

# EMERGENCY NURSING RESOURCE: NON-INVASIVE TEMPERATURE MEASUREMENT IN THE EMERGENCY DEPARTMENT

What method of non-invasive body temperature measurement is the most accurate and precise for use in patients (newborn to adult) in the emergency department?

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## Background/Significance

A patient's temperature is a critical vital sign that may be used by Emergency Department (ED) clinicians to determine the degree of illness and the need for further assessment and intervention. Accurate body temperature measurement in the ED is necessary for the timely detection and management of fever or hypothermia; as well as evaluating treatment effectiveness (Crawford, Hicks, & Thompson, 2006; Sund-Levander & Grodzinsky, 2009). Pulmonary artery (PA) temperature is considered the "gold" standard for measuring core body temperature (Fulbrook, 1993), as mixed venous blood temperature reflects thermoregulation by the hypothalamus. Other invasive methods include esophageal, rectal and bladder measurements. Rectal temperature is considered the least invasive among these invasive temperature measures, and often is assumed to approximate core temperature (Fulbrook, 1993). Noninvasive temperature measurement methods include oral, temporal artery (TA), axillary and aural [tympanic membrane (TM)] measurements (Bridges & Thomas, 2009). All types of temperature measurements have advantages and limitations related to accuracy and precision, as well as practicality and feasibility in the ED setting (Craig, Lancaster, Taylor, Williamson, & Smyth, 2002; Fadzil, Choon, & Arumugam, 2010; Farnell, Maxwell, Tan, Rhodes, & Philips, 2005; Hooper & Andrews, 2006; Lawson et al., 2007; Lawson et al., 2007). This Emergency Nursing Resource (ENR) focuses on evidence-based practices regarding temperature measurement of patients across the lifespan in the ED setting.

## Methodology

This ENR was created based on a thorough review and critical analysis of the literature following ENA's [Guidelines](#)

for the Development of the Emergency Nursing Resources. Via a comprehensive literature search, all articles relevant to the topic were identified. The following databases were searched: PubMed, Google Scholar, MEDLINE, CINAHL, Cochrane - British Medical Journal, Agency for Healthcare Research and Quality (AHRQ; [www.ahrq.gov](http://www.ahrq.gov)), and the National Guideline Clearinghouse ([www.guideline.gov](http://www.guideline.gov)). Searches were conducted using a variety of different search combinations with: temperature, measurement, methods, devices, thermometry, invasive, non-invasive, oral, rectal, tympanic, temporal, esophageal, pulmonary artery, core, body, emergency, emergency department, critical care, adults, pediatrics, children, infants and neonates. Initial searches were limited to English language articles from December 1980 – October 2011. In addition, the reference lists in the selected articles were hand searched for additional pertinent references. Research articles from ED settings, non-ED settings, position statements and guidelines from other sources were also reviewed.

Articles that met the following criteria were chosen to formulate the ENR: research studies, meta-analyses, systematic reviews, and existing guidelines relevant to body temperature measurement. Other types of articles were reviewed and included as additional information. Articles that did not include a comparison to core temperature measurements (including rectal temperature) and/or comparison to oral temperatures were not included in the evidence summary as there was no way to determine the accuracy, precision and/or bias of temperature measurements. All temperature measurement devices described in this review are currently commercially available. The ENR authors used [standardized worksheets](#), including the Reference Table, Evidence-Appraisal Table, Critique Worksheet and AGREE Work Sheet, to prepare tables of evidence ranking each article in terms of the level of evidence, quality of evidence, and relevance and applicability to practice. Clinical findings and levels of recommendations regarding patient management were then made by the Emergency Nursing Resource Development Committee according to the ENA's classification of levels of recommendation for practice, which include: Level A High, Level B. Moderate, Level C. Weak or Not recommended for practice (Table 1).

### Evidence Table and Other Resources

The articles reviewed to formulate the ENR are described in the [Evidence Table](#). Other articles relevant to temperature measurement were reviewed and identified as additional resources ([Other Resources Table](#)).

