). We chose these patients because they are usually initially somewhat hypothermic, but often subsequently develop fever in a matter of hours. Most thus demonstrate a suitable range of $T_{core}$.
Methods

With written consent from the participating patients and approval from the Human Studies Committees at the University of Louisville and Defence R&D Canada-Toronto, Canada, we studied 56 patients (30 adults and 26 children) who were recovering from cardiac surgery with CPB. The adults were between 36 and 83 years of age and the children between 9 days and 13 years old.

Protocol and Measurements

Morphometric and demographic characteristics of the participating patients were recorded. No external warming devices were used on any of the patients during the study period. Fluid, pressor, ventilatory, and pain managements were per clinical routine. When considered clinically appropriate, shivering was treated with meperidine. Temperatures were recorded at 15-min intervals for the first 3 h of postoperative recovery. In patients whose Tcore continued to increase at the end of 3 h, temperature measurements continued at 15-min intervals until no further increase was observed or until 4 postoperative hours had elapsed. Per clinical routine, Tcore was recorded from a pulmonary artery catheter in the adults and from a bladder catheter in the infants and children. The accuracy of these devices is ±0.2°C. Tcore was simultaneously estimated from a SensorTouch™ infrared thermometer using a standardized technique recommended by Philips, Inc. The tip of the instrument was positioned directly on the patient’s skin above the eyebrow. The device was activated, and slowly moved across the skin until the tip reached the top of the ear; this process required 5–7 s. This measurement procedure was repeated three times (trials), and the values averaged. Measurements were performed by a single investigator who was trained in the use of the SensorTouch™ thermometer. We also recorded the number of patients who demonstrated visible forehead sweating and the effect of sweating on the SensorTouch™ readings.

Data Analysis

To assure a good range of temperatures in each patient, we restricted data analysis a priori to adult and pediatric patients who developed at least a low-grade fever (37.8°C) during the initial postoperative period. Our primary analysis was as recommended by Bland and Altman (8). This method of comparing two measurement techniques measures the strength of the relation between two variables. We determined a priori that an accuracy (difference between Tcore and Tst) and precision (sd of the difference) of 0.5°C would 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 (9,10), and because we have used this value previously (11). Results are expressed as means ± sd.

We further evaluated the sensitivity and specificity of the infrared thermometer for detecting low-grade fever (Tcore ≥ 37.8°C). Sensitivity was calculated as the fraction of measurements with fever that was correctly identified by the SensorTouch™; specificity was calculated as the fraction of measurements without fever that was correctly identified by SensorTouch™.

Results

Fifteen of the 30 adults and 16 of the 26 children reached a temperature of at least 37.8°C during the postoperative period; data analysis was restricted to these 31 patients. Demographic and morphometric characteristics of the two study populations, along with initial and maximum Tcore and temperature ranges are presented in Table 1. Visible forehead sweating was detected during one measurement trial each in three of the adults. The SensorTouch™ thermometer was unable to produce a reading during these episodes (i.e., no temperature was displayed) so these trials could not be included in the analysis. Sweating was also observed during a single measurement trial in one pediatric patient. The SensorTouch™ displayed a temperature during this episode, and the value was included in the data analysis. However, sweating increased the difference between the bladder and SensorTouch™ values from 0.2°C on the previous measurement trial to 1°C.

There was poor correlation between body temperature measured at the pulmonary artery and with the SensorTouch™ infrared temporal-artery thermometer in adults: Tcore = 0.7 · Tst + 13, r² = 0.3 (294 measurements). Infrared values in adults differed from measured Tcore by an average of 1.3 ± 0.6°C. Thus, 89% of the infrared measurements in adults differed from pulmonary artery temperature by more than 0.5°C (Fig. 1). Not a single SensorTouch™ value in the adults exceeded 37.4°C, although 59% of the core measurements exceeded this value. Consequently, the SensorTouch™ performed with sensitivity for detecting fever of 0% and specificity of 100% in the adults.

The initial temperature in the pediatric patients was 37.5 ± 0.8°C, but decreased to 37.0 ± 0.8°C before increasing to febrile values. Tcore measured via the bladder catheter correlated better with the infrared thermometer in pediatric patients than in adults: Tcore = 0.7 · Tst + 12, r² = 0.6 (246 measurements). Infrared values in children differed from measured Tcore by an average of only 0.3, but the sd of the difference was 0.5°C. Thus, 31% of the values in the infants and
children differed by more than 0.5°C (Fig. 2). The sensitivity and specificity for detecting fever in the pediatric patients was 84% and 83%, respectively.

