Body temperature measurement in paediatrics: Which gadget should we believe?

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Many decisions regarding the investigation and treatment of paediatric patients are determined by body temperature. In the 21st century, we still struggle to find a quick and convenient method that parents and health care workers can use to measure body temperature accurately.

The goal of measuring body temperature is to approximate the core temperature, which is the temperature of the blood that bathes the temperature-regulating centre in the hypothalamus. However, there is a gradient between every body site where temperature can be measured and the hypothalamus. Contrary to popular dogma, this gradient is not constant (ie, rectal temperature is not reliably 1°C higher than axillary temperature). Therefore, it is difficult to choose a body site to use as the reference standard for comparing readings obtained by different instruments or at different sites.

The following sites have been used in studies of body temperature measurement in children:

- **Pulmonary artery (PA):** This site is vascular, and it is anatomically relatively close to the hypothalamus. In adults, PA readings are only 0.18°C lower than readings from blood returning from the brain in the high internal jugular vein (1). PA catheters are usually only placed in children during cardiac surgery, but this remains the best site to use as the reference standard for core temperature in studies comparing measurements taken from other body sites and with different instruments.

- **Distal esophagus:** This site is easily accessible in sedated patients, and readings in paediatric patients are closer to PA readings than are rectal, axillary, bladder or tympanic readings (2). Therefore, this site is a good choice for temperature measurement in sedated patients or for use as a reference standard when PA readings are not practical.

- **Rectal:** Although used as the reference standard in many previous studies, the rectum is a long distance from the hypothalamus. Decreased splanchnic flow can result in falsely low readings and rectal temperature is slow to respond to changes in core temperature, especially if stool is present in the lower rectum (2,3). There is often reluctance on the part of parents and older children to measure rectal temperature, and nosocomial infections have been attributed to the use of rectal thermometers in hospital (4). There are rare case reports of rectal perforation caused by rectal thermometers in neonates and the safety of doing rectal temperatures in neutropenic patients has not been established.

- **Bladder:** Urinary catheters with thermistors are available, but the results of studies are disparate as to whether bladder temperatures are closer to PA readings than rectal temperatures (2,5). Readings may be falsely low if urine output is decreased.

- **Nasopharyngeal:** In the only paediatric study (5) to date that compared nasopharyngeal temperature with other sites, mean difference from PA temperature was 0.43°C, which was higher than the difference for bladder temperatures, but lower than the difference for rectal, tympanic or axillary temperatures. Induction of nasopharyngeal bleeding is a potential risk.

- **Axillary:** To obtain an accurate reading, the thermometer probe must be placed over the axillary artery, which is a great challenge in children. Local cooling ('drawdown') can occur from placement of the thermometer in a neonate (6). Axillary readings are expected to be lower than readings from other sites, and this appears to be the case with all types of thermometers (7). For all these reasons, fever is often not detected by axillary readings.

- **Tympanic:** Tympanic temperatures were initially measured with a probe applied directly to the tympanic membrane and were found to closely approximate the temperature in the circle of Willis (8). Infrared thermometers were then developed, and readings can be obtained within a few seconds by blindly directing the tip of the instrument toward the tympanic membrane. Readings are not affected by cerumin or

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otitis media (2). Readings tend to be closer to PA temperatures than are rectal temperatures when the patient is febrile (9) or when the temperature is changing (2,10), but the opposite is true in the steady state (11). It is difficult to gauge the accuracy of tympanic thermometers when used in a routine hospital setting. Many studies have compared readings with those taken by rectal or axillary thermometers and found tympanic thermometers to be inaccurate, but these are not ideal reference standards. One problem may be that health care workers who are not accustomed to using an otoscope may not retract the pinna sufficiently to straighten the external auditory meatus and direct the instrument at the tympanic membrane (especially in neonates). Confusion arises from the fact that some brands of tympanic thermometers have built-in offsets that attempt to estimate the core, oral or rectal temperature from the actual tympanic temperature, and operators may have them set in the incorrect mode. Even in published studies comparing rectal with tympanic temperature, the tympanic thermometer was sometimes set in an inappropriate mode (12). Tympanic thermometers are now marketed for home use, but in one study, parents did not detect 24% of fevers that were detected by nurses with the same instrument (unpublished data).

- **Skin:** Chemical thermometers can be applied to the forehead or axilla, and the temperature is read to the nearest 1°C based on colour change. Some thermometers display the actual temperature, but others contain an offset, and therefore, display the estimated core temperature. Sensitivity for detecting fever was close to 90% in some studies (13,14), but it was as low as 28% (using a different brand of thermometer) in others (15), with rectal temperatures being the reference standard. Ambient temperature can affect measurements.
- **Oral:** This site is only practical in older children, or in infants who will suck on a pacifier thermometer (16). Ingestion of hot or cold liquids and use of oxygen can all alter the results (17). Readings are consistently lower than rectal readings.

Clearly, there is not an ideal body site for measuring temperature. There is also debate about the choice of thermometer for measuring oral (mercury or electronic), rectal (mercury or electronic) and axillary temperatures (mercury, electronic, infrared or chemical). Mercury thermometers can be inaccurate, especially after prolonged storage (18). Mercury thermometers take about 7 min to equilibrate, and it can be difficult to 'shake down' the mercury between readings. Parents sometimes have difficulty reading a mercury thermometer accurately (19). The American Academy of Pediatrics now suggests their use be curtailed because of the risks of mercury poisoning (20). Electronic thermometers equilibrate in variable times (depending on if they operate in a predictive or contact equilibrium mode [4,21]), and are simple to use and read. Studies comparing electronic and mercury readings at the same body site have yielded both comparable readings (21) and readings that vary by a clinically significant amount (22). Readings from a mercury thermometer are more reproducible than readings from an electronic thermometer when repeated several times by the same operator (4), and were a mean of 0.14°C close to PA temperature than were readings from an electronic thermometer (23). However, these studies were reported in 1986 (4) and 1990 (23), and there have been improvements in electronic thermometers since then. Axillary readings from a chemical (24,25) or electronic (24) thermometer appear to be similar to readings from a mercury thermometer.

Infrared readings obtained from the temporal artery (TA) have recently been introduced into this confusing jungle of sites and technologies for measuring body temperature. If accurate, TA thermometers offer all the advantages of tympanic thermometry without the problem of the operator needing to aim the instrument blindly at the tympanic membrane. Readings obtained by parents closely match those obtained by nurses (26). The well-conducted study by Al-Mukhaizeem et al (pages 461-465) demonstrated that TA readings were as accurate as rectal readings, using esophageal readings as the reference standard. However, previous studies showed TA readings to have poor sensitivity at detecting fever, using rectal (26,27) or PA (28) readings as the reference standard. One possible explanation is that only two of the 80 children in the Al-Mukhaizeem et al study were febrile, and possibly, TA thermometers perform best in the normothermic range. It is also possible that the built-in offset in the TA thermometer needs to be adjusted if TA readings are to be interpreted as equivalent to rectal readings, or that we need to use different normal temperature ranges with TA thermometers.

Consistency in the methods by which temperatures are measured would simplify interpretation. Ideally, parents and health care workers would use the same body site and the same type of thermometer. The Canadian Paediatric Society guidelines (29) recommend the use of rectal temperature for children up to five years of age (although they mention that the American Academy of Pediatrics' guidelines recommend screening first with axillary temperature in neonates because of the risk of rectal perforation) and oral temperature in children five years of age or older. It seems likely that currently there is an available method of measuring temperature that is safer and less cumbersome than rectal temperatures, and faster and more accurate than oral temperature. Perhaps that method is TA temperature. However, there is a great need for studies that compare temperatures measured in febrile children at readily accessible body sites using mercury, electronic chemical and infrared thermometers to PA or esophageal temperatures.

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