TABLE 1

#### Levels of Recommendation for Practice

##### Level A recommendations: High

- Reflects a high degree of clinical certainty
- Based on availability of high quality level I, II and/or III evidence available using Melnyk & Fineout-Overholt grading system (Melnyk & Fineout-Overholt, 2005)
- Based on consistent and good quality evidence; has relevance and applicability to emergency nursing practice
- Is beneficial

##### Level B recommendations: Moderate

- Reflects moderate clinical certainty
- Based on availability of Level III and/or Level IV and V evidence using Melnyk & Fineout-Overholt grading system (Melnyk & Fineout-Overholt, 2005)
- There are some minor inconsistencies in quality evidence; has relevance and applicability to emergency nursing practice
- Is likely to be beneficial

##### Level C recommendations: Weak

- Level V, VI and/or VII evidence available using Melnyk & Fineout-Overholt grading system (Melnyk & Fineout-Overholt, 2005) - Based on consensus, usual practice, evidence, case series for studies of treatment or screening, anecdotal evidence and/or opinion
- There is limited or low quality patient-oriented evidence; has relevance and applicability to emergency nursing practice
- Has limited or unknown effectiveness

##### Not recommended for practice

- No objective evidence or only anecdotal evidence available; or the supportive evidence is from poorly controlled or uncontrolled studies
- Other indications for not recommending evidence for practice may include:
  - Conflicting evidence
  - Harmfulness has been demonstrated
  - Cost or burden necessary for intervention exceeds anticipated benefit
  - Does not have relevance or applicability to emergency nursing practice
- There are certain circumstances in which the recommendations stemming from a body of evidence should not be rated as highly as the individual studies on which they are based. For example:
  - Heterogeneity of results
  - Uncertainty about effect magnitude and consequences,
  - Strength of prior beliefs
  - Publication bias

## Summary of Literature Review

### ACCURACY AND PRECISION OF TEMPERATURE MEASUREMENT METHODS

All non-invasive methods to measure body temperature (e.g., oral, axillary, tympanic, temporal artery) have accuracy and precision variances unique to each type of method when compared to core temperature methods (e.g., rectal temperature) (Bridges & Thomas, 2009). In evaluating accuracy and precision of temperature measurement methods, it is important to note that a clinically significant difference in temperatures between core temperature measures and other non-invasive measures is considered to be 0.5 °C (Sessler, Lee, & McGuire, 1991; Tayefeh, Plattner, Sessler, Ikeda, & Marder, 1998), as this reflects the range of normal circadian body temperatures.

### ORAL TEMPERATURE MEASUREMENT

Oral temperatures slightly underestimated core temperatures (PA), however, oral temperatures along with TA were the most accurate and precise compared to other non-invasive temperature measures (axillary and TM) (Lawson et al., 2007). Oral and TA temperatures had a mean difference from PA temperatures of  $0.09 \pm 0.43$  °C and  $-0.02 \pm 0.47$  °C respectively; as compared mean differences from PA of  $0.23 \pm 0.44$  °C (axillary) and  $-0.36 \pm 0.56$  °C (TM) (Lawson et al., 2007). Oral temperatures measured by electronic thermometry in normothermic critical care (Giuliano et al., 2000) and post-anesthetic adult patients (Calonder et al., 2010) were compared to core temperatures (either PA catheter or esophageal). Oral and mean core temperatures (PA) differed by  $-0.02$  to  $+0.5$  °C (Giuliano et al., 2000) and oral compared to core (esophageal) temperatures had a relative bias of 0.12 °C (Calonder et al., 2010); indicating oral temperatures were 0.12 °C higher than core (esophageal) temperatures. Although the differences were statistically significant, these differences were not considered clinically significant since the differences were less than 0.5 °C. An integrative review indicated concluded that oral temperature measurements closely reflected core temperature in the absence of a PA catheter, even among acutely ill patients receiving oxygen therapy (Hooper & Andrews, 2006).

