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Temperature Measurement in Critically Ill Adults: A Comparison of Tympanic and Oral Methods

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• ***Background*** *Despite increasing use of tympanic thermometers in critically ill patients who do not have a pulmonary artery catheter in place, variations in measurements obtained with the thermometers are still a problem.*
• ***Objective*** *To compare the range of variability between tympanic and oral electronic thermometers.*
• ***Methods*** *Subjects were a convenience sample of 72 patients admitted to a 24-bed adult medical-surgical intensive care unit. For each patient, temperatures were measured concurrently (within a 1-minute period) with an oral (SureTemp 678) thermometer, a pulmonary artery catheter (Baxter VIP Swan-Ganz Catheter), and 2 tympanic (FirstTemp Genius II and ThermoScan Ear Pro-1) thermometers. Each subject was used up to 3 times for data collection. Measurements obtained with the oral and tympanic thermometers were compared with those obtained with the pulmonary artery catheter. Nonparametric analysis of data was used.*
• ***Results*** *The magnitude of error for the ThermoScan tympanic thermometer differed significantly from that of the Genius II tympanic thermometer and the SureTemp oral thermometer ($P < .001$). Application of the Bland and Altman method to frame the data on the basis of an accuracy tolerance zone of ±0.5°C indicated variability with both the oral and tympanic methods. The overall degree of variability was lower for the oral thermometer.*
• ***Conclusions*** *Oral thermometers provide less variable measurements than do tympanic thermometers. Use of oral thermometry is recommended as the best practice method for temperature evaluation in critical care patients when measurement of core temperature via a pulmonary artery catheter is not possible. (American Journal of Critical Care. 2000;9:254-261)*

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Body temperature has long been regarded as an indication of physiological integrity. It is one of the many pieces of clinical data commonly used to make diagnoses and to evaluate treatments and patients' responses to treatments. Intermittent measurement of a patient's temperature is a routine task of nursing care. Most critically ill patients have body temperature measured repeatedly throughout the course of their illness. In collaboration with hospital biomedical engineers, critical care nurses are responsible for ensuring that routine temperature measurements are obtained in an accurate, safe, and comfortable manner.

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With the development of electronic thermometry, temperatures can be measured more quickly with both oral and rectal thermometers than with mercury-in-glass thermometers. Rectal temperatures are used in critical care and correlate well with core temperatures for patients whose temperature is constant. However, changes in rectal temperatures take longer to detect than changes in core temperatures, especially during sharp fluctuations in temperature.[1-5] Although oral temperatures are much simpler to obtain than are rectal temperatures, measurements of oral temperature in orally intubated adults, in patients receiving supplemental oxygen, and in patients who rely on openmouthed breathing have been considered inaccurate.[6,7] However, recent research[6,8-13] supports the accuracy and usefulness of oral temperature measurements in both orally intubated patients and patients receiving supplemental oxygen.

Nonetheless, use of tympanic thermometry has become more widespread because the method is convenient, fast, and noninvasive. The ear canal is a well-vascularized and accessible structure that provides a good site for measurement of core body temperature via indirect measurement of the temperature of the cerebral vasculature (the external cerebral artery largely supplies the tympanic membrane). Several studies have indicated the accuracy of tympanic temperatures in relation to core temperatures. Many researchers[14-24] have underscored the necessity of proper operator technique and have cautioned clinicians about variations in tympanic readings that are due to variability in operator technique.

In critically ill patients, use of a pulmonary artery catheter is the most well supported and accurate method for measuring core body temperature. Indeed, measurements obtained with a pulmonary artery catheter are generally considered the gold standard for measurement of core body temperature.[20-22,25-30] However, when use of a pulmonary artery catheter is not warranted, other methods must be used to obtain an accurate temperature.

Purpose

The purpose of this study was to compare commonly used methods for measuring body temperature via oral and tympanic routes in a sample of critically ill adults. Core temperatures measured via a pulmonary artery catheter were used as the criterion measure or the gold standard. The following a priori hypotheses were formulated on the basis of previous research[8]:

1. Compared with core temperatures measured via a pulmonary artery catheter, oral measurements will vary less than tympanic measurements will.
2. The variability of tympanic measurements will increase when patients are febrile, that is, have a temperature greater than 38°C as indicated by measurements obtained via a pulmonary artery catheter.

