Title: Measuring Temperature with Infrared Tympanic Thermometers versus Oral, Axillary and Rectal Thermometers for Proper Patient Management

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Context and Policy Issues:
Accurate body temperature measurement is important, particularly in neonates and immune compromised children in whom suspicion of infection could result in investigations, treatment and even hospitalization. Consequently, inaccurate temperature monitoring may result in patients remaining undiagnosed and untreated, or receiving unnecessary or inappropriate interventions. Core temperature or deep body temperature is generally defined as the temperature measured within the pulmonary artery, a sight which is not easily accessible and highly invasive. As a result, less invasive measures have been employed for routine temperature monitoring with the realization that normal body temperature varies within and between individuals and is affected by the site of measurement and type of thermometer used. For example, the range of normal adult body temperature measured peripherally is documented to range from 33.2°C to 38.2°C. Hence, controversy exists regarding the best anatomical site and most appropriate thermometer to detect temperature and ensure optimal patient management.

Types of thermometers available include mercury-in-glass, electronic, chemical, and infrared. Mercury thermometers are gradually being phased out because of concerns regarding the toxic environmental effect of mercury, toxicity from mercury absorption after thermometer breakage, and risks of cross infection. In fact, because mercury is an environmental hazard and the accuracy of digital thermometers is comparable with traditional mercury thermometers, the Canadian Paediatric Society no longer recommends the use of mercury thermometers. Infrared thermometers consist of an infrared probe which collects and transforms emitted infrared energy into electrical energy which is displayed as a temperature. Because infrared thermometers determine the temperature of infrared emissions from a source rather than absorbing heat from a tissue and reaching thermal equilibrium with it, temperatures can typically be obtained in less than 5 seconds.

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Common, accessible, measurement sites include the mouth, axilla, rectum or ear.\(^5\) Oral temperature is measured in the sublingual pocket on either side of the tongue’s frenulum.\(^5\) Disadvantages of oral thermometry include: the influence of recently ingested food or drink,\(^4,5,9\) mouth breathing,\(^4,9\) smoking, crying, hypertension,\(^3\) hot baths and exercise;\(^4\) reliance on the mouth remaining sealed with the tongue depressed for 3 to 4 minutes limiting its use in young children or unconscious or uncooperative patients;\(^4,5,9\) variation in temperature recorded depending on exactly where the bulb of the thermometer is placed;\(^4\) the possibility of cross-infection;\(^4\) and facial injuries may affect blood flow or prohibit use due to pain or discomfort.\(^11\) Axillary thermometry is considered convenient, but inaccurate in adults.\(^5\) Reported disadvantages include: supervision to ensure maintained proper placement over the axillary artery;\(^4,9\) requiring more time than rectal or sublingual measurement;\(^4\) failing to detect fever because the intense peripheral vasoconstriction, which accompanies the onset of fever, may cause skin temperature to cool while core temperature rises;\(^4\) the effect of sweating and evaporation which can cause axilla temperature to be lower than core temperature;\(^4\) being influenced by environmental conditions;\(^9\) and its reported poor sensitivity to detect fever.\(^4\) Nonetheless, it is recommended by the American Academy of Pediatrics as a screening test for fever in neonates because of the risk of rectal perforation with rectal thermometry.\(^9\) Rectal thermometry is considered the most accurate non-percutaneous indicator of core body temperature\(^5,9,10,12-14\) but has the following reported limitations: a lagged response to changes in core body temperature;\(^4,9,12,14,15\) being affected by depth of measurement, conditions affecting local blood flow and the presence of stool;\(^4,9\) the possibility of rectal perforation and cross-contamination;\(^4,5,9\) the uneasiness of patients and their carers;\(^9\) being painful for patients with perirectal infection or irritation;\(^4,5\) and the requirement for privacy and substantial time.\(^4,5,12\) Tympanic thermometry has been advocated for several reasons. First, the tympanum receives a portion of its blood supply from the same vasculature that supplies the hypothalamus, the thermoregulatory centre of the body. This may result in the tympanic membrane temperature correlating closely with core body temperature,\(^4,5,9,16\) although this shared blood supply has been described as insignificant.\(^11\) Second, its fast and easy to use\(^1,2,4,12\) without risk of cross-infection.\(^2,4,10,12\) Third, it is not directly affected by respiration, food intake, or smoking.\(^5\) Fourth, it does not require the removal of clothing.\(^12\) Fifth, it is acceptable to both patients and clinicians.\(^17\) Finally, because estimates of core temperature measured at different body sites will vary, manufacturers build in conversion scales or offsets which convert the temperature measured at the ear to one that would be obtained at a more conventional site, such as the mouth or rectum.\(^9,10,16,18\) Notwithstanding these advantages, limitations have been reported. First, the infrared technology used in tympanic thermometers has a wide angle of view and limited depth of penetration into the auditory canal making the documented temperature an average of the auditory canal and tympanum temperature. Like any other body region, the temperature of the auditory canal is affected by local metabolism, the temperature of the arterial blood supply, heat flow to adjacent tissues, and environmental factors. Thus, the temperature of air within the canal may be as much as 3°C below core temperature. As a general rule, the deepest portion of the ear canal is the most stable and most closely reflects the tympanic membrane temperature and thus core temperature. Consequently, poor penetration, improper aiming, and obstruction will result in lower temperature measures.\(^5,10\) Second, in adults, the ear canal has a definite S-shape\(^11\) which has resulted in the application of an “ear tug” when using infrared thermometers, but there is inconsistency with respect to whether or not an ear tug is used and, if used, the direction of the pull.\(^18\) Third, although the canal is straighter in children it is also narrower.\(^11\) The average diameter of the meatus in young children (4mm at birth and 5mm at two years) can limit adequate penetration by the infrared probe.\(^9\) Hence, the field of view in the neonate may also include some surface skin in addition to the ear canal and tympanic membrane, but the more uniform temperature of neonates minimizes this limitation.\(^10\) Fourth, improper use of the tympanic thermometers with respect to application of the probe...
cover and cleaning of the probe lens could result in inaccurate measures of temperature.\textsuperscript{10,19} Finally, there is also debate as to whether the presence of ear wax or significant pathology, such as chronic inflammatory change or grommets, interfere with recording of tympanic temperature.\textsuperscript{11}

Temperature measurement should accurately reflect core body temperature in all age groups; be convenient, easy, and comfortable for patient and practitioner; not cause embarrassment; give rapid results; not result in cross-infection; not be influenced by ambient temperature or local blood flow; be safe; and cost-effective.\textsuperscript{4,11,14} Additional considerations include the equipment being reliable and traceably standardized; consistency of measures from bilateral sites; the presence of a sufficiently large population-based data pool on which to base population norms and standard deviation; and scientifically researched cut points for clinically relevant conditions such as hypothermia and fever.\textsuperscript{11} This HTIS report evaluates the empirical evidence regarding the adequacy of infrared tympanic thermometry with respect to the above criteria. Note that the tympanic thermometry discussed in this report is different from direct tympanic thermometry in which measurements are made by an electronic probe in direct contact with the tympanum.\textsuperscript{20}

Research Questions:

1) How does the accuracy and precision of infrared tympanic thermometry compare with oral, axillary and rectal thermometry in clinical populations?