### TEMPORAL ARTERY TEMPERATURE MEASUREMENT

Temporal artery temperatures measured in normothermic pediatric patients correlated well with core temperatures (esophageal or rectal) as measured using both rectal probes and electronic thermometer; correlations were  $r = 0.91$  (esophageal probe and TA),  $r = 0.95$  (rectal probe and TA) and  $r = 0.88$  (rectal electric and TA) (Al-Mukhaizeem et al., 2004). TA temperatures compared to rectal tempera-

tures in pediatric patients had similar variability (precision) with rectal ( $37.4 \pm 0.9$  °C for TA,  $37.6 \pm 1.1$  °C for core-rectal); the mean bias was  $0.17 \pm 0.78$  °C (Hebbar, Fortenberry, Rogers, Merritt, & Easley, 2005). In another study of pediatric patients (Paes, Vermeulen, Brohet, & de Winter, 2010), TA temperatures (measured using two different devices) were significantly different compared to rectal temperatures, with mean temperatures of 37.56 °C, 36.79 °C and 37.3 °C for rectal, Beurer® TA and Thermofocus® TA temperatures respectively. The TA (infrared skin) thermometer readings had varying sensitivity from low to moderate (Beurer® device = 0.12 sensitivity, Thermofocus® = 0.64 sensitivity) (Paes et al., 2010). In a study of infants under 1 year old in the ED, TA and TM temperatures were compared to rectal temperatures (Greenes & Fleisher, 2001). Temperatures were  $37.9 \pm 1$  °C for rectal,  $37.6 \pm 0.9$  °C for TA and  $37.1 \pm 0.9$  °C for TM; indicating the TA measurement was more accurate than TM temperatures compared to rectal. It should be noted that there were no significant differences in mean differences of TM or TA temperatures from rectal temperatures in these afebrile infants (Greenes & Fleisher, 2001).

In a study of normothermic post-anesthesia adult patients where TA temperatures were compared to esophageal temperatures, there were statistically significant differences ( $P < 0.05$ ) with the TA temperature mean bias of 0.07 °C compared to esophageal temperature. Although the differences were statistically significant, the differences were not considered clinically significant since the differences were less than 0.5 °C (Calonder et al., 2010). In normothermic critically ill adults, TA temperatures were not significantly different from PA temperatures; TA temperatures had a mean difference from PA of  $0.14 \pm 0.51$  °C (Myny, De Waele, Defloor, Blot, & Colardyn, 2005).

### TYMPANIC TEMPERATURE MEASUREMENT

A meta-analysis compared TM temperature measurements to rectal temperatures in pediatric patients (Craig et al., 2002). Pooled mean differences between TM and rectal temperatures was 0.29 °C, with limits of agreement ranging from  $-0.74$  to  $+1.32$  °C. This wide range of variance in the temperatures (limits of agreement) reflects the limits of precision using TM temperature measurement in this study (Craig et al., 2002). In adult critical care patients, TM temperatures were the least accurate and precise compared to PA temperatures with a mean difference of  $-0.36$  to  $+0.56$  °C, compared to TA, oral and axillary temperatures that had a mean difference from core (PA) temperatures of:  $-0.02$  to  $+0.47$  °C,  $0.09$  to  $+0.43$  °C and  $0.23$  to  $+0.44$  °C respectively (Lawson et al., 2007). Tympanic temperatures were significantly different from rectal temperatures among

hospitalized pediatric patients with mean rectal temperature of 37.56 °C compared to 37.29 °C for TM temperatures. The TM thermometry had a sensitivity of 0.8 (Paes et al., 2010). Tympanic temperatures were less accurate than axillary temperatures among adult critical care patients, as TM temperatures had a concordance with core PA temperatures of 0.77 as compared to concordance of 0.83 for axillary (mercury-in-glass) temperatures (Moran et al., 2007).

In a study of pediatric patients, ages 3 to 36 months, TM and axillary (infrared) measures were compared to rectal temperatures (Jean-Mary, Dicanzio, Shaw, & Bernstein, 2002). The TM was more accurate than axillary when compared to rectal temperatures; the TM bias was -0.24 °F (0.13 °C) and axillary bias was -0.33 °F (0.18°C). In a study of intensive care pediatric patients, comparing TM, axillary, and rectal temperatures were compared to PA temperatures (Maxton, Justin, & Gillies, 2004); TM was the least accurate compared to axillary and rectal temperatures with mean differences from core (PA) temperatures of -0.97 °C, -0.90 °C and -0.69 °C respectively.

