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Testing of a New Temporal-Artery Thermometer in Adult and Pediatric Patients

by

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Executive Summary

SensorTouch is a new noninvasive temperature monitor which consists of an infrared scanner that detects the highest temperature on the skin of the forehead, presumably over the temporal artery. From this value, 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 were recorded at 15-minute intervals throughout recovery with the SensorTouch thermometer and from the pulmonary artery (adults) or bladder (children). Pulmonary artery (T_{core} and SensorTouch (T_{st} temperatures correlated poorly in adults: $T_{core} = 0.6 \cdot T_{st} + 18$, $r^2 = 0.2$. 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 standard deviation of the difference was 0.5°C. Thus 31% of the values in the infants and children differed by more than 0.5°C.

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

Key words: Anesthesia. Surgery. Temperature, measurement: infrared, pulmonary artery, bladder.

Introduction

It is by now well established that even mild hypothermia causes numerous serious 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 under-utilized (6). One reason is that perioperative temperature monitoring is difficult in certain patients.

It is relatively easy to measure core temperature (T_{core}) in the distal esophagus in intubated patients. However, it is more difficult in patients ventilated with a face mask or laryngeal mask airway. Accurate measurement of core temperature is similarly difficult during neuraxial anesthesia. Temperature measurement difficulty surely contributes to the low rate of monitoring during neuraxial anesthesia (6) — although these patients are equally susceptible to hypothermia (7).

There is thus considerable clinical need for a non-invasive, but nonetheless accurate core-temperature monitor that can be used in the perioperative period. And of course such a thermometer could be used to advantage in other parts of the hospital, ambulatory clinics, and even at home. A potential system is the SensorTouch™ thermometer from Philips, Inc. (Rotterdam, The Netherlands). It 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 core temperature ($T_{\text{ }}$). 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. 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 core temperatures.

Methods

With written consent from the participating patients and approval from the Human Studies Committees at the University of Louisville and Defence & Civil Institute of Environmental Medicine, we studied 56 patients (30 adults and 26 children) who were recovering from cardiac surgery with cardiopulmonary bypass. The adults were between 36-83 years of age and the children between 9 days and 13 years old. They were all American Society of Anesthesiologist status III and IV. Enrollment in the study was not otherwise restricted. All studies were conducted at Jewish Hospital, Louisville, KY.

Protocol and Measurements

Morphometric and demographic characteristics of the participating patients was recorded. No external warming devices were used on any of the patients during the study period. Fluid and pressor management was per clinical routine, as was ventilatory and pain management. When considered clinically appropriate, shivering was treated with meperidine.

Temperatures were recorded at 15-minute intervals for the first three hours of postoperative recovery. In patients whose core temperatures continued to increase at the end of three hours, temperature measurements continued at 15-minute intervals until no further increase was observed or until four postoperative hours had elapsed. Per clinical routine, core temperature was recorded from a pulmonary artery catheter in the adults and from a bladder catheter in the infants and children.

Core temperatures were 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 seconds. This measurement procedure was repeated three times, and the values averaged.

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 *a priori* restricted data analysis 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).

We determined *a priori* that an accuracy (difference between T_{core} and T_{st}) and precision (standard deviation 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 (core temperature •37.8°C). Sensitivity was calculated as the fraction of patients with fever who were correctly identified fever by the Sensor Touch; specificity was calculated as the fraction of patients without fever who were correctly identified by Sensor Touch.

Results

Fifteen of the 30 adults and 16 of the 26 children reached a postoperative temperature of at least 37.8°C during the measurement period; data analysis was restricted to these 31 patients. Demographic and morphometric characteristics of the two study populations, along with initial and maximum core temperatures and temperature ranges are presented in table 1.

Visible forehead sweating was detected during one measurement period each in three of the adults. The SensorTouch thermometer was unable to produce any reading during these episodes (*i.e.*, no temperature was displayed) so these periods could not be included in the analysis. Sweating was also observed during a single measurement period 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 during the previous measurement period 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: $T_{core} = 0.6 \cdot T_{st} + 18$, $r^2 = 0.2$ (294 measurements). Infrared values in adults differed from measured core temperature 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 a 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. Core temperatures measured via the bladder catheter correlated better with the infrared thermometer in pediatric patients: $T_{core} = 0.7 \cdot T_{st} + 12$, $r^2 = 0.6$

(246 measurements). Infrared values in children differed from measured core temperatures by an average of only 0.3, but the standard deviation 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

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 roughly ±0.5°C (14,15).

Our results indicate that the SensorTouch thermometer was inaccurate in adults recovering from cardiopulmonary bypass, with the difference between estimated and measured core temperatures being 1.3 ± 0.6°C. As a result, 89% of the infrared measurements in adults differed from pulmonary 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 core temperatures being only 0.3. However, the standard deviation 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.

Why the results were better in pediatric than adult populations remains unclear. However, a potential problem in the adult cardiac patients is coexistence of temporal artery atherosclerotic disease. This might reduce temporal artery flow sufficiently to make the SensorTouch thermometer underestimate core temperature. A second possibility is that adults have a relatively thick layer of skin over the artery compared with infants and children. This added insulation will also reduce temporal skin temperature, thus causing the infrared monitor to underestimate core temperature. And 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 towards ambient temperature.