2) What are the Canadian and international guidelines for taking temperature?

Methods:

A literature search was conducted on key health technology assessment resources, including PubMed, The Cochrane Library (Issue 2, 2007), University of York Centre for Reviews and Dissemination (CRD) databases, ECRI’s HTAIS and Health Devices Gold, EuroScan, international HTA agencies, and a focused Internet search. Results include English language publications from 2002 to date. Links to online full-text are provided when available.

Summary Of Findings:

Health Technology Assessments

One health technology assessment,\textsuperscript{5} completed by the US Institute for Clinical Systems Improvement in 1995, was identified. The assessment was based on a critical review of studies assessing the safety and efficacy of tympanic membrane thermometry and was completed primarily by physicians and a registered nurse. It concluded that tympanic thermometry is helpful in the outpatient and inpatient environment when measures of body temperature are useful to the clinical evaluation but not critical to clinical decisions. Specifically, tympanic thermometry should not be used in patients requiring a precise measure of body temperature or in patients with significant clinical toxicity or possible sepsis by clinical evaluation, particularly in infants under the age of 60 days. Furthermore, since proper technique is important in obtaining accurate readings, the authors stated that adequate training must be provided to medical professionals who use such devices. Interestingly, this technology assessment report was inactivated in April 2005 because the technology was perceived as having low utilization, being no longer applicable to the general medical community, and lacking substantial literature over the past five years. However, the volume of literature identified in this limited review suggests otherwise.
Systematic Reviews or Meta-analyses

One meta-analysis published in 2002 was identified. It investigated agreement between infrared devices measuring temperature in the ear and electronic, mercury, or indwelling thermocouple devices measuring temperature in the rectum of children aged 0-18 years in a variety of environments ranging from general practice to intensive care. Exclusion criteria included children with hypothermia (rectal temperature <35.0°C) and pre-term infants (born at <37 weeks gestation). A total of 26 studies (n=4,441) were included in the meta-analysis producing a pooled mean temperature difference (rectal minus aural) of 0.29°C (95% limits of agreement (LOA): -0.74°C, 1.32°C). The 95% LOA provide an interval within which 95% of the differences between measurement methods would be expected to lie whereas a 95% confidence interval (CI) would provide an interval within which the true pooled mean temperature difference would be expected to lie with 95% confidence. Subgroup analyses by ear device mode revealed the following pooled mean differences (95% LOA): actual 0.70°C (-0.20°C, 1.6°C), tympanic 0.62°C (-0.40°C, 1.64°C), rectal 0.15°C (-0.95°C, 1.25°C), core 0.25°C (-0.78°C, 1.27°C), oral 0.34°C (-0.86°C, 1.54°C), and mode undefined 0.32°C (-0.57°C, 1.21°C). An examination of the impact of age, which included 2,611 children, did not reveal an association between age and the rectal-aural temperature differences (no data reported). Methodological or reporting limitations detailed by Craig et al. included: verification bias (selecting out participants on the basis of a temperature measurement); treatment paradox (initiating treatment before all temperature measurements are complete); failure to ensure the two measurements are carried out independently of each other; lack of clarity about whether all children had both tests; delays between the two measurements; and failure to report thermometer placement time, placement depth of rectal thermometer, and thermometer calibration. The authors concluded that although the pooled mean differences between rectal and ear temperature measurements were small, the wide LOA indicated that ear temperature was not a good approximation of rectal temperature, even when the ear thermometer was used in the rectal mode. Thus, ear thermometry should not be used in situations where body temperature needs to be measured with precision. In a subsequent publication utilizing the same studies, Dodd et al. evaluated diagnostic accuracy by examining the sensitivities and specificities available in 23 studies (n=4,098 children). For the majority of studies, 38°C was defined as the cut-off for fever for both rectal and tympanic temperatures. Using the rectal temperature as the standard, pooled estimates (95% CIs) for sensitivity and specificity were 63.7% (55.6%, 71.8%) and 95.2% (93.5%, 96.9%), respectively. Thus, infrared ear thermometry would fail to diagnose fever in 3 to 4 of every 10 febrile children. The authors concluded that the diagnostic inaccuracy may arise from the lack of clarity regarding appropriate use of the various modes available, and that standardization of offsets across manufacturers and guidance on appropriate use of modes is needed before ear thermometry can be considered accurate.

Guidelines

Two recent guidelines on temperature measurement in children were identified. In February 2007, the Canadian Paediatrics Society (CPS) reaffirmed a position statement regarding temperature measurement. Position statements are developed by an expert CPS committee, reviewed by the CPS board of directors, and posted after publication in the CPS peer-reviewed journal. For children 2 years of age or younger, the CPS recommends the axillary method be used for screening and the rectal method be considered definitive. For children older than 2 years and up to 5 years old, the axillary or tympanic measures should be used for screening and the rectal method be considered definitive. Finally, for children older than 5 years, the axillary or tympanic method should be used for screening and the oral method be considered
definitive. With respect to conversion scales or offsets for tympanic thermometers, it was stated that most researchers advise eliminating these adjusted modes and simply comparing the unadjusted ear temperature to the normal aural temperature range (35.8°C to 38°C).

Guidelines on how to measure fever were also included in a National Institute for Health and Clinical Excellence guideline on assessment and initial management of children (≤ 5 years old) presenting to health services with a feverish illness. A group, consisting primarily of paediatric health professionals, developed and refined the guidelines using systematic review of published research (up to 1 Sep 2006), the Delphi method in the absence of substantial evidence, and an external review by stakeholders and independent reviewers. It was recommended that oral or rectal routes should not routinely be used to measure body temperature in children aged 0 to 5 years. Rather, infants less than 4 weeks old should have temperature measured with an electronic thermometer in the axilla. In children aged 4 weeks to 5 years, healthcare professionals should measure body temperature using an electronic or chemical dot thermometer in the axilla or an infrared tympanic thermometer.

**Comparison Studies**

Sixteen comparison studies involving infrared tympanic thermometry in a variety of health service environments ranging from primary care to intensive care were identified and are detailed in the appended Table. Five of these studies involved adults, and eleven involved children.