In a study of ED patients, TM temperatures had a mean difference compared to oral (mercury-in-glass) temperature of -0.015 °C, with limits of agreement -0.88 to +0.85 °C, compared to chemical oral thermometry which had a mean difference from oral temperatures of -0.077 °C with limits of agreement from -1.14 to 0.98 °C, thus indicating TM measures were more accurate and precise than chemical oral thermometry (Fadzil et al., 2010). When TM temperatures (using measurements in both ears) were compared to oral temperature measurements in both febrile and afebrile adult ED patients the mean differences were not significant, however there were significant differences ( $P < 0.0001$ ) between older patients (65 years or older) and younger patients (under 65 years) when comparing oral to TM temperature measurements (Onur, Guneysek, Akoğlu, Aydin, & Denizbasi, 2008). Integrative review analyses concluded that there is a lack of high-quality evidence to support the accuracy of temperature measurement using TM thermometers, given the variability in the accuracy and precision of TM measurements in a number of published research studies (Hooper & Andrews, 2006).

#### AXILLARY TEMPERATURE MEASUREMENT

Axillary mean (M) temperatures were compared to rectal and PA temperatures in pediatric patients. Axillary ( $M = 37.2 \pm 0.9$  °C) and rectal ( $M = 37.6 \pm 1.1$  °C) temperatures had similar variability (precision) compared to PA temperatures; axillary measurements had a mean bias was  $0.51 \pm 0.41$  °C (Hebbar et al., 2005). Among intensive care pediatric patients, TM, axillary, and rectal tempera-

tures were compared to PA temperatures (Maxton et al., 2004). Axillary measures were more accurate than TM, but less accurate than rectal temperatures compared to PA temperatures; mean differences for axillary, TM and rectal temperature measurements were -0.90 °C, -0.97 °C, and -0.69 °C respectively.

Among normothermic critically ill adult patients, axillary temperatures differed significantly ( $P < 0.001$ ) from PA temperatures, with a mean difference of  $0.46 \pm 0.39$  °C (Myny et al., 2005). When PA temperatures were compared to axillary using gallium-in-glass (non-mercury), chemical (reactive strip) and digital measures of axillary temperatures in critically ill adults; the gallium-in-glass readings (in axilla for 12 minutes) had the most accuracy with a mean difference from core temperatures of 0.4 °C, ranging from -0.4 + 1.2 °C, compared to either the digital or chemical (reactive strip) axillary measurements (Rubia-Rubia, Arias, Sierra, & Aguirre-Jaime, 2011). In a study of adult trauma patients, axillary temperatures had a mean temperature difference from oral temperatures of 0.03 °C, with limits of agreement ranging from -1.97 to +2.03 °C, which was significantly better than TA mean differences from oral temperatures of 0.27 °C, with limits of agreement of -2.13 to +2.66 °C (Marable, Shaffer, Dizon, & Opalek, 2009).

In both febrile and afebrile adult ED patients, oral compared to axillary temperatures were not significantly different overall. However there were significant differences ( $P < 0.0001$ ) by age groups of older patients (65 years or older) and younger patients (under 65 years) when comparing oral to axillary temperature measurements (Onur et al., 2008). In a meta-analysis, comparing axillary and rectal temperatures among pediatric patients, the mean differences between rectal and axillary temperature for neonates was 0.17 °C (-0.15 °C to +0.5 °C) and 0.92 °C (-0.15 °C to +1.98 °C) among older children and adolescents (Craig, 2000). These wide limits of agreement (precision) between rectal and axillary temperatures may prevent low grade fever from being detected by axillary temperature measurement in pediatric patients.