Materials and Methods

This study was approved by the hospital's institutional review board. The board waived the need for informed consent because measurement of temperature is considered part of the routine care provided in the intensive care unit, and no identifying data on the subjects would be saved. In order to ensure confidentiality and patients' anonymity, each subject was assigned a number as he or she was entered into the study, and all identifying information was discarded.

Subjects

The subjects in the study were a convenience sample of 72 critically ill adults admitted to a 24-bed medical-surgical (did not include cardiac surgery patients) intensive care unit in a 600-bed university-affiliated medical center during a period of 3 consecutive months. All subjects had a pulmonary artery catheter already in place because of clinical necessity and for reasons unrelated to this study. Although the majority of subjects were intubated, intubation was not a criterion for inclusion in the study.

Because only one study[18] specifically examined temperature measurement in critically ill febrile patients, febrile subjects (defined as patients with temperatures greater than 38°C as indicated by measurements obtained with a pulmonary artery catheter) were included in the study. Deliberate inclusion of these subjects permitted comparison of measurements across a broader range of measured temperatures. Such a comparison is particularly relevant for determining the accuracy and precision of tympanic thermometry for critical care practice.

Accuracy and Reproducibility of Temperature Measurements

The thermometers were used solely for data collection. In order to ensure that all thermometers remained within calibration throughout the period of the study, each thermometer was checked every Friday by a critical care nurse specialist according to instructions specified by the manufacturers. A black-body reference calibrator (model 9600; Welch Allyn, San Diego, Calif) in degrees Fahrenheit was used. Thermometers were recalibrated if they were within 0.4°F of the standard and were exchanged for another thermometer if they fell out of range by more than 0.4°F.

Data were collected by 3 experienced critical care nurses (E.P., S.E., and D.W.; each with a minimum of 14 years of experience) who were intensively trained before the study began by a clinical nurse specialist according to each product manufacturer's guidelines. During training for use of the oral thermometer, proper placement of the probe in the posterior sublingual pocket was emphasized to ensure accuracy of oral measurements.[29] For training with the tympanic thermometers, proper technique included placement of the probe so it pointed toward the tympanic membrane, penetrated at least one third of the external ear canal, and formed a complete seal with the external ear canal.[24]

Temperature Measurements

For each subject, 4 measurements of temperature were obtained within a 1-minute period: 1 oral, 2 tympanic (ie, 1 measurement with each of 2 devices), and 1 pulmonary artery core. Each subject was used up to 3 times in the study, with subsequent measurements obtained no less than 20 minutes apart.

Oral Temperatures. Oral temperatures were obtained by using a SureTemp thermometer (model 678; Welch-Allyn, San Diego, Calif). No oral measurements were obtained from patients who had received mouth care or had had anything to eat or drink within 30 minutes of the data collection.

Tympanic Temperatures. Two tympanic thermometers were used: the FirstTemp Genius II (model 3000A; Sherwood Medical, Carlsbad, Calif) and the ThermoScan Ear Pro-1 (model IR-1; Thermoscan, Inc, San Diego, Calif). For each subject, 2 tympanic measurements were obtained, 1 with the FirstTemp Genius II in one ear and 1 with the ThermoScan Ear Pro-1 in the opposite ear. Right and left ear sites were alternated between the 2 thermometers, and all measurements were completed in the core equivalence mode.[23] When tympanic measurements had to be repeated, the second measurement was delayed for 2 minutes to allow passage of the cooling effect of the tympanic probe on the ear canal (a phenomenon known as temperature draw-down, which causes falsely low tympanic values if not enough time elapses between measurements).