**Tympanic Thermometry in Adults**

Two of the five adult studies involved comparisons between tympanic and pulmonary artery catheter temperatures. In a study of 110 intensive care unit patients, Moran et al. found that pulmonary artery temperatures were more consistent with mercury-in-glass axillary temperatures (mean difference (95% LOA) = 0.295 (-0.424°C, 1.014°C)) than tympanic temperatures (0.358°C (-0.560°C, 1.276°C)). Moran et al. proposed that the poor performance of the tympanic measures relative to the pulmonary artery measures may indicate that changes in tympanic membrane blood flow may reflect that of other peripheral sites in the critically ill. Specifically, the peripheral vasoconstriction that occurs with inotropes and some forms of shock may occur in the tympanic membrane. They concluded that tympanic membrane measurements could not be used as accurate measures of core body temperature in the critically ill. In a smaller study of 25 intensive care unit patients, Farnell et al. found that pulmonary artery catheter temperatures were more consistent with axillary and tympanic temperatures obtained with a chemical thermometer (mean difference (95% LOA) = 0.2°C (-0.5°C, 0.9°C)) than tympanic temperatures (0.0°C (-1.2°C, 1.2°C)). With respect to clinical errors, 15.3% and 21.1% of axillary and tympanic temperatures, respectively, might have resulted in delayed intervention. Similarly, 28.8% and 37.8% of axillary and tympanic temperatures, respectively, might have resulted in unnecessary or inappropriate intervention. Farnell et al. concluded that the chemical thermometer was more accurate, associated with fewer clinically important temperature differences, and would produce fewer occurrences of delayed or inappropriate interventions relative to the tympanic thermometer.

One study compared tympanic and rectal temperatures in 95 acute stroke unit patients. Greater agreement within than across methods (95% LOA = (-0.8°C, 0.7°C)) was found. Christensen and Boysen concluded that if one accurate reading is all that is required for clinical decision making, mercury-in-glass rectal temperature probably remains the method of choice, but if serial measurements are performed, as in acute stroke patients, the accuracy of tympanic thermometry is satisfactory.
Two studies compared tympanic and oral temperatures. In 200 emergency room attendees, Rajee and Sultana found greater agreement within tympanic measures than between tympanic and mercury-in-glass oral temperatures (mean difference (95%LOA)=0.0°C (-1.0°C, 1.1°C)). With fever defined as a temperature of 38°C or greater measured orally, sensitivity and specificity of tympanic thermometry was 60% and 97% respectively. In 100 adult surgical patients, Lo et al. found greater agreement between tympanic and oral temperatures in afebrile patients (mean difference (95%LOA)= 0.018°C (-0.52°C, 0.56°C)) than febrile patients (0.24°C (-0.43°C, 0.9°C)). They concluded that mercury-in-glass oral thermometry should not be replaced with tympanic thermometry.

Tympanic Thermometry in Children

Only one paediatric study used an invasive surrogate measure of core temperature to evaluate the accuracy of tympanic thermometry. In 36 children (mean age=20 months) admitted to paediatric and cardiac intensive care units at a children’s hospital, tympanum, rectum and axilla temperatures were compared with bladder temperature. Fever was defined as a bladder temperature of 100.4°F (38°C) or greater. Bladder temperatures agreed more closely with tympanic temperatures (mean difference (± 2 sd)=-0.03 (1.43)°F, sensitivity=80%, specificity=81%) than with rectal temperatures (-0.62 (1.44)°F, sensitivity=67%, specificity=93%) and axillary temperatures (-1.25 (1.73)°F, sensitivity=40%, specificity=98%). Nimah et al. discouraged the use of axillary thermometry in critically ill children and stated that tympanic thermometry was accurate, reliable, practical and a less invasive substitute for bladder or rectal measurements.

Six paediatric studies involved comparisons between rectal and tympanic temperatures. In 106 infants attending an accident and emergency department, El-Radhi and Patel compared tympanic and axillary temperatures to those obtained rectally. Agreement between rectal and tympanic temperatures appeared greater in both afebrile children (mean difference (range)=0.38°C (0.25°C, 0.50°C) and febrile children (0.42°C (0.27°C, 0.58°C)). For infants with a rectal temperature of 38°C to 38.9°C, sensitivity was 76% and 24% for tympanic and axillary measures, respectively. Similarly, for infants with a rectal temperature greater than 38.9°C, sensitivity was 100% and 89%, respectively. El-Radhi and Patel concluded that tympanic thermometry was more accurate than axillary thermometry and offered additional practical benefits. In 145 children (median age=40 months) admitted to hospital with severe malaria, Musumba et al. compared rectal temperatures to tympanic temperatures (mean difference (95% LOA)=0.42°C (-1.6°C, 2.44°C)) and axillary temperatures (0.74°C (-0.85°C, 2.33°C)). They concluded that in children with severe malaria, tympanic temperatures were a more accurate reflection of core temperatures at admission and should be preferably used where available. In 120 febrile children (mean age=4.4 years), Sehgal et al. compared rectal and tympanic temperatures in 60 children with signs and symptoms of meningitis (mean difference (sd)=0.8 (0.5)°C, p=0.001) and 60 children without (0.1 (0.1)°C, p>0.05). When examining a range of rectal temperature cut-points to define fever (38°C to 40°C), tympanic thermometry had a sensitivity of 100% throughout and specificity peaked at 89% when using 39.5°C as the cut-point. Sehgal et al. concluded that tympanic thermometry can reliably predict core temperature over a wide range of readings. In 41 children (mean age=5.9 years) admitted to a general paediatric ward of a children's hospital or presenting with fever to one of three participating general practices, van Staaij et al. compared rectal temperature to tympanic temperature obtained with the thermometer in oral mode. An analysis of variance revealed no statistically significant differences between rectal, right tympanic, or left tympanic temperatures. Right tympanic and rectal temperature differed by more than 0.5°C in 10 children with the maximum difference being 1.78°C. When fever was defined as a rectal temperature of 38°C or greater, sensitivity and specificity were 93.3% and 92% respectively. van Staaij et al.
concluded that tympanic membrane temperature measured by the Braun Pro 3000 accurately reflects rectal temperature and validly assesses the presence of fever in children. In 198 children (mean age=1.3 years) attending a hospital-based primary care practice for “well child” visits or acute illness, Jean-Mary et al.\(^2\) compared rectal temperatures with aural temperatures (mean difference=-0.24°F, p<0.01, sensitivity=68.3%, specificity=94.8%) and axillary temperatures (-0.33°F, p<0.01, sensitivity=63.5%, specificity=92.6%), both obtained with infrared thermometers in oral mode. For the sensitivity and specificity estimates, fever was defined as a rectal temperature of 100.4°F or greater and an aural or axillary temperature of 99.4°F or greater. Jean-Mary et al.\(^2\) concluded that for a healthcare visit in the outpatient setting, use of either of these devices is an appropriate screening tool, but if the history or physical examination raise concerns for possible febrile illness, the rectal value should be used for the purpose of clinical accuracy. Finally, in 110 children (mean age=7.7 years) seen in the emergency room, Kocoglu et al.\(^2\) compared rectal temperatures with tympanic temperatures (mean difference (sd)=0.17 (0.37°C), p<0.01) and axillary temperatures (0.72 (0.36°C), p<0.01). Using a rectal temperature greater than 38.3°C as the cut-point for fever, 5 of the 33 febrile children were not identified by either tympanic or axillary measures. It is difficult to accept the conclusions of Kocoglu et al.\(^2\) because of the questionable statistics presented in the paper and the apparently faulty interpretation of the results. For example, the authors state there was no statistically significant difference between the three temperature measurement modalities when, in fact, paired t-tests did indicate statistically significant differences (p<0.01).