We restricted our study population to patients recovering from cardiopulmonary bypass because this population provided a large temperature range and high likelihood of developing fever. But a limitation of this approach is that our results strictly apply on to the special population we studied — in whom better methods of measuring temperature are readily available. The question then is to what extent our finding 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 (r^2) was 0.69; the sensitivity was only 66%. Available data thus fails to support the use of the SensorTouch thermometers in infants. Our results suggest that it is also insufficiently accurate in adults.

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

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

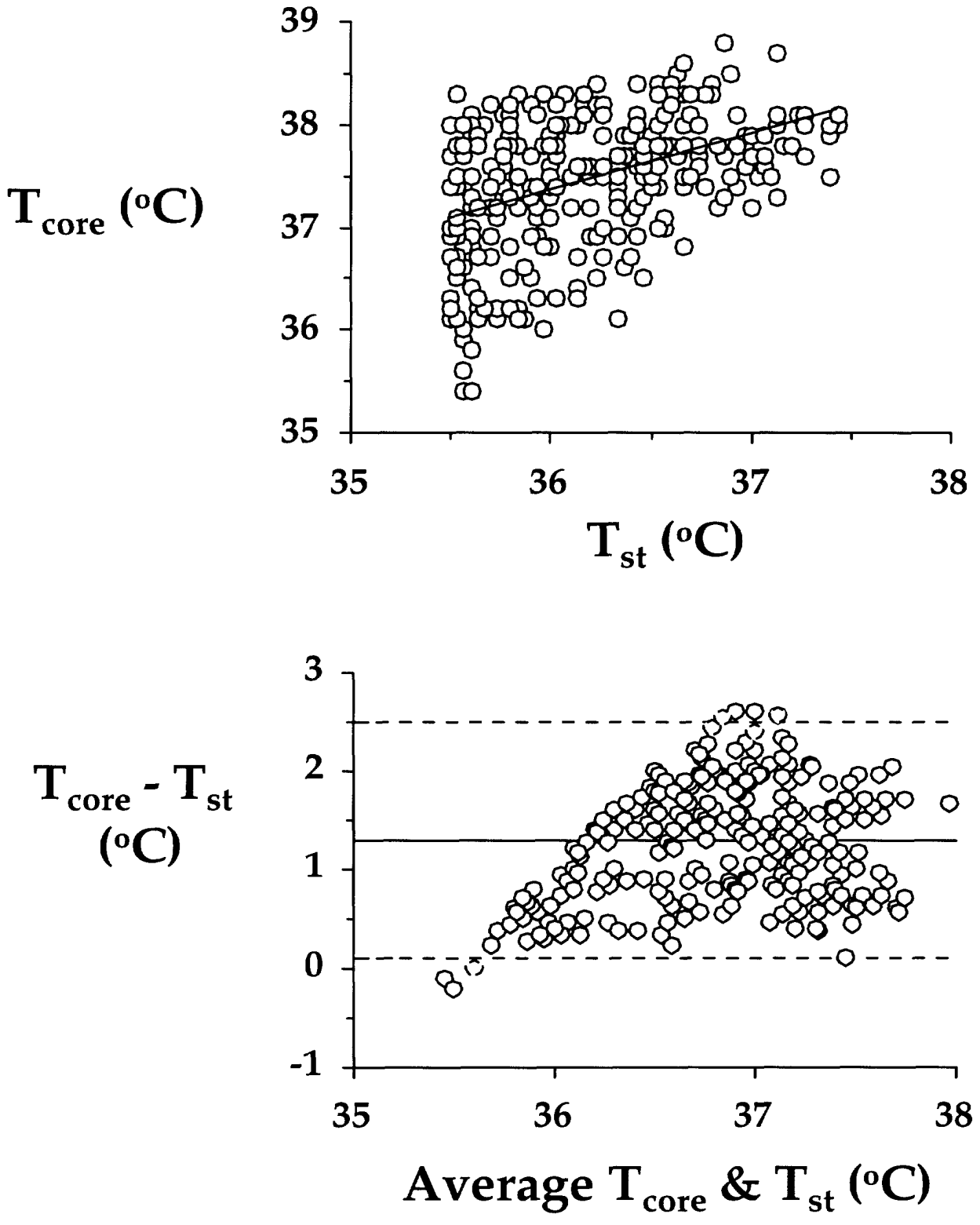
	Pediatric Patients (n = 16)	Adults (n = 15)
Age (yr)	3 ± 4	56 ± 15
Height (cm)	77 ± 30	161 ± 6
Weight (kg)	15 ± 12	86 ± 18
Sex (male / female)	6/10	12/3
Initial Postoperative Core Temperature (°C)	37.5 ± 0.8	36.1 ± 0.7
Maximum Postoperative Core Temperature (°C)	38.0 ± 0.8	38.1 ± 0.3
Core Temperature Range Evaluated (°C)	1.1 ± 0.4	2.0 ± 0.6

Data presented as means ± SDs. No statistical comparisons were performed between the two studied populations.