Core Temperatures. Core temperature was measured by using the thermistor port of a pulmonary artery catheter (VIP Swan-Ganz Catheter, model 93A831H7; Baxter Healthcare Corp, Irvine, Calif), and the cardiac output module of a bedside monitor (model M1046C; Hewlett-Packard Co, Andover, Mass). Before core temperature was measured, each thermistor port was checked for accuracy by using an electronic simulator (model 14232C; Hewlett-Packard Co, Andover, Mass). All 72 pulmonary artery catheters were calibrated at exactly 37°C.

Data Analysis

Although previous comparison studies typically compared and focused on measures of central tendency, this method is not the most clinically meaningful way to critically evaluate performance data or to determine implications for day-to-day care of individual patients. Measures of central tendency compress or aggregate the information contained in data derived from a group of subjects. In contrast, clinicians are necessarily more concerned with the accuracy of devices in individual patients rather than with aggregate or group data. Therefore, measures of deviation from the criterion value or error variables were the most important data points for analysis.

Because of the relatively large sample size, statistical significance could easily be achieved despite the possibility of relatively small differences. The most important question was whether or not these relatively small differences represented clinically meaningful and important differences.

Because the error variables were not normally distributed (see Table), nonparametric methods were used to analyze the data. Software used for the data analysis was SAS version 6.12 for Windows (SAS Institute, Cary, NC). The NPAR1WAY procedure was used.

In a manner similar to that recommended by Bland and Altman[31] for assessing agreement between different methods of clinical measurement, each error data point was plotted against the temperature obtained via a pulmonary artery catheter (Figures 1-3). The method of Bland and Altman more appropriately focuses directly on and examines mean differences from the criterion or reference value, which in this study was the pulmonary artery core temperature. The parallel lines on the graphs represent "accuracy tolerance" zones of ±0.5°C or limits of agreement and provide a frame of reference for understanding the data and the performance of each measurement method compared with the pulmonary artery core reference method.

Results

A total of 812 measurements of temperature were obtained from 72 subjects: 203 oral, 203 tympanic with the FirstTemp Genius II thermometer, 203 tympanic with the ThermoScan Ear Pro-1 thermometer, and 203 with a pulmonary artery catheter. For each set of 203 measurements, 65 (32%) were obtained from subjects who were febrile and 138 (68%) from subjects who were afebrile.

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Error variables for devices used to measure temperature

Device/error	Mean, °C	SD, °C	Minimum, °C	Maximum, °C	Median, °C
SureTemp 678 (oral)	37.60	1.00	34.56	40.06	37.5
FirstTemp Genius II (tympanic)	37.56	0.93	34.67	39.44	37.6
ThermoScan Ear Pro-1 (tympanic)	37.41	1.05	34.06	40.50	37.4
Pulmonary artery catheter (core)	37.56	0.78	34.72	39.28	37.5
SureTemp error	0.04	0.50	−1.56	1.17	0.11
FirstTemp error	0.00	0.67	−2.44	1.28	0.06
ThermoScan error	−0.14	0.64	−2.44	1.72	0.00

Calibration

During the weekly calibration, the FirstTemp Genius II thermometer fell out of range (±0.4°F) 7 times during the 12-week period of data collection. In contrast, the ThermoScan Ear Pro-1 and the SureTemp thermometers both remained within calibration ranges throughout the entire period of data collection and required no adjustments or instrument exchanges.

Data Analysis

The Table gives basic descriptive statistics for each thermometer and the calculated degree of error from the pulmonary artery core criterion value. Based on the Wilcoxon scores of the rank sums, a chi-square test showed that the error for the ThermoScan thermometer differed significantly from the errors for the SureTemp and the FirstTemp thermometers ($P = .007$).

Figure 1 shows the performance of the SureTemp oral thermometer relative to the thermistor of the pulmonary artery catheter. A total of 47 data points are outside the tolerance region. The SureTemp thermometer also tended to overshoot the pulmonary artery core temperature when used to measure temperature in febrile patients; the mean difference for the febrile group was 0.18°C. Nonetheless, the SDs for differences from pulmonary artery core temperatures for febrile and afebrile patients were comparable (afebrile = 0.50°C; febrile = 0.47°C).