Three paediatric studies involved comparisons between tympanic and axillary temperature. In 102 hospitalized children (mean age=4.6 years), Devrim et al.\(^2\) compared axillary temperatures (fever defined as >38.3°C) with those obtained with a clinical tympanic thermometer (mean difference (95% LOA)= -0.74°C (-1.75°C, 0.27°C), sensitivity=95%, specificity=96%) and a home tympanic thermometer (-0.14°C (-1.27°C, 0.98°C), sensitivity=69%, specificity=85%). Devrim et al.\(^2\) concluded that home tympanic thermometer measurements could be used for screening but not to decide patient follow-up. The authors did not delineate how the clinical and home tympanic thermometers differed but a web-based search (conducted by the HTIS) indicated that the clinical model was larger and heavier, had multiple modes available, had greater reported accuracy, provided a larger number of measures per battery, allowed for storage of probe covers in a mountable base, and had a longer warranty. In 40 to 50 children (mean age=9.2 years) undergoing bilateral myringotomy with at least one grommet insertion, Pandey et al.\(^2\) found no statistically significant mean differences pre-operatively (36.8°C vs 36.4°C) or post-operatively (36.7°C vs 36.2°C). Pandey et al.\(^2\) concluded that aural and axillary measurements are comparable both pre- and post-operatively, and that the accuracy of infrared thermometry is not affected by recent minor ear surgery. In 116 preschool children presenting to one of eight practices, Hay et al.\(^17\) concluded that the mean difference and 95% LOA (1.18°C (-0.73°C, 3.09°C)) were too large for the evaluated tympanic thermometer to replace the mercury thermometer in normal clinical practice, and that tympanic thermometry was poor at detecting febrile children defined as having an axilla temperature of 37°C or greater (sensitivity=15%, specificity=98.6%).

Finally, in 60 children recruited from a general paediatric clinic, emergency department, and inpatient unit of a children’s hospital, Robinson et al.\(^2\) compared three types of tympanic measures: parent with home tympanic thermometer, nurse with home tympanic thermometer, and nurse with hospital tympanic thermometer. Fever was defined as a temperature of 38.5°C or greater measured by the nurse using the hospital thermometer. When comparing parent and nurse measurements using the home thermometer, the mean absolute difference was 0.44°C with 33% of differences being 0.5°C or greater. When comparing the parent and nurse using the hospital thermometer, the mean absolute difference was 0.51°C, 72% of the differences...
were 0.5°C or greater, sensitivity was 76%, and specificity was 95%. When comparing the nurse measures with the home and hospital thermometer, the mean absolute difference was 0.24°C, 13% of the differences were 0.5°C or greater, sensitivity was 94%, and specificity was 88%. Robinson et al. concluded that readings obtained by parents with a home tympanic thermometer often differ by a clinically important amount (≥5°C) from readings obtained by a nurse.

**Limitations**
Several limitations should be acknowledged when interpreting the above studies. First, 13 of the 16 studies reviewed utilized a peripheral temperature measurement when evaluating tympanic thermometry. Since limitations have been identified in these peripheral sites, the appropriateness of the comparisons could be questioned. Second is the lack of details regarding thermometer calibration, temperature measurement methods, such as depth of penetration, placement time, mode used, or "ear tug" use, and whether measures were concurrent or sequential and the time to complete all measures. Third is the lack of otoscopic examination or reporting thereof. Fourth is the lack of information regarding or lack of blinding across temperature measurement sites and during repeated measurements at the same site. Fifth is the relatively small sample sizes, i.e. less than 50 in some studies. Sixth is the low participation rates or lack of information regarding participation rates and potential selection bias. Seventh is the substantial loss to follow-up or missing data. Finally, is the lack of acknowledgement of multiple measurements from the same patient in the analysis.

**Conclusions and Implications for Decision or Policy Making:**
Inaccurate temperature monitoring may result in patients remaining undiagnosed and untreated, or receiving unnecessary or inappropriate interventions. Since core or deep body temperature measurement is invasive, clinicians and caregivers use a variety of measurement devices at a variety of anatomical sites in order to accurately assess this vital sign. The speed, ease of use, safety and acceptability of tympanic thermometry combined with its imperviousness to such factors as respiration, food intake, and smoking, makes it preferable to the more conventional methods of temperature assessment. The identified health technology assessment and systematic review both concluded that tympanic thermometry should not be used in situations where body temperature needs to be measured with precision. Similarly, the two identified guidelines targeting paediatric populations consider tympanic thermometry useful as a screening tool although the lower age limits for use vary between the CPS position statement and the National Institute for Health and Clinical Excellence guideline. Recently published comparison studies indicate that axillary thermometry may be more accurate than tympanic thermometry when using pulmonary artery catheter measures as the reference in adult intensive care unit patients. Furthermore, comparisons of tympanic temperatures with other peripheral temperatures in hospitalized or emergency room adult patients have demonstrated clinically important temperature differences. Conversely, in paediatric samples, tympanic thermometry was found more accurate than rectal and axillary thermometry when using bladder temperatures as the reference in an intensive care unit study. Similarly, when using rectal temperatures as the reference, tympanic thermometry appeared more accurate than axillary thermometry. Nonetheless, LOA and sensitivity estimates have revealed clinically important differences between tympanic and rectal temperatures and tympanic and axillary temperatures. With respect to temperature assessment by caregivers, there is evidence to suggest that home tympanic thermometers are less accurate than clinical tympanic thermometers in paediatric populations and that readings obtained by parents with a home
tympanic thermometer often differ by a clinically important amount ($\geq 0.5^\circ C$) from readings obtained by a nurse using the same thermometer.\textsuperscript{2}

Although the reported limitations in the reviewed literature are numerous, the empirical evidence presently suggests that infrared tympanic thermometry could be used as a screening tool to provide caregivers and clinicians additional useful information, but not when a precise estimate of core temperature is needed for critical decision-making. However, this conclusion is based primarily on comparisons with temperatures obtained at peripheral anatomical sites, many of which have their own limitations. Perhaps it is unrealistic to expect exact agreement between tympanic temperatures and temperatures obtained at peripheral sites or core temperatures. Infrared tympanic thermometry would probably be of greater clinical use if there was a greater volume of population-based data to provide population norms and scientifically researched cut points for clinically relevant conditions such as hypothermia and fever.\textsuperscript{11}