Legends

Fig. 1. There was poor correlation between body temperature measured at the pulmonary artery and with the SensorTouch infrared temporal-artery thermometer in adults: $T_{core} = 0.6 \cdot T_{st} + 18$, $r^2 = 0.2$. Infrared values in adults differed from measured core temperature by an average of 1.3 ± 0.6°C.

Fig. 2. There was a marginal correlation between core temperatures measured via a bladder catheter and the SensorTouch infrared thermometer in pediatric patients: $T_{core} = 0.7 \cdot T_{st} + 12$, $r^2 = 0.6$. Infrared values in children differed from measured core temperatures by an average of 0.3 ± 0.5°C.


T_{core} (°C)
39
38
37
36
35
35
36
37
38
T_{st} (°C)
T_{core} - T_{st} (°C)
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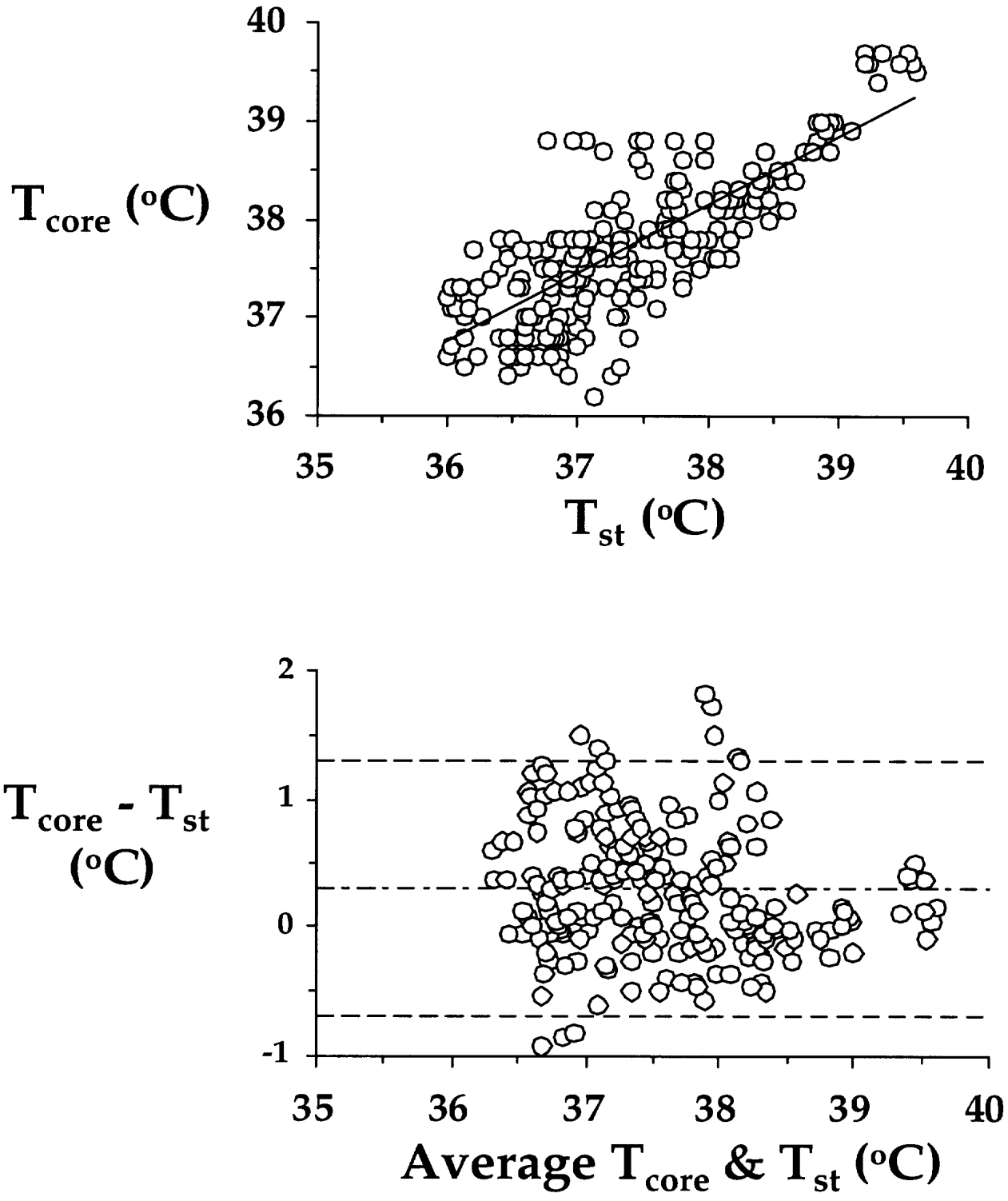
1
0
-1
35
36
37
38
Average T_{core} & T_{st} (°C)

Fig. 1


40
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T_{core} (°C)
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T_{st} (°C)
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T_{core} - T_{st} (°C)
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Average T_{core} & T_{st} (°C)

Fig. 2

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14. ABSTRACT

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15 KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Infrared measurement; core temperature; non-invasive

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