#### CHEMICAL THERMOMETERS

A comparison of temperatures obtained by TM and chemical axillary temperature (Tempa.DOT™) methods to PA temperatures demonstrated that chemical axillary measurements (limits of agreement -0.5-0.9 °C) were more accurate than TM (limits of agreement -1.2 to +1.2 °C) (Farnell et al., 2005). When comparing chemical axillary thermometry (Tempa.Dot™ Ax.), TM and PA temperatures, both TM and axillary chemical mean temperatures were statistically different from PA temperatures ( $P < 0.05$ ). The TM measures had a mean difference from PA readings of 0.37 to

$\pm 0.32$  °C, and the axillary chemical thermometer had a mean difference from PA readings of 0.46 to  $\pm 0.45$  °C. Thus, the axillary chemical was slightly less accurate and precise than TM temperatures (Fulbrook, 1993). A different chemical temperature device (3M Tempa-Dot®) was used to obtain chemical oral and axillary temperatures and comparisons were made with oral or axillary temperatures measured with an electronic device among post anesthesia patients. All temperatures were compared to operating room (OR) core temperatures (esophageal) (Washington & Matney, 2008). The chemical temperature measurements were an average of 0.57 °F higher, compared to temperatures obtained with an electronic thermometer that were 0.48 °F lower than OR core temperatures. Both the chemical and electronic thermometer measurements were significantly ( $P < 0.001$ ) correlated with OR core temperatures, with modest correlations of  $r = 0.61$  and  $r = 0.54$  respectively (Washington & Matney, 2008).

Oral chemical (Nextemp®) temperature measurements were compared to both oral (mercury measured) and TM temperatures in adult ED patients (Rajee & Sultana, 2006). The chemical oral temperature modality was more precise than TM measurements when compared to oral (mercury measured) temperatures; with the chemical oral measurements within  $-0.6$  to  $+0.5$  °C of oral (mercury in glass) temperatures as compared to TM measurements that ranged from  $-1.0$  to  $+1.1$  °C (Rajee & Sultana, 2006). Using a chemical TA thermometer (Liquid Crystal Fever Temp Ultra®), the mean difference compared to oral (mercury in glass) temperatures was  $-0.077$  °C, compared to digital oral and oral (mercury in glass) temperatures (mean difference  $+0.049$  °C), and digital TM to oral (mercury in glass) temperatures (mean difference  $-0.015$  °C) in ED patients indicating chemical TA thermometry had less accuracy and precision than digital oral and digital TM temperatures as compared to oral (mercury in glass) temperatures (Fadzil et al., 2010).

#### TEMPERATURE MEASUREMENT TO DETECT HYPERTHERMIA

Several studies examined thermometry to detect hyperthermia in pediatric patients. In febrile (temperature than 38 °C) pediatric patients younger than 24 months, TA and rectal temperature measurements were highly correlated ( $r = 0.77$ ) (Carr et al., 2011). The mean TA temperature was  $37.59 \pm 0.82$  °C compared to  $37.56 \pm 0.82$  °C for rectal; 94.7% of the measurements differed by less than 1 °C (Carr et al., 2011). In another study of both febrile and afebrile pediatric ED patients, one to four years of age (Titus, Hulsey, Heckman, & Losek, 2009), TA temperature of 37.3 °C or greater was equivalent or com-

parable to a rectal temperature of 38.3 °C (100% sensitivity and 93.5% specificity). In febrile pediatric subjects, both TA and axillary temperatures had low sensitivity and specificity for detecting fever; neither TA or axillary temperatures were adversely influenced in the presence of shock or vasopressor use (Hebbar et al., 2005). Temporal artery (TA) temperatures of infants (age under 1 year old) with fever (rectal temperatures greater than 38 °C) or high fever (rectal temperatures greater than 39 °C) in the ED, were significantly more sensitive than TM temperatures ( $P < 0.005$ ) (Greenes & Fleisher, 2001). Professional and home models of TA measurements were compared to rectal temperatures in ED pediatric patients (Schuh et al., 2004). The TA professional thermometer accurately ruled out fever for non-febrile pediatric patients; however, it was not accurate for febrile patients (temperature over 38 °C), as accuracy was only 90%; and even lower with the home TA thermometer with an accuracy of 67% (Schuh et al., 2004). Thus, a temperature under 37.7 °C measured by the professional TA thermometer could be accurately used as a screening mechanism to exclude fever (defined as temperature over 38.3 °C rectally) in pediatric patients 3 to 24 months old (Schuh et al., 2004).

In a subsample of febrile (greater than 100.4 °F) pediatric patients ( $n = 63$ ), ages one to three years, TM and axillary (infrared) measures were compared to rectal temperatures. TM bias was  $-0.36$  °F ( $0.20$  °C) (sensitivity 68.3%, specificity 94.8%) compared to axillary bias of  $-1.2$  °F ( $0.67$  °C) (sensitivity 63.5%, specificity 92.6%), indicating that TM temperatures more closely correlated with rectal temperatures than axillary temperatures (Jean-Mary et al., 2002). Similarly, in a systematic review of studies examining ear-based infrared (TM) temperatures compared to rectal temperatures. Mean differences in temperature varied and ranged from 37.04-39.2 °C, when the rectal temperature was 38 °C (Craig et al., 2002). These findings indicate that clinician could under or overtreat fever in children based on TM temperature measurement alone.

Among febrile critical care adult patients, oral temperatures were more precise than TM temperatures when compared to PA temperatures, with a mean difference from PA temperatures of  $0.18 \pm 0.47$  °C for oral and  $-0.17 \pm 0.54$  °C for TM; thus, TM temperatures underestimated PA temperatures (Giuliano et al., 2000). Temporal artery thermometry had only moderate sensitivity to detect fever (sensitivity 0.72) among neurosurgical perioperative and critical care adult patients (Kimberger, Cohen, Illievich, & Lenhardt, 2007). Both axillary and TA temperature measurements had approximately 90% or greater agreement rate of detecting fever as measured by an oral thermometer in adult trauma patients (Marable et al., 2009).

Description of Decision Options/Interventions and the Level of Recommendation										
Temperature Measurement Device	Adult		Adult Hypo-Thermic	Adult Critically Ill /Intubated	Pediatrics 0-3 Months	Pediatrics 3 Months – 3 Years	Pediatric 3 Years – 18 Years	Pediatric Febrile	Pediatric Hypo-Thermic	Pediatric Critically Ill /Intubated
	Adult	Adult Febrile								
Oral	A	A	A	A	N/R	A	A	A	N/E	N/R
Tympanic	I/E	N/R	N/E	I/E	N/R	I/E	N/R	N/R	N/E	I/E
Temporal Artery	A	N/R	N/E	I/E	N/R	I/E	A	A*	N/E	I/E
Chemical Dot	I/E	I/E	N/E	I/E	N/R	N/E	N/R	N/R	N/E	N/E
Axillary	B	N/R	N/E	I/E	N/R	I/E	B	N/R	N/E	I/E

Level A (High) Recommendation: Based on consistent and good quality of evidence; has relevance and applicability to emergency nursing practice.

Level B (Moderate) Recommendation: There are some minor inconsistencies in quality evidence; has relevance and applicability to emergency nursing practice.

Level C (Weak) Recommendation: There is limited or low-quality patient-oriented evidence; has relevance and applicability to emergency nursing practice.

N/R: Not recommended based upon current evidence.

I/E: Insufficient evidence upon which to make a recommendation.

N/E: No evidence upon which to make a recommendation.

\*Temporal artery temperature greater than 37.3°C indicates rectal temperature of 38.3°C or greater in subjects 3-24 months (Schuh, 2004).

## TEMPERATURE MEASUREMENT TO DETECT HYPOTHERMIA

Temporal artery thermometers had more sensitivity than oral measurements compared to PA temperatures to detect hypothermia (temperature under 35 °C) in adult critical care patients (Lawson et al., 2007). Oral temperatures had a mean difference from PA of  $-0.8 \pm 0.2$  °C, compared to TA temperature mean difference from PA of  $-0.3 \pm 0.1$  °C. In another study TA temperatures had as similar level of sensitivity for detecting hypothermia (0.29 Positive Predictive value-PPV) compared to core temperature (bladder temperature measurement) (Kimberger et al., 2007). Tympanic temperatures overestimated the presence and severity of hypothermia compared to oral temperatures, with mean TM temperatures of 31.6 °C and mean of 34.3 °C for oral temperatures, based on readings of subjects who had been swimming in cold water (Rogers et al., 2007).

## ADDITIONAL INFORMATION

### *Using Rectal Temperature Measurement in ED Setting*

This ENR addressed only non-invasive temperature measurement. Given the limitations in accuracy and precision of non-invasive temperature measurements and lack of invasive core temperature measures for the ED patient (e.g., PA, esophageal, bladder), there are clinical situations (e.g., suspected fever) that warrant the use of rectal tem-

perature measurement (Jensen et al., 1994; Kresovich-Wendler, Levitt, & Yearly, 1989). Specifically, only rectal temperature measurements are recommended in children 3 months and younger, unless contraindicated (Jean-Mary et al., 2002). Rectal temperatures are contraindicated in neutropenic patients (Segal et al., 2008), and are not recommended in patients who have had rectal surgery/trauma or have diarrhea.

## Evidence Supporting the Level of Recommendation

1. Adult Temperature Measurement
  - i. Oral temperature measurement (Calonder et al., 2010; Giuliano et al., 2000; Lawson et al., 2007; Washington and Matney, 2008)
  - ii. Temporal Artery (TA) temperature measurement (Calonder et al., 2010; Myny et al., 2005)
  - iii. Axillary temperature measurement (Fulbrook, 1993; Marable et al., 2009; Myny et al., 2005; Rubia-Rubia et al., 2011; Washington and Matney, 2008)
2. Febrile Adult Temperature Measurement
  - i. Oral temperature measurement (Bridges and Thomas, 2009; Giuliano et al., 2000; Kimberberger et al., 2007; Marable et al., 2009)
3. Hypothermic Adult Temperature Measurement
  - i. Oral temperature measurement (Kimberger et al., 2007; Lawson et al., 2007, Rogers et al., 2007)

4. Critically Ill/Intubated Adult Temperature Measurement
  - i. Oral temperature measurement (Fadzil et al., 2010; Hooper & Andrews, 2006)
5. Pediatrics (0 to 3 Months) Temperature Measurement
  - i. Rectal temperature measurement (Jean-Mary et al., 2002)
6. Pediatric (3 to 18 years) Temperature Measurement
  - i. Oral temperature measurement (Fadzil et al., 2010)
  - ii. Temporal Artery (TA) temperature measurement (Al-Mukhaizeem et al., 2004; Asher and Northington, 2008; Hebbbar et al., 2005; Paes et al., 2010; Titus et al., 2009)
  - iii. Axillary temperature measurement (Maxton et al., 2004)
7. Febrile Pediatric Temperature Measurement
  - i. Oral temperature measurement (Fadzil et al., 2010)
  - ii. Temporal Artery (TA) temperature measurement (Carr et al., 2011; Titus et al., 2009)

### Glossary of Terms to Describe Temperature Measurement

**Accuracy:** The degree to which the means of a temperature method measures differ when compared to one or more other temperature method measures. Often the comparison temperature measurement method is the core temperature. Accuracy is reported as mean differences in temperature methods.

**Bias or Instrument Bias:** This term is used interchangeably with accuracy. Bias or instrument bias refers to the difference between the mean of one temperature method measures compared to the mean(s) of temperature measures using different temperature method(s).

**Preciseness/Precision:** The amount of variability (measured as the standard deviation of mean differences between temperatures) that a given temperature method measure has compared to another standard or core temperature method measure.

**Sensitivity:** Refers to the proportion of temperature method measurements that are accurate when compared to core temperature or another standard temperature method measure. This can also be used in reference to detecting fever or hypothermia. For example, high sensitivity of a given temperature method of measurement to correctly detect fever (as measured by core temperature or another standard temperature measurement method) would indicate that a higher proportion of the patients with fever would be detected by the temperature method measure of interest. In other words the temperature measurement method of interest was accurate in predicting fever.

**Specificity:** Refers to the proportion of temperature measurement measures that are able to discern normal temperature from an abnormal temperature (e.g., hypothermia, fever) when compared to core temperature measures or another standard temperature method measurement. For example, high specificity of a given temperature method measure of interest to accurately identify patients without fever (as measured by core temperature or another standard temperature method) would indicate a higher proportion of patients without fever would be accurately measured by the temperature method measure of interest. The emphasis of specificity is on the accuracy of the temperature measurement method on identifying when patients do not have an abnormal temperature—such as fever.

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