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<td>Devrim et al. 2007</td>
<td>-102 (47 girls, 55 boys) hospitalized paediatric patients between Dec 1, 2004 and Mar 1, 2005 -mean age (range)= 4.6 years (1 day to 16 years), 54% male -a total of 886 temp sets were obtained -exclusion criteria: unstable conditions, anatomic abnormalities that would effect temp measurement</td>
<td>-reference: axillary measure with mercury-in-glass thermometer -comparisons: clinical infrared tympanic temp (First Temp Genius) and home infrared tympanic temp (Microlife IR 1DA1) -axillary region was dried with towel before measurement; the mercury thermometer was shaken before each recording to decrease its temp below 35°C; thermometer was left in place for 5 min -for tympanic measures, the pinna was pulled backward or backward and up depending on the thermometer model and age of child, the probe directed toward the eye, and maintained in position until the triple beep was heard -all measurements were performed by the same trained nurse -fever was defined as axillary temp&gt;38.3°C</td>
<td>-clinical tympanic vs axilla: mean Δ (95% LOA)=-0.74 (-1.75, 0.27); Sen=95%; Spec=96% -home tympanic vs axilla: mean Δ (95% LOA)=-0.14°C (-1.27, 0.98); Sen=69%; Spec=85%</td>
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<td>Moran et al. 2007</td>
<td>-110 patients admitted to intensive care during a seven month period -58.2% male, mean (sd) age=64.6 (15.9) years -659 PA, 2165 tympanic, 1761 urinary, and 2118 axillary temp were obtained -exclusion criteria: &lt;18 years of age; declined participation; insertion of urinary catheter not clinically indicated -measures obtained by 90 on duty clinical nurse observers trained via in-service education to ensure standardization of technique</td>
<td>-reference: PA temp measured with Baxter Pulmonary Artery Catheters -comparisons: bilateral tympanic with Sherwood Medical First Temp, urinary bladder temp measured with a thermistor foley catheter (Bard temperature-sensing urinary catheter), and bilateral axillary with glass mercury thermometers (Livingstone AS2190-1978 C) -bilateral tympanic measured concurrently in core mode using the ear-tug method (pulling the pinna upward and backward) -bilateral axillary temp measured concurrently, thermometer positioned for 5 minutes -ambient temp was measured twice daily to maintain a temp between 21°C and 22°C</td>
<td>- tympanic vs PA (n=648): mean ∆ (sd)=0.358 (0.469) °C; 95% LOA =(-0.560°C, 1.276°C); LCC*=0.77; Pearson’s r=0.841 -urinary vs PA (n=355): mean ∆ (sd)=0.052 (0.327) °C; 95% LOA =(-0.694°C, 0.589°C); LCC=0.92; Pearson’s r=0.923 -axillary vs PA (n=634): mean ∆ (sd)=0.295 (0.367) °C; 95% LOA =(-0.424°C, 1.014°C); LCC=0.83; Pearson’s r=0.889 -linear mixed effects regression modelling, which accommodated the dependency of multiple measures from the same patient, produced consistent conclusions</td>
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<td>El-Radhi &amp; Patel 2006</td>
<td>-106 infants attending an accident and emergency department</td>
<td>-reference: rectal thermometry (device not stated) -comparisons: tympanic thermometry (Thermoscan Pro-3000) and axilla with electronic thermometer (IVAC) -fever was defined as a rectal temp≥38°C, axillary temp≥37.5°C, and a tympanic temp≥37.6°C -body temp was measured in the daytime</td>
<td>-tympanic vs rectal (all infants): Pearson’s r=0.87 (p&lt;0.0005) -tympanic vs rectal (afebrile): mean Δ (range)= 0.38°C (0.25°C, 0.50°C) -tympanic vs rectal (febrile): Pearson’s r=0.83 (p&lt;0.0005); mean Δ (range)= 0.42°C (0.27°C, 0.58°C) -tympanic vs rectal: Sen=76% (infants with rectal temp 38 to 38.9°C); Sen=100% (infants with rectal temp&gt;38.9°C) -axilla vs rectal (all infants): Pearson’s r=0.69 (p&lt;0.0005) -axilla vs rectal (afebrile): mean Δ (range)= 1.11°C (0.92°C, 1.31°C) -axilla vs rectal (febrile): Pearson’s r=0.67 (p&lt;0.0005); mean Δ (range)= 1.58°C (1.37°C, 1.80°C) -axilla vs rectal: Sen=24% (infants with rectal temp 38 to 38.9°C); Sen=89% (infants with rectal temp&gt;38.9°C) -tympanic thermometry was 5 times faster than axillary thermometry</td>
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<td>Nimah et al., 2006</td>
<td>-children &lt;7 years old who had indwelling bladder catheters inserted after admission to the paediatric and cardiac intensive care units at a children’s medical hospital centre between Oct 2000 and Oct 2002 -mean age (sd) = 20.0 (18.6) months, mean weight (sd) = 9.9 (4.4) kg, 58% male -exclusion criteria: induced hypothermia, overhead warming, diabetes insipidus, urine output &lt;1ml/kg/hr, otitis externa, drainage from either ear, mastoiditis, hearing aid in measurement ear, contraindications for rectal probe placement, anatomic abnormalities that would affect temp measurement at the ear/forehead/axilla/rectum, platelet count of &lt;50,000/µL, neutrophil count of &lt;500/µL</td>
<td>-reference: bladder temp measured using the indwelling RSP Foley Catheter with 400 Series thermistor -comparisons: tympanic temp measured with Braun Thermoscan IRT 3020 and IRT 3520, rectal temp measured with an indwelling Mon-a-therm rectal probe, forehead temp measured with Philips Sensor-Touch temple thermometer, and axillary temp measured with a Turbo-Temp Digital thermometer -all thermometers were calibrated by manufacturers -for tympanic temp ear tug was used (posterior in children &lt; 1 year of age, and superiorly and posteriorly in older children); the probe was placed snugly into the external auditory canal -forehead and axillary temp measurement was executed as per manufacturer instructions -for rectal measures the tip of the probe was inserted 3 cm into the child’s rectum -temp were measured from all 5 sites in a rapid sequential manner (sequence not defined) -temp were recorded at least hourly and every 5 minutes after a change of at least 1°F until the temp stabilized again -two clinical research nurses, who were extensively trained, obtained all measures -fever was defined as a bladder temp of ≥100.4°F</td>
<td>-tympanic vs bladder: mean Δ (± 2 sd)= -0.03 (1.43) °F ; Sen=80%; Spec=81%; PPV=81%, NPV=79% -rectal vs bladder: mean Δ (± 2 sd)= -0.62 (1.44) °F ; Sen=67%; Spec=93%; PPV=91%, NPV=73% -forehead vs bladder: mean Δ (± 2 sd)= -0.56 (1.81) ; Sen=57%; Spec=87%; PPV=83%, NPV=66% -axilla vs bladder: mean Δ (± 2 sd)= -1.25 (1.73); Sen=40%; Spec=98%; PPV=96%, NPV=61% -findings were similar for specific measurement periods such as increasing temp, decreasing temp, and plateaus</td>
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| Pandey et al. 2006 | -40 or 50 children (publication unclear) undergoing bilateral myringotomy with at least one grommet insertion  
- age ranged from 3 to 16 years (mean=9.2 years)  
- exclusion criteria: children requiring the administration of topical drops | - reference: axillary temp with digital thermometer (Accu-Beep-Becton)  
- comparison: bilateral tympanic temp with First Temp  