Figure 2 indicates the performance of the FirstTemp Genius II tympanic thermometer relative to the tolerance zone. The performance of this thermometer differed notably from that of the oral thermometer. A total of 75 data points are outside the tolerance region. The greater degree of variability is also reflected

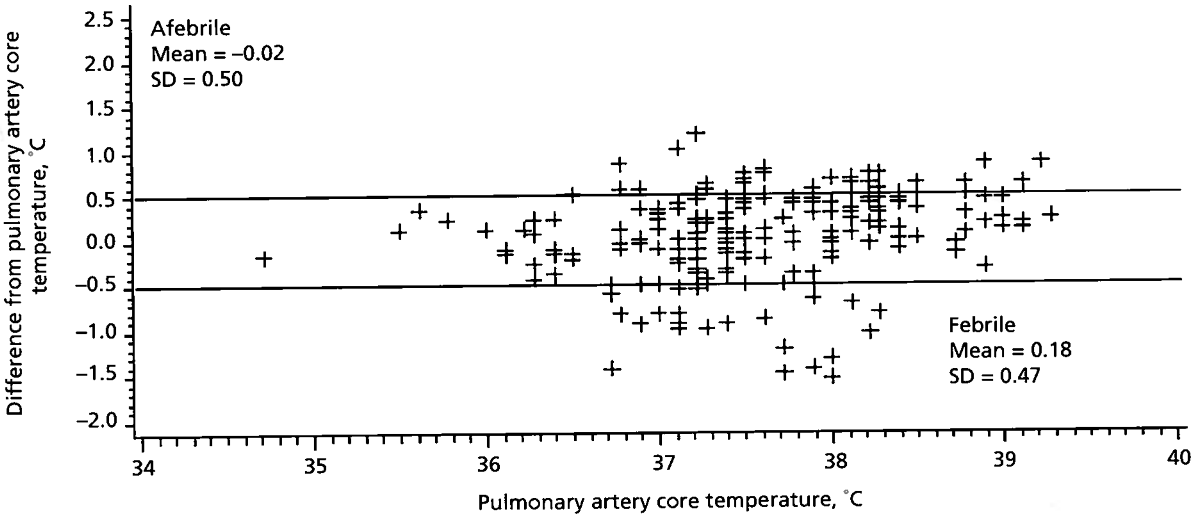

Figure 1 Differences between measurements obtained with the SureTemp 678 oral thermometer and those obtained via a pulmonary artery catheter.