Discussion

Our results indicate that the SensorTouch™ thermometer was inaccurate in adults recovering from CPB, with the difference between estimated and measured Tcore being 1.3 ± 0.6°C. As in previous studies (11), we considered an accuracy of ±0.5°C to be clinically acceptable. This value was chosen for several reasons: 1) it approximates commonly observed differences between accepted body temperature monitoring sites (9,12); 2) the physiological consequences of body temperature alterations within a 1°C range are probably modest (13); and 3) the normal circadian body temperature range is ap-

Table 1. Demographic and Morphometric Characteristics, and Initial and Maximum Postoperative Temperatures

<table>
<thead>
<tr>
<th></th>
<th>Pediatric patients (n = 16)</th>
<th>Adults (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>3 ± 4</td>
<td>56 ± 15</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>77 ± 30</td>
<td>161 ± 15</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>15 ± 12</td>
<td>86 ± 18</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>6/10</td>
<td>12/3</td>
</tr>
<tr>
<td>Initial postoperative core temperature (°C)</td>
<td>37.5 ± 0.8</td>
<td>36.1 ± 0.7</td>
</tr>
<tr>
<td>Maximum postoperative core temperature (°C)</td>
<td>38.0 ± 0.8</td>
<td>38.1 ± 0.3</td>
</tr>
<tr>
<td>Core temperature range evaluated (°C)</td>
<td>1.1 ± 0.4</td>
<td>2.0 ± 0.6</td>
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Data presented as means ± sd. No statistical comparisons were performed between the two studied populations. Core temperature was recorded from the pulmonary artery in adults and from the bladder in the pediatric patients.

Figure 1. There was poor correlation between body temperature measured via a pulmonary artery catheter and the SensorTouch™ infrared temporal artery thermometer in adults: Tcore = 0.7 · Tst + 13, r² = 0.3 (upper graph). Infrared values in adults differed from measured Tcore by an average of 1.3 ± 0.6°C. The solid line indicates the average difference between pulmonary artery and SensorTouch™ temperatures; the dashed lines show ± two sd (lower graph).

Figure 2. There was a marginal correlation between Tcore measured via a bladder catheter and the SensorTouch™ infrared thermometer in pediatric patients: Tcore = 0.7 · Tst + 12, r² = 0.6 (upper graph). Infrared values in children differed from measured Tcore by an average of 0.3 ± 0.5°C. The solid line indicates the average difference between bladder and SensorTouch™ temperatures; the dashed lines show ± two sd (lower graph).
approximately ±0.5°C (14,15). Eighty-nine% of the infrared artery temperature by more than 0.5°C. The results were slightly more favorable in the infants and children, with the difference between estimated and measured Tcore being only 0.3. However, the square of the difference was 0.5°C. Thus 31% of the values in the infants and children differed by more than 0.5°C. Furthermore, the sensitivity for detecting fever was 0% in adults. We are thus forced to conclude that the SensorTouch™ thermometer is insufficiently accurate for clinical use in both adults and children, at least in postoperative cardiac patients. To the extent that intense vasoconstriction or other factors unique to cardiac surgery contributed, performance may prove better in other patient populations.

Why the results were superior in pediatric than adult populations remains unclear. The most likely reason is that adults have a relatively thick layer of skin over the artery compared with infants and children. This added insulation will reduce temporal skin temperature, and thus may cause the infrared monitor to underestimate Tcore. Finally, there is far more bone and other tissue between the brain and the skin surface. This added insulation may be important, since skin temperature is likely influenced by brain temperature through conductive and convective heat transfer (16,17). The SensorTouch™ thermometer actually measures skin temperature; thus increasing thermal insulation between the brain and skin will cool the skin by shifting the temperature balance toward ambient temperature. An additional potential problem in the adult cardiac patients is coexistence of temporal artery atherosclerotic disease, which might reduce temporal artery flow sufficiently to make the SensorTouch™ thermometer atherosclerotic disease. This added insulation may be important, since skin temperature is likely influenced by brain temperature through conductive and convective heat transfer (16,17). The SensorTouch™ thermometer actually measures skin temperature; thus increasing thermal insulation between the brain and skin will cool the skin by shifting the temperature balance toward ambient temperature. An additional potential problem in the adult cardiac patients is coexistence of temporal artery atherosclerotic disease, which might reduce temporal artery flow sufficiently to make the SensorTouch™ thermometer underestimate Tcore. Finally, circulating catecholamine concentrations may be larger in the adults, increasing cutaneous vasoconstriction and thus decreasing forehead temperature.

We restricted our study population to patients recovering from CPB because this population provided a large temperature range and high likelihood of developing fever. However, a limitation of this approach is that our results strictly apply to the special population we studied—in whom better methods of measuring temperature are readily available. The question then is to what extent our findings might reasonably be extrapolated to relevant populations, including outpatients and those undergoing regional anesthesia.

The accuracy and precision of the SensorTouch™ thermometer has previously been compared to rectal temperature in infants presenting to an emergency department (18). The results were similar to ours: the regression slope was 0.79 and the correlation coefficient (r²) was 0.69; the sensitivity was only 66%. Available data thus fail to support the use of the SensorTouch™ thermometers in infants. Our results suggest that it is also insufficiently accurate in adults.

A limitation of our study analysis is that we evaluated multiple sets of temperatures in each patient. This approach is suboptimal from a statistical point of view since regression analysis is designed for independent samples. Nonetheless, this allowed us to evaluate a clinically relevant temperature range in each patient. A more serious limitation is that the reference temperature-monitoring site in the pediatric patients was the bladder. This is not a true Tcore site and some of the divergence between bladder and SensorTouch™ temperatures may have resulted from inaccuracies of the bladder measurements. To the extent that bladder temperatures were inaccurate, the SensorTouch™ may prove more reliable than indicated by our results.

In summary, the SensorTouch™ thermometer proved more accurate in children than adults but was insufficiently precise for clinical use in either population of patients recovering from CPB. Poorer performance in adults may have resulted from coexistence of a relatively thick layer of skin over the artery and temporal artery atherosclerotic disease.

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