- axillary and tympanic temp were measured at admission and 30-45 minutes post-operatively on the recovery ward | - tympanic and axillary temp did not ss differ pre- (mean(sd): 36.8(0.54)°C vs 36.4(0.43)°C, p>0.05) or post-operatively (mean(sd): 36.7(0.44)°C vs 36.2(0.39)°C, p>0.05) |
| Rajee and Sultana 2006 | -200 adult attendees to an ER between Dec 2003 and Mar 2004  
- mean age=54 years, range=18-91 years  
- 55% were male  
- exclusion criteria: <18 years of age, hearing aids, ear infections, wax obscuring ear drum, oral trauma, having eat or drunk within 20 min of data collection, two oral mercury temp readings below 35.5°C or above 40.4°C since NexTemp does not record beyond this range  
- 6 of the 200 patients were excluded from analysis because of obvious errors in reading the NexTemp | - reference: oral measured with mercury in glass thermometer (Handyplast)  
- comparisons: oral with chemical dot thermometer (NexTemp), and tympanic with Genius model 300A  
- NexTemp and mercury thermometers were left in place for 3 min prior to reading  
- tympanic thermometer was calibrated prior to study; brief ear examination was used to assess exclusion criteria  
- two readings were taken with each device and all were completed within 20 minutes  
- 3 different data collectors executed the different approaches for each patient and each data collector was blinded to all measures except their own  
- all data collectors were instructed regarding appropriate use of the measuring devices  
- fever defined as ≥38°C measured orally with mercury thermometer | - mercury#1 vs mercury#2: mean Δ (95%CI)=0.0°C (0.0°C, 0.1°C); 95% LOA=(-0.4°C, 0.5°C)  
- tympanic#1 vs tympanic#2: mean Δ (95%CI)=-0.1°C (-0.2°C, -0.1°C); 95% LOA=(-0.8°C, 0.5°C)  
- tympanic#1 vs mercury#1: mean Δ (95%CI)=0.0°C (-0.1°C, 0.1°C); 95% LOA=(-1.0°C, 1.1°C); Sen (95%CI) and Spec (95% CI) were 60% (26%, 88%) and 97% (93%, 99%) respectively  
- NexTemp#1 vs NexTemp#2: mean Δ (95%CI)=0.1°C (0.0°C, 0.1°C); 95% LOA=(-0.3°C, 0.4°C)  
- NexTemp#1 vs mercury#1: mean Δ (95%CI)=0.1°C (-0.1°C, 0.0°C); 95% LOA=(-0.7°C, 0.6°C); Sen (95%CI) and Spec (95% CI) were 80% (44%, 98%) and 100% (97%, 100%) respectively  
- the authors hypothesized that the negative bias for the second tympanic measure might be due to the cooling of the ear canal with the first measure |
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<td>Farnell et al(^3) 2005</td>
<td>-25 adults from one intensive care unit over a 6-month period (Jul 2002 to Jan 2003) &lt;br&gt;-mean age (sd)=65 (11) yrs &lt;br&gt;-all patients requiring a PAC over the study period were recruited &lt;br&gt;-160 temp sets were obtained from the 25 patients</td>
<td>-reference: PAC temp &lt;br&gt;-comparisons: axillary chemical thermometer (Tempa.DOT™) and tympanic thermometer in core mode (Genius™ First Temp M3000A) &lt;br&gt;-an expert panel (six senior nurses and doctors) was used to determine clinical significance of temp differences &lt;br&gt;-chemical thermometer was placed in axillary pocket for 3 minutes with dots facing torso &lt;br&gt;-tympanic and PAC temp were recorded immediately prior to removing chemical dot thermometer &lt;br&gt;-non-dependent ear was used for all temp measures; the tympanic thermometer probe was examined prior to use to ensure that the lens was clean and not damaged</td>
<td>-tympanic vs PAC: 50.9% of tympanic were within 0.4°C of PAC; Pearson’s r=0.59 (p&lt;0.0001); mean Δ (95% LOA)=0.0 (-1.2,1.2); 21.1% of tympanic readings might have resulted in patients receiving delayed interventions and 37.8% might have resulted in patients receiving unnecessary or inappropriate interventions &lt;br&gt;-axilla vs PAC: 75.2% of chemical were within 0.4°C of PAC, Pearson’s r=0.81 (p&lt;0.0001), mean Δ (95% limits of agreement)=0.2°C (-0.5°C, 0.9°C), 15.3% of chemical readings might have resulted in delayed interventions, 28.8% of chemical readings might have resulted in unnecessary or inappropriate intervention &lt;br&gt;-chemical thermometer accuracy was influenced by extraneous variables such as warming blankets and haemofiltration</td>
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<td>Musumba et al(^27) 2005</td>
<td>-145 children admitted to hospital with severe malaria &lt;br&gt;-median age 40 months</td>
<td>-reference: rectal temp taken with electronic thermometer &lt;br&gt;-comparison: tympanic temp (Thermoscan) and axillary temp with electronic thermometer</td>
<td>-tympanic vs rectal: mean Δ (95% LOA)=0.42°C (-1.6°C, 2.44°C) &lt;br&gt;-axillary vs rectal: mean Δ (95% LOA)=0.74°C (-0.85°C, 2.33°C) &lt;br&gt;-significantly greater average bias between rectal and axillary temp than between rectal and tympanic (no statistics presented)</td>
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| Robinson et al.² 2005 | -parents of 60 febrile and afebrile patients, aged 6 months to 16 yrs, from the general pediatric clinic, emergency department, or inpatient units of a children’s hospital | -reference: nurse with hospital tympanic thermometer (CORECHECK)  
-comparisons: parent with home tympanic thermometer (Braun Thermoscan), and nurse with home tympanic thermometer  
-measures were executed as per product manual  
-parents measured their child’s temp when they felt they understood the instructions  
-ignorant of the parent’s measure, the study nurse performed a measure using the same thermometer and then again using the CORECHECK  
-all readings were done in the same ear with a new probe cover  
-fever was defined as a temp ≥38.5°C obtained by the nurse using the hospital thermometer | -parent (home thermometer) vs nurse (home thermometer): mean absolute Δ (sd)=0.44 (0.61)°C; % of absolute Δ≥0.5°C=33%; results were consistent across fever status of child  
-parent (home thermometer) vs nurse (hospital thermometer): mean absolute Δ (sd)=0.51 (0.63) °C; % of absolute Δ≥0.5°C=72%; Sen (95%CI)=76% (50%, 93%); Spec (95%CI)=95% (84%, 99%); PPV (95%CI)=87% (60%, 98%); NPV (95%CI)=91% (79%, 98%)  
-nurse (home thermometer) vs nurse (hospital thermometer): mean absolute Δ (sd)=0.24 (0.22) °C; % of absolute Δ≥0.5°C=13%; Sen (95%CI)=94% (71%, 100%); Spec (95%CI)=88% (75%, 96%); PPV (95%CI)=76% (53%, 92%); NPV (95%CI)=97% (87%, 100%) |
| Hay et al.¹⁷ 2004 | -116 preschool children presenting with acute cough to eight practices during one winter | -tympanic membrane vs axilla  
-axilla temp measured with standard mercury thermometer placed in axilla for 5 minutes  
-tympanic membrane temp measured according to manufacturer instructions using an Omron Gentle Temp™ (model MC-509-E) calibrated by manufacturer prior to study  
-"ear tug" technique was used to straighten curvature of the canal  
-fever defined as temp≥37°C measured in axilla | -tympanic vs axilla: mean Δ (95% CI) = 1.18°C (0.98°C, 1.76°C); 95% LOA=(-0.73°C, 3.09°C); Sen (95%CI)=15.0% (3.2%, 37.9%); Spec (95%CI)= 98.6% (92.7%, 99.9%); PPV (95%CI)=0.75% (0.25%,0.96%); NPV (95%CI)=0.19% (0.16%, 0.22%) |