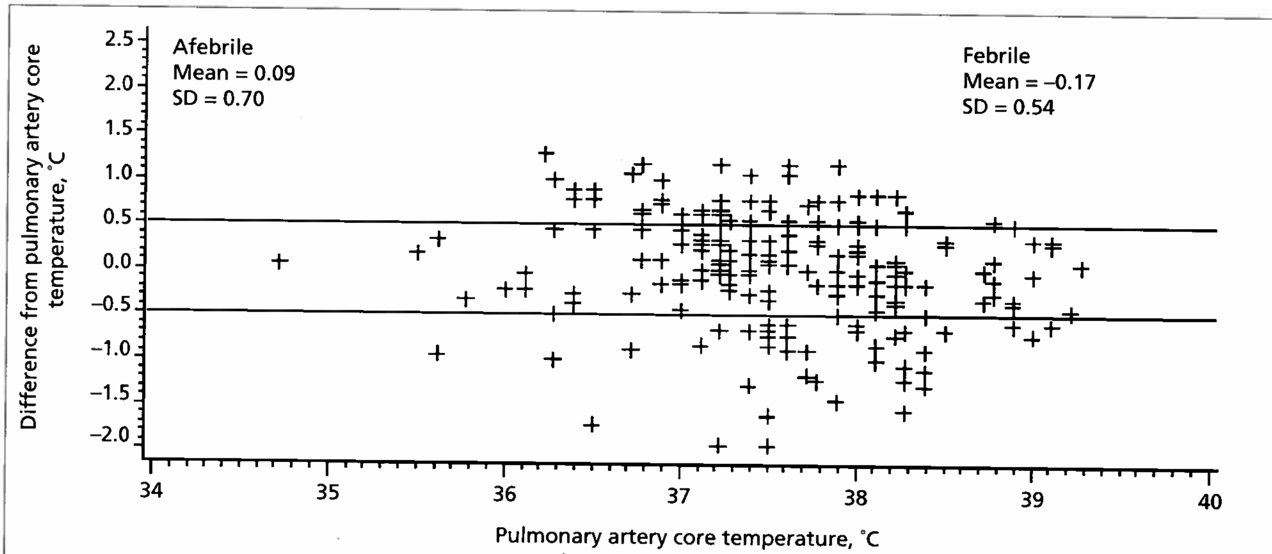

Figure 2 Differences between measurements obtained with the FirstTemp Genius II tympanic thermometer and those obtained via a pulmonary artery catheter.

in the larger SD of 0.67°C of the error of the measurements, which is 0.17°C greater than that for the SureTemp oral thermometer (see Table). More specifically, the data indicate that core temperature was underestimated when this tympanic thermometer was used to measure temperature in febrile patients (mean difference from pulmonary artery core temperature = –0.17°C), although the degree of variability for temperatures measured in febrile patients was less than that for temperatures measured in afebrile patients. Note, for example, that more of the data points are within the tolerance range on the right side of the scatterplot (febrile group) than on the left side (afebrile group).

As indicated by Figure 3, the ThermoScan Ear Pro-1 thermometer delivered the least optimal performance. The points in this graph show the greatest

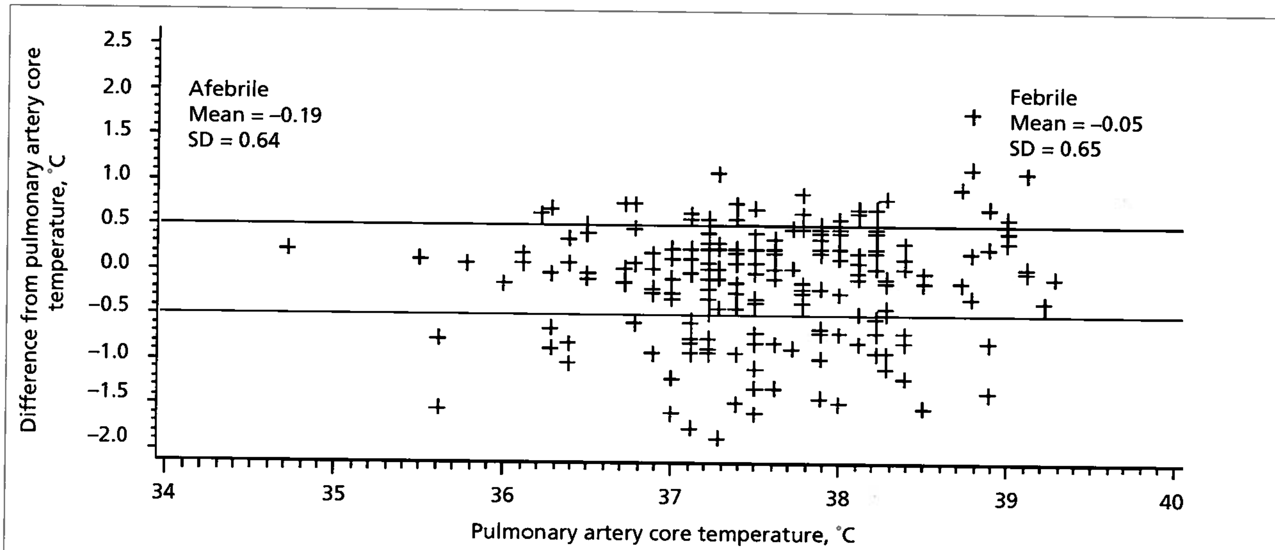

Figure 3 Differences between measurements obtained with the Thermoscan Ear Pro-1 tympanic thermometer and those obtained via a pulmonary artery catheter.

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