*Adequacy of infrared tympanic thermometry*
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<td>Lo et al.<strong>3</strong> 2003</td>
<td>-100 adult surgical ward patients recruited in April 2002 (50 consecutive febrile and 50 consecutive afebrile patients as determined by mercury-in-glass oral thermometer) -afebrile patients were 90% female and had an average age of 60.8 years -febrile patients were 88% female and had an average age of 60.4 years -exclusion criteria: otitis media, perforated eardrum</td>
<td>-reference: oral temperature with mercury-in-glass thermometer -comparison: tympanic temperature measured with FirstTemp Genius Model 3000A -right tympanic membrane temperature was taken by pulling the ear outward and backward and gently inserting the probe as far as possible until the ear canal was fully sealed off -mercury-in-glass thermometer with disposable cover was placed in the right sublingual pocket for 5 min -measurements were obtained by 4 trained nurses</td>
<td>-tympanic vs oral (afebrile patients): mean Δ (95% LOA) = 0.018°C (-0.52°C, 0.56°C) -tympanic vs oral (febrile patients): mean Δ (95% LOA) = 0.24°C (-0.43°C, 0.9°C)</td>
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<td>Sehgal et al. 2003</td>
<td>-120 children with fever (60 with signs and symptoms of meningitis, 60 without features of meningitis) seen in an emergency department of a children’s hospital between Nov 1999 and Apr 2000 -mean age (range)=4.4 (.5 to 9) years -exclusion criteria: children less than 6 months of age due to infrared thermometer probe size, suppurative/serous otitis media, otitis externa, moderate to large amounts of earwax, anal fissures, receiving enemas, ingestion of anti-pyretics within 6 hours of measurement</td>
<td>-reference: rectal temp with electronic thermometer -comparison: tympanic temp with Thermoscan Instant therometer IRT 1020 -rectal thermometers were pre-calibrated; probe was inserted 2 cm into the rectum and removed when an audible beep indicated calibration with body temp -tympanic thermometer undergoes self calibration before every reading; otoscopic examination was performed prior to obtaining temp; probe orientated toward contralateral eye while ear tug was applied to pinna (in children &lt; 1 year old, pull was applied posteriorly while in older children it was applied in a postero-superior direction); trigger was depressed for 2 seconds; plastic probe cover was changed with each measurement -each ear received 2 readings prior to one rectal temp; overall average tympanic temp was used in analysis -attempted to complete all readings within 5 minutes -ambient temp was maintained between 20°C-24°C -fever was defined using a range of cut-points (38°C to 40°C) measured rectally</td>
<td>-tympanic vs rectal (meningitis): Pearson’s r=0.812; mean Δ (sd)=0.8 (0.5) °C (p=0.001) -tympanic vs rectal (non-meningitis): Pearson’s r=0.994; mean Δ (sd)=0.1 (0.1) °C (p&gt;0.05) -tympanic vs rectal (all children): Sen=100% across the range of cut-points; Spec peaked at 89% using 39.5°C as the cut-point</td>
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| van Staaij et al. 2003 | -41 children were recruited by two means: those admitted to the general paediatric ward of a child's hospital or presenting with fever to one of three participating general practices  
- mean age (sd) = 5.9 (2.5) years, range 2 to 10 years, 51.2% were male  
- exclusion criteria: external otitis, otorrhea, recovery phase from an ear operation, craniofacial malformations, Down’s syndrome, coagulation disorders, rectal disorders, and severe diarrhea | - reference: rectal temp with digital thermometer (Omron MC 63)  
- comparison: bilateral tympanic temp with Braun Pro 3000 in oral mode  
- tympanic thermometers were calibrated by study personnel and faulty thermometers not used; temp taken according to manufacturer instructions; new probe cover was used for each measurement; otoscopy was performed and the presence of ear wax occluding the ear canal was noted; no attempt was made to remove ear wax from the canal; ear was pulled up and backwards (ear tug) while the probe was fit snugly into the ear as far as possible and the activation button was pressed being released when an acoustic signal was heard; temp was measured from both ears prior to the rectal temp  
- for rectal temp, a disposable sleeve was fit over the tip of the thermometer before insertion to a depth of at least 3 cm until an acoustic signal was heard  
- all measurements were performed by one of three observers trained to follow standardized procedure  
- fever was defined as 38°C and 38.5°C measured rectally | - tympanic vs rectal: ANOVA revealed no ss differences between rectal temp (mean (sd) = 38.0 (1.2) °C), right tympanic temp (38.0 (1.3) °C), or left tympanic temp (38.0 (1.3) °C); Spearman’s r was 0.89 and 0.93 for right and left tympanic temp; right tympanic and rectal differed by more than 0.5°C in 10 children (max difference = 1.78°C); when fever defined as ≥ 38.0°C, Sen (95% CI) = 93.3% (85%, 100%), Spec = 92% (84%, 100%), PPV = 87.5% (78%, 98%), NPV = 95.8% (90%, 100%); when fever defined as ≥ 38.5°C, Sen, Spec, PPV, and NPV were all 100%  
- left and right tympanic temp were highly correlated (Spearman’s r = 0.93)  
- the disparity between right and left tympanic temp was greater than 0.5°C in 3 children (max diff = 0.7°C); paired t-test showed no ss difference  
- in the 11 children with unilateral ear wax occlusions, no difference in mean tympanic temp were found between ears (statistics not provided)  
- 4% of the tympanic thermometers did not pass calibration and were rejected, reinforcing the importance of calibration to get accurate results |
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<td>Christensen &amp; Boysen\textsuperscript{22} 2002</td>
<td>-95 patients admitted to an acute stroke unit between Mar and Aug 2000 -specific age information not provided -155 temp sets were obtained from the 95 patients</td>
<td>-reference: rectal temp with mercury thermometer -comparison: tympanic with FirstTemp Genius 3000A -tympanic thermometer was calibrated by the manufacturer at regular intervals -hygienic cover and vaseline was used with rectal thermometer; placement time was two minutes; the thermometer was “put down” between measurements -all measurements performed by same nurse within 5-10 minutes</td>
<td>-rectal temp: mean=37.16°C; range 36.2°C -38.1°C; 95% LOA between two rectal temp=(-0.3°C, 0.4°C); Pearson's r between two rectal temp=0.940 (p&lt;0.001); -tympanic temp: mean=37.12°C; range 35.5°C-38.3°C; 95% LOA between two tympanic temp=(-0.4°C, 0.5°C); Pearson's r between tympanic temp=0.860 (p&lt;0.001) -tympanic vs rectal: 95% LOA=(-0.8°C, 0.7°C); Pearson's r=0.665 (p&lt;0.001) -tympanic temp tended to be lower than rectal temp at lower temp and higher than rectal at higher temp</td>
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<td>Dowding et al. 2002</td>
<td>-a convenience sample of 145 healthy university students and staff members from an acute hospital recruited over a 4 month period  -incomplete data was available for 2 subjects who were excluded from the analyses  -sample included 123 females and 20 males  -mean age (range)=33 (17 to 54) years</td>
<td>-reference: axilla temp with mercury in glass thermometer  -comparisons: oral by digital thermometer (DigiTemp), oral by disposable thermometer (3M TempaDot), axilla by digital thermometer, axilla by disposable thermometer, left ear tympanic thermometer (Genius), right ear tympanic thermometer -mercury thermometers were calibrated before the study and were left in place for 10 minutes  -Genius supplied the tympanic thermometers, associated equipment and training for data collectors; calibration occurred before the study; disposable probe covers were used to prevent cross infection  -3M TempaDot provided equipment and training for data collectors  -DigiTemp did not provide training for the electronic thermometers which were already in use; disposable probe covers were used to prevent cross-infection  -all devices were used according to manufacturer instructions  -to avoid an order effect, the order in which measurements were taken were varied  -data collectors were registered nurses or nurse teachers</td>
<td>-oral digital vs oral mercury: mean Δ=-0.27 (p&lt;0.05)  -axilla digital vs oral mercury: mean Δ=-0.34 (p&lt;0.05)  -oral disposable vs oral mercury: mean Δ=-0.41 (p&lt;0.05)  -axilla disposable vs oral mercury: mean Δ=0.13 (p&lt;0.05)  -tympanic left ear vs oral mercury: mean Δ=0.00 (p&gt;0.05)  -tympanic right ear vs oral mercury: mean Δ=-0.09 (p&gt;0.05)  -the DigiTemp thermometers were perceived as the least reliable devices with 5 of 12 devices being discarded due to problems with registering temp</td>
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<td>Jean-Mary et al. 2002</td>
<td>-large, urban, hospital-based primary care practice -198 children aged 3 to 36 months (mean=1.3 years) attending for “well child” or acute illness visits over the 5 month period of the study -exclusion criteria included: contraindications to rectal temp measurement or known hypothalamic dysfunction</td>
<td>-reference: rectal temp with Ivac digital thermometer -comparisons: axillary and aural temp measured with infrared thermometers -infrared thermometers were used as per manufacturer’s user manual -each thermometer was calibrated according to hospital protocol or user manual -since the manufacturer’s stated the axillary and aural temp reflect oral temp and the authors note that oral temp is generally considered to be 1°F less than rectal temp, the authors added 1°F to all axillary and aural values before the data were analyzed -measurements were taken sequentially by a single experienced nurse practitioner starting with the axilla and ending with the rectal measure -fever was defined as a rectal temp ≥100.4°F and an aural/axillary temp ≥99.4°F</td>
<td>-tympanic vs rectal: mean Δ=-0.24°F (p&lt;0.01); Sen=68.3%; Spec=94.8% -axillary vs rectal: mean Δ=-0.33°F (p&lt;0.01); Sen=63.5%; Spec=92.6% -multiple stepwise regression indicated that bias of axillary temp was significantly correlated with rectal temp (partial R^2=0.35, p&lt;0.01) and patient age (partial R^2=0.05, p&lt;0.01); as rectal temp increased, axillary temp underestimated rectal temp to a greater degree -multiple stepwise regression indicated that bias of aural temp was significantly correlated with rectal temp (partial R^2=0.03, p=0.03); as rectal temp increased, tympanic temp underestimated rectal temp to a greater degree -tympanic bias was ss less (p&lt;0.002) than axillary bias for afebrile children less than 1 year old and febrile children 1 to 3 years old</td>
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### Adequacy of infrared tympanic thermometry

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| Kocoglu et al. 2002 | -110 randomly selected paediatric patients seen in an ER in 1999  
- each child had temp measured in three different ways  
- mean age (sd)=7.7 (2.2) years, range was 5 to 10 years, 60% male, mean height (sd)=124.3 (13.4) cm, mean weight (sd)=25.2 (5.3) kg | - reference: rectal temp with mercury in glass thermometer  
- comparison: tympanic temp with Braun ThermoScan IRT 1020 and axilla temp with mercury in glass thermometer  
- each child was undressed and exposed to constant environment for 10 minutes prior to measurement  
- thermometer was left in place for 2 minutes for rectal temp readings  
- during tympanic measures, the pinna was pulled backwards, the probe was directed towards the eye, and the device held in place until a beep was heard; the cover of the probe was changed after each measurement  
- axillary region was dried using a towel before temp measurement and the thermometer was left in place for 5 minutes  
- mercury thermometer was shaken before each recording to decrease its temp below 35°C  
- a rectal temp above 38.3°C was defined as fever  
- same physician performed all measurements | - tympanic vs rectal: mean Δ (sd)= 0.17 (0.37)°C (p<0.01)  
- axillary vs rectal: mean Δ (sd)= 0.72 (0.36)°C (p<0.01)  
- according to rectal temp, 33 of 110 children had fever  
- 5 of the 33 children with fever were not identified by either tympanic or axillary measures  
- the position of the body and occlusion of the ear did not appear to impact tympanic measures  
- results of the first, second, and third tympanic measures on the ears were similar suggesting that multiple measures are not necessary |

Note. temp=temperature(s), minute(s)=min, LOA=limits of agreement, Sen=sensitivity, Spec=specificity, PPV=positive predictive value, NPV=negative predictive value, PAC=pulmonary artery catheter, LCC=Lin concordance correlation coefficient, Δ=difference, sd=standard deviation, CI=confidence interval, ANOVA=analysis of variance, ss=statistically significant.

*Lin concordance correlation coefficient compares agreement between two sets of measurements by assessing the variation from the 45-degree line through the origin, the line of perfect concordance.*
REFERENCES:


