EMERGENCY NURSES ASSOCIATION

Clinical Practice Guideline: Non-invasive Temperature Measurement

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 and Significance

The detection of and degree of fever are critical to the appropriate practice of emergency medicine (Hoffman et al., 2013). The importance of accurate temperature measurement is well recognized as an objective and reliable indicator of physical wellbeing. An elevated temperature is one of the most frequent reasons for emergency department visits by children (Bahorski et al., 2012). Pulmonary artery (PA) temperature is considered the "gold" standard for measuring core body temperature (Fulbrook, 1993; Furlong et al., 2015), 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). This Clinical Practice Guideline (CPG) focuses on evidence-based practices regarding temperature measurement of patients across the lifespan in the ED setting.

Methodology

This CPG was created based on a thorough review and critical analysis of the literature following ENA's Requirements for the Development of Clinical Practice Guidelines. Via a comprehensive literature search, all articles relevant to the topic were identified. The articles reviewed to formulate the recommendations in this CPG are described in Appendix 1. The following databases were searched: PubMed, Google Scholar, CINAHL, Cochrane Library, British Medical Journal, Agency for Healthcare Research and Quality, and the National Guideline Clearinghouse. 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, revision search November 2011–March 2015 (Appendix 3). 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 CPG: 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. Clinical findings and levels of recommendations regarding patient management were made by the CPG Committee according to ENA's classification of levels of recommendation for practice (Table 1).

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 or 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 such as (axillary and 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

An adult study of 60 febrile adult cardiac intensive care unit patients demonstrated the accuracy of temporal artery (TAT) in core mode when compared to Pulmonary artery temperatures (PAT) with temperatures >100.4°F. The repeated measure design allowed a direct comparison of the PA and TA in the in the febrile adult. No TA measurements were 0.9°F greater than corresponding PAT measurement (Furlong et al., 2015)

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 temporal artery temperature(TAT) 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 ± 0.51 °C (Myny, De Waele, Defloor, Blot, & Colardyn, 2005).

Currently there is not enough evidence to make a recommendation based on the evidence for the utilization of TA in the pediatric population due to the information identified in the following studies. There is a need for further well developed studies to identify best practices for TAT in the pediatric population.

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).

A descriptive comparative study in an inpatient setting compared RT to TAT evaluated patient comfort and required nursing time. A total of 450 pairs of measurements were compared by descriptive analysis with a Pearson's correlation (r=0.0776). There was an 84.7% level of agreement between RT and TA and 94.7% of the measurements differed by 1°C or less. The patient comfort assessment utilized the Face, Legs, Activity, Cry, Consolability (FLACC) assessment to assess patient comfort during procedure. Average FLACC score post procedure was RT 3.9 compared with TA 1.88 (Carr, Wilmoth, Eliades, Baker, Shelestak, Heisroth, Stoner, 2011).

A method comparison study design was utilized in a pediatric emergency department setting to compare three different methods of temperature measurement, comparing TAT and axillary to the standard rectal temperature in a convenience sample of stable pediatric emergency department patients younger than 4 years old. Each participant served as their own control. The measured rectal temperatures ranged from 36.6°C to 40.1°C, with 15% (N = 18) of participants having temperatures >37.9°C demonstrating the accuracy of the TAT when compared with the RT. The TAT can avoid physical and psychological discomfort for the child and parent that is associated with rectal temperatures (Reynolds et al., 2014).

A retrospective cohort study using chart review identified that the sensitivity of the TA decreases as the rectal temp increases. TA was 53% sensitive to a rectal temp of 100.4°F (38°C) or greater and sensitivity decreased to 27% in detecting a rectal temp of 102.36°F (39.09°C) or greater (Hoffman, Etwaru, Dreisinger, Khokhar, & Husk, 2013). The greatest single temperature difference was 6.8-F (104.4°F rectal and 97.6°F temporal temperature pair). A statistically significant t statistic for difference between paired temporal artery temperature and rectal temperature was noted ($p<0.0001$). The mean RT 102.36°F (39.09°C) compared to a mean TAT 100.36°F (37.98°C) resulting in a mean difference of 1.99°F (1.11°C) (Hoffman, et al., 2013).

A comparison study of RT to TA completed within five minutes of each other in children aged 0-18 years with and without fever mean difference between TAT and RT was 0.11 (SD 0.63)°C, with an agreement of 0.812. The sensitivity and specificity of the temporal artery thermometer for detecting fever were 67.9 and 98.3%, respectively (Penning, H van der Linden, Tibboel & Evenhuis, (2011).

A study by Bahorski et al. (2012) compared temporal and rectal temperatures and found no statistically significant difference. TA temperatures compared to RT in normothermic and febrile pediatric patients had similar variability (precision) with rectal temperatures, t (25.01) = −1.77, p = .089. Relational analysis revealed a statistically significant relationship between temporal artery thermometry and rectal temperature measures using Pearson's r (r=0.85, n=47, p=0.01) and Spearman's rho (p=0.86, n=47, p=0.01). In this study, a comparison did not reveal a statistically significant difference between the afebrile and febrile groups, t (28.33) = −1.61, p=0.118. Therefore, the statistics in this study indicate that TAT is an acceptable alternative to RT; however, the authors caution that consideration should be made for the potential of missing an acute febrile state with the TAT approach (Bahoriski et al., 2012).

Temperature measurement simultaneously by TA and rectal mercury in eligible children younger than 5 years old demonstrated TAT (37.80°C + 1.07°C) was significantly lower than the mean rectal temperature (38.07°C ± 0.95°C), P < 0.001. In neonates, however, the mean difference was not significant, 0.02 ± 0.59 (p=0.810). There was a significant positive correlation between the rectal and the temporal temperatures (r=0.80, p<0.01).The Bland-Altman plot showed wide variation in the limit of agreement between the rectal and the TA temperatures which ranged from −1.02°C to +1.56°C. The sensitivity of the TA thermometer was 64.6% (Odinaka, Edelu, Nwolisa, Amamilo, & Okolo, 2014).

In a study by 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 ± 1°C for rectal, 37.6 ± 0.9°C for TAT and 37.1 ± 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).

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 were 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, Guneysel, Akoglu, 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 ± 0.9°C) and rectal (M=37.6 ± 1.1°C) temperatures had similar variability (precision) compared to PA temperatures; axillary measurements had a mean bias was 0.51 ± 0.41°C (Hebbar et al., 2005). Among intensive care pediatric patients, TM, axillary, and rectal temperatures 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 +/- 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 to 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 +/-0.32°C, and the axillary chemical thermometer had a mean difference from PA readings of 0.46 to +/-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 ± 0.82°C compared to 37.56 ± 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 comparable 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 nor 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 over treat 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 ± 0.47°C for oral and -0.17 ± 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).

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 +/- 0.2°C, compared to TA temperature mean difference from PA of -0.3 +/- 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 CPG 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 temperature 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.

Description of Decision Options/Interventions and the Level of Recommendation

Description of Decision Options / Interventions and the Level of Recommendation: ADULTS					
	ORAL	TYMPANIC	TEMPORAL ARTERY	CHEMICAL DOT	AXILLARY
Adult (over 18 years)	A	I/E	A	I/E	B
Febrile	A	NR	NR	I/E	NR
Hypothermic	A	N/E	N/E	N/E	N/E
Critically Ill/ Intubated	A	I/E	I/E	I/E	I/E

Description of Decision Options / Interventions and the Level of Recommendation: PEDIATRICS						
	RECTAL	ORAL	TYMPANIC	TEMPORAL ARTERY	CHEMICAL DOT	AXILLARY
0-3 months	A	NR	NR	NR	NR	NR
3 months – 3 years	A	NR	I/E	I/E	N/E	I/E
3 years – 18 years	A	A	NR	A	NR	B
Febrile	A	A	NR	A[1]	NR	NR
Hypothermic	A	N/E	N/E	N/E	N/E	N/E
Critically Ill/Intubated	A	NR	I/E	I/E	N/E	I/E

A	Level A (High)	Based on consistent and good quality of evidence; has relevance and applicability to emergency nursing practice.
B	Level B (Moderate):	There are some minor inconsistencies in quality evidence; has relevance and applicability to emergency nursing practice.
C	Level C (Weak)	There is limited or low-quality patient-oriented evidence; has relevance and applicability to emergency nursing practice.
NR	Not Recommended	Based upon current evidence.
I/E	Insufficient Evidence	Insufficient evidence upon which to make a recommendation.
N/E	No Evidence	No evidence upon which to make a recommendation.

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

Evidence supporting the Level of Recommendation

1. **Adult Temperature Measurement**
   - Oral temperature measurement (Calonder et al., 2010; Giuliano et al., 2000; Lawson et al 2007; Washington & Matney, 2008)
   - Temporal Artery (TA) temperature measurement (Calonder et al., 2010; Furlong et al. 2015; Myny et al., 2005)
   - Axillary temperature measurement (Fulbrook, 1993; Marable et al., 2009; Myny et al., 2005; Rubia-Rubia et al., 2011; Washington & Matney, 2008)

2. **Febrile Adult Temperature Measurement**
   - Oral temperature measurement (Bridges & Thomas, 2009; Giuliano et al., 2000; Kimberger et al., 2007; Marable et al., 2009)

3. **Hypothermic Adult Temperature Measurement**
   - Oral temperature measurement (Kimberger et al., 2007; Lawson et al., 2007; Rogers et al., 2007)

4. **Critically Ill/Intubated Adult Temperature Measurement**
   - Oral temperature measurement (Fadzil et al., 2010; Hooper & Andrews, 2006)

5. **Pediatrics (0 to 3 Months) Temperature Measurement**
   - Rectal temperature measurement (Jean-Mary et al., 2002)

6. **Pediatric (3 to 18 years) Temperature Measurement**
   - Oral temperature measurement (Fadzil et al., 2010)
   - Temporal Artery (TA) temperature measurement (Al-Mukhaizeem et al., 2004; craBahorski et L., 2012; Hebbar et al., 2005; Hoffman et al., 2013; Odinaka et al., 2014; Paes et al., 2010; Penning et al., 2011; Reynolds et al. 2014; Schuh et al., 2004; Titus et al., 2009)
   - Axillary temperature measurement (Maxton et al., 2004)

7. **Febrile Pediatric Temperature Measurement**
   - Oral temperature measurement (Fadzil et al., 2010)
   - Temporal Artery (TA) temperature measurement (Carr et al., 2011; Titus et al., 2009)

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Authors

2015 ENA Clinical Practice Guideline Committee:
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Acknowledgments

ENA would like to acknowledge the following members of the 2015 Institute for Emergency Nursing Research (IENR) Advisory Council for their review of this document:

Paul Clark, PhD, MA, RN

Developed: December 2011
Revised: October 2015

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Al-Mukhaizeem, F., Allen, U., Komar, L., Naser, B., Roy, L., Stephens, D., … Schuh, S. (2004). Comparison of temporal artery, rectal and esophageal core temperatures in children: Results of a pilot study. Paediatr Child Health, 9(7):461-5.	Examine the agreement between the TA and esophageal core thermometers, and to compare it with that between rectal and esophageal temperatures.	Design/Method: prospective, cross-sectional agreement Sample: N=80, convenience sample, intubated children under 18 Setting: Outpatient surgery	Measurement of TA, Rectal, and Esophageal temperature. TA measured with TA Scanner, model LXTA, Exergen corp. USA; Rectal temp measured with 2 devices: IVAC 2000, ALARIS Medical & Tele-thermometer YSI Incorp, USA; Esophageal temp measured with TeleThermometer, YSI Incorp, USA; Appropriate Statistical Analysis: Appropriate statistical analysis including comparison between methods. 95% CI, linear regression, and t-test	Agreement between TA and esophageal temperature measurement. No significant difference between TA-Esophageal and Esophageal-Rectal temperatures	I	IV
Bahorski, J., Repasky, T., Ranner, D., Fields, A., Jackson, M., Moultry, L., ... Sandell, M. (2012). Temperature measurement in pediatrics: a comparison of the rectal method versus the temporal artery method. *J Pediatr Nurs,* 27(3):243-7. doi:10.1016/j.pedn.2010.12.015	Purpose of this study was to determine if there is a difference between temperature readings obtained using two different electronic temperature devices: one measuring temporal artery temperature (TAT) and one measuring rectal temperature (RT).	Design/Method: Comparative single-group design was used with each person acting as his or her control Sample: 47 pediatric patients- Setting: in the ER, ICU, and Outpatient Unit.	MTAT obtained by one RN, immediately followed by a RT measurement. The data were analyzed using Levene's test for equal variances with revealed the variances were not equal t test for equality of means was run, the equal variances not assumed line was used for interpretation of the data. Pearson's r and Spearman's rho were both used to consider relationship between the two readings and between afebrile and febrile measurements.	Data analysis revealed no statistically significant differences between TAT and RT.	II	II

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Bridges, E., & Thomas, K. (2009). Ask the experts. noninvasive measurement of body temperature in critically ill patients. *Crit Care Nurse, 29*(3):94-7. doi:10.4037/ccn2009132	Accuracy of noninvasive temperature measurement compared with pulmonary artery temperature in adult patients in the intensive care unit.	Design: Integrative Review of the literature Method: 16 studies that compared a non-invasive temperature measurement to core temperature measured by pulmonary artery catheter.r Accuracy of measure if mean difference within + 0.3 OC. & Precise if standard deviation (SD) ranging from 0.3 OC-0.5 OC. Sample: Study subject sample sizes ranged from 15-300 subjects Setting: Intensive care units	Measures/ Instruments: Oral, ear-based, temporal artery, axillary modes of measuring temperature compared to pulmonary artery (PA) core temperature Appropriate Statistical Analysis: Descriptive statistics to determine accuracy and precision	Oral, ear-based and temporal artery are generally equivalent with respect to accuracy. Axillary temperature underestimates core temperature (PA). Precision varied across the measures: oral, SD=0.24-0.6 °C. ear-based, SD=0.4-0.57 °C. temporal artery, DD=0.5-1.1 °C. axillary, SD=0.16-0.6 °C. Oral thermometer most accurately detected fever, whereas ear-based thermometer least accurate in detecting a fever.	I	V
Calonder, E. M., Sendelbach, S., Hodges, J. S., Gustafson, C., Machemer, C., Johnson, D., & Reiland, L. (2010). Temperature measurement in patients undergoing colorectal surgery and gynecology surgery: A comparison of esophageal core, temporal artery, and oral methods. *J Perianesth Nurs, 25*(2):71-8. doi:10.1016/j.jopan.2010.01.006	Purpose: To determine the difference between core temperature as measured by an esophageal thermometer and temperatures measured by oral and temporal artery.	Design: Repeated measures design. Method: 2 series of intraoperative temperature taken of oral and temporal artery and compared to core temperature measured by esophageal probe. First set of temperatures taken after subject was in OR and anesthetized, and second set of temperatures within 30 minutes of the first set of temperatures. Sample: Convenience sample of 23 adult patients, mean age 55.7 years old, who were undergoing colorectal or gynecology surgery over a 2-week period. Setting: Intraoperative setting.	Measures/ Instruments: Oral temperatures measured with SureTemp Plus Electronic Thermometer, Temporal artery measured with TAT 5000, and esophageal temperature measured with ES400-18 Level 1 Acuostascope Esophageal stethoscope with temperature sensor and the Thermisor Appropriate Statistical Analysis: Appropriate use of Bland-Altman analysis and repeated measures analysis of variance.	1. Oral temperatures overestimated the core temperature by a mean of 0.12 °C. This bias was significantly different ($p<0.0008$), however the value was still within the 0.4 °C. clinically acceptable standard. 2. Temporal artery temperatures overestimated the core temperature by a mean of 0.7 °C.	I	IV

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Carr, E., A., Wilmoth, M., L., Eliades, A., Beoglos, Baker, P., J., Shelestak, D., Heisroth, K., L., & Stoner, K., H. (2011). Comparison of temporal artery to rectal temperature measurements in children up to 24 months. *J Pediatr Nurs, 26*(3):179-85. doi:10.1016/j.pedn.2009.12.072	Purpose: To examine the relationship between temporal artery (TA) and rectal thermometry measurements in febrile patients while hospitalized.	Design: Descriptive, comparative design Method: TA and rectal temperatures taken initially and every 2 hours while subject was febrile. FLACC scores and amount of nursing time to obtain temperatures was obtained at each measurement interval. Sample: 40 children <24 months old with a fever > 38 OC. Mean age of subjects was 10.9 months, ranging from 1-20 months old. A total of 450 pairs of measurements available for analysis. Setting: In the ED prior to transfer to an inpatient pediatric unit or in the inpatient pediatric unit.	Measures/ Instruments: TA measured with Temporal Scanner (Exergen, Corp.) & rectal temp measured with Sure Temp (Welch Allyn Instruments, Skaneateles Falls, NY). Behavioral pain was measured with the Face, Legs, Activity, Cry Consolability (FLACC) score was used at each temperature measurement.	Correlations between TA and rectal temperatures was r=0.77,} the mean TA temperature was 37.59 +.82 °C compared to 37.56 +.82 °C for rectal; with 94.7% of the measurements differing by 1 °C. or less. There were significant differences in the FLACC scores for rectal temperature measurement (t=4.78, p<0.000). The mean nursing time for obtaining rectal temps was 47 seconds, compared to a mean of 6 seconds for the TA temp measurements.	I	IV
Craig, J. V. (2000). Temperature measured at the axilla compared with rectum in children and young people: Systematic review. *BMJ, 320*(7243):1174-8.	Purpose: To evaluate the level of agreement between temperature measured at the axilla and rectum in children and young people.	Design: Systematic Review of research with meta-analysis. Method: Relevant studies identified through electronic search Sample: Total sample included 5,528 children; from 40 studies included in systematic review; Age birth to 18 years old.	Measures/instruments/ Appropriate statistical analysis: Meta-analysis conducted and appropriate.	1. Mean temperature difference (rectal minus axillary temperature) for mercury thermometers was 0.25 OC (limits of agreement -0.15 OC to 0.65 OC) and electronic thermometers was 0.85 °C (-0.19 OC to 1.9 OC). 2. The pooled mean temperature difference (rectal minus axillary temperature) for neonates was 0.17 OC (-0.15 OC to 0.5 OC) and for older children/ young people was 0.92 °C (-0.15 OC to 1.98 OC). 3. Implications: Temperatures measured in axilla do not agree sufficiently compared to rectal. Variability in results was related to the age of the child and duration of placement time.	I	I

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Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Craig, J. V., Lancaster, G. A., Taylor, S., Williamson, P. R., & Smyth, R. L. (2002). Infrared ear thermometry compared with rectal thermometry in children: A systematic review. *Lancet, 360*(9333):603-9.	Purpose: To evaluate agreement between temperature measured at the rectum and ear in children.	Design/Method: Systemic review, using Meta-analysis with review of subgroups based on mode of thermometer. 44 studies containing 58 comparisons (5,935 children)	Measures/instruments/ Appropriate statistical analysis: Systematic Review conducted and appropriate.	1. Mean differences between rectal and ear temperature measurements were small; however the wide limits of agreement mean that tympanic membrane ™ or ear temperature is not a good approximation of rectal temperature	I	I
Fadzil, F. M., Choon, D., & Arumugam, K. (2010). A comparative study on the accuracy of noninvasive thermometers. *Aust Fam Physician, 39*(4):237-9.	Purpose: To assess the concordance of the temperatures of the digital, liquid crystal forehead and digital infrared tympanic thermometers with the mercury in glass thermometer. Questions/ Hypothesis: Compare each type of temperature measurement to mercury in glass thermometer.	Design: Prospective, comparative design Method: Temperature measurements were taken simultaneously using the four different types of thermometers. Sample: 207 patients; the majority were adults, only 5 pediatric patients in the sample Setting: Selected from the non-acute (triage category 3 and 4) ED patients at the University of Malaya Medical Centre	Measures/ Instruments: Mercury in the glass thermometer (Dmcare Clinical thermometer); digital thermometer (DT-01A), liquid crystal forehead thermometer (Liquid Crystal Fever Temp Ultra, Digi Temp); and digital infrared tympanic thermometer (Microlife IR 1DB1, Microlife). Appropriate Statistical Analysis: Appropriate. Bland-Altman analysis was used.	1. High concordance between all four measurement methods. 2. The digital thermometer had the highest concordance with the mercury in the glass thermometer, having the smallest limits of agreement across the range of temperature.	I	IV
Farnell, S., Maxwell, L., Tan, S., Rhodes, A., & Philips, B. (2005). Temperature measurement: Comparison of non-invasive methods used in adult critical care. *J Clin Nurs, 14*(5):632-9.	Purpose: Compare non-invasive temperature methods used in adult critical care Questions/ Hypothesis: 1) To assess accuracy and reliability of two non-invasive methods of temperature measurement against the «gold standard» (PA catheter) 2) to determine the clinical significance of any temperature discrepancy using an expert panel.	Design: Prospective, comparative Method: All three temperature measurements were obtained on subjects with PA catheter. No more than 20 complete temperature measurements were obtained per patient with at least one hour between each set of readings. Sample: 25 adult patients who required a pulmonary artery (PA) catheter; resulting in a total of 160 temperature measurements obtained. Subjects had a mean of 6.1 (SD=4.7) sets of temperature measurements recorded. Setting: Intensive Care	Measures/ Instruments: Chemical thermometer (3M Tempa.DOT); infrared tympanic thermometer (Genius First Temp M3000A, Tyco Healthcare, Gosport, UK) and Pulmonary Artery Catheter. Clinical Panel consisted of six senior nurses and doctors asked to specify when they would consider implementing certain interventions and treatments based on temperature alone (e.g., use of warming blanket, obtaining specimens, using ice). Appropriate statistical analysis.	1. Mean temperature differences between PA catheter were 0.2 OC. ($p<0.00001$) for chemical and 0 OC. for tympanic temperature ($p=0.39$). Both the chemical and tympanic measures significantly correlated with PA temperatures ($r=0.81$, $p<0.0001$ and $r=0.59$, $p<0.0001$ respectively). 2. 75.2% (n=115) of chemical and 50.9% (n=78) of tympanic readings were within + 0--0.4 OC. range of PA catheter. 3. Clinical significance: 15.3% (n=26) of chemical and 21.1% (n=35) of the tympanic measures might have resulted in delayed treatments; 28.8% (n=44) of chemical and 37.8% (n=58) of tympanic readings might have resulted in unnecessary interventions.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Fulbrook, P. (1993). Core temperature measurement in adults: A literature review. *J Adv Nurs, 18*(9):1451-60.	Determine the validity and reliability of tympanic measurements and axillary chemical measurements compared with pulmonary artery temperatures.	Design: Prospective, observational design. Sample: N: 60, age 19-86, ICU patients, mean age 63.4 + 14 Convenience sample of patients. Setting: Intensive care unit, UK.	Five measurements, Left and right tympanic, and left and right axillary and PA temp Statistical Analysis: Appropriate: t-test, Pearson's product moment correlation	Axillary measurements: no significant differences between left and right, correlation: r = 0.58, between sides, correlation with PA: left axillary r = 0.48, right axillary: r= 0.44. Non-significant differences between axillary and PA. However 6 subjects did have a 1 degree difference and 1 had a 3 degree difference. Correlation between axillary and tympanic: r = 0.48, 13 subjects with greater than 1 degree difference. Tympanic temps similar to axillary. Left to right correlation: r = 0.63 Correlation to PA: r = 0.78. Concerns when patients are placed on their side and then that side is used for temp measurement.	I	III

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Furlong, D., Carrol, D., Finn, C, Gay, D., Gyrglik, C., Donahue, V. (2015). Comparison of temporal to pulmonary artery temperature in febrile patients. *Dimens Crit Care Nurs, 34*(1):47-52. doi: 10.1097/DCC.00000000090	Purpose: The purpose of this study was to measure the precision and accuracy of 2 commonly used methods of collecting body temperature: PAT considered the criterion standard and the temporal artery thermometer (TAT) in those patients with a temperature greater than 100.4oF.	Design/Method: Repeated measures design. Method: Data collection involved 3 nurses who obtained temperatures with a dedicated TAT calibrated regularly and cleaned before each use. Sample: N=60 subjects Convenience Sample Setting: Post cardiac surgery in ICU.	This is a repeated-measures design with each patient with a PAT in the intensive care unit acting as their own control to investigate the difference in PAT readings and readings from TAT in the core mode. Accuracy and precision were analyzed. Summary statistics were used to describe the subjects, demographic and clinical variables. The mean difference between Pat and TAT was calculated and plotted as described by Bland and Altman. The accuracy of TAT was assessed as the mean difference of all the pairs for the non-invasive mode of TAT and PAT. The precision (SD) and confidence limits (mean difference, plus or minus 1.96XSD) of the core noninvasive mode (TAT) relative to PAT were also calculated. In a manner consistent with previous research, a clinically significant difference was defined a priori as a greater than ±0.9oF from PAT, and the number of data pairs outside ±0.9oF limit will be analyzed. For all analysis, the significance was set at .05.	There was a statistically significant difference between PAT and TAT (101.0oF [SD, 0.5oF] vs 100.5oF [SD, 0.8oF]; bias, -0.49oF; P <.001). Differences in temperature between the 2 methods were clinically significant (i.e., > 0.9oF different) in 15 to 60 cases (25%). No TAT measurement (0%; 95% confidence interval, 0%-6%).	I	III

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Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Giuliano, K. K., Giuliano, A. J., Scott, S. S., MacLachlan, E., Pysznik, E., Elliot, S., & Woytowicz, D. (2000). Temperature measurement in critically ill adults: A comparison of tympanic and oral methods... CE online. *Am J Crit Care, 9*(4):254-61.	Purpose: To compare the range of variability between tympanic and oral electronic thermometers	Design/Method: Cross-sectional Sample: Convenience sample of adult patients (N=72) with Pulmonary artery catheters, Each subject was used up to 3 times to achieve a statistically adequate number of measurements Setting: Adult ICU	PA, oral, and ear measurements were obtained within 1 minute from each subject using Swanz Ganz catheter, Genius II tympanic, Thermosure Tympanic, and SureTemp Oral thermometers by specially trained ICU Nurses Nonparametric analysis and plotting on a Bland-Altman chart	1. When compared to PA temperature, both oral and tympanic methods showed variability. 2. Oral measurement was less variable than tympanic measurements. 3. The Thermosure tympanic thermometer had the greatest degree of variability.	I	IV
Greenes, D. S., & Fleisher, G. R. (2001). Accuracy of a noninvasive temporal artery thermometer for use in infants. *Arch Pediatr Adolesc Med, 155*(3): 376-81.	Purpose: To assess the accuracy of noninvasive temporal artery (TA) and tympanic thermometry to rectal thermometry in infants	Design: Descriptive, comparative design Method: TA, tympanic, and rectal temperatures taken successively among infants presenting to the ED Sample: 304 infants < 1 year old Setting: Urban ED	Four successive temperature measurements were made, including a rectal temperature, a tympanic temperature, and left- and right-sided TA temperatures. Rectal temperatures were measured using the Diatek™ electronic thermometer (Welch Allyn Inc, Skaneateles Falls, NY). Tympanic temperatures were measured using the First Temp Genius™ tympanic thermometer (Sherwood Medical, St Louis, MO). Appropriate Statistical analysis: Yes, descriptive comparisons and limits of agreement analyses; and linear regression analyses.	1. TA thermometer more sensitive than tympanic for detecting rectal fever (temp > 38 OC) and high rectal fever (temp > 39 OC). 2. There were no statistical differences in the specificity of either the TA or tympanic thermometer compared to rectal thermometry. Implications: Rectal is still preferred method. TA thermometry a better choice for infants than tympanic. However, 35% of the rectal fever cases and 6% of the high rectal fever cases as determined by rectal temperature measurement would have been missed by TA thermometry.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Hebbar, K., Fortenberry, J. D., Rogers, K., Merritt, R., & Easley, K. (2005). Comparison of temporal artery thermometer to standard temperature measurements in pediatric intensive care unit patients. *Pediatr Crit Care Med, 6*(5):557-61.	Purpose: To determine the accuracy of noninvasive infrared temporal artery thermometry compared with rectal, axillary and pulmonary artery (PA) catheter measurements in pediatric intensive care patients, and to determine whether temporal artery temperature are affected by circulatory shock or vasopressor use. Hypothesis: TA temperatures do not differ from axillary and rectal temperatures in critically ill children, but TA accuracy is decreased by shock or vasopressor use.	Design: Observational, unblinded design. Method: Bedside nurses trained in temperature measurement protocols recorded temperatures. Sample: 75-comparison pairs obtained in 44 pediatric patients. Setting: Pediatric Intensive Care	Measures/ Instruments: Appropriate Statistical Analysis: Appropriate. Used Bland-Altman analysis.	1. No significant differences in mean bias between method pairs for all temperatures. 2. Bias was significantly less in PA catheter-rectal pairs compared with other method pairs ($p<0.008$). 3. In febrile patients, bias in rectal-temporal and rectal-axillary was significantly greater than temporal-axillary pairs ($p<0.001$). 4. Temporal and axillary temperature measurements had variability compared to rectal temperatures; and had marked variability in febrile children. 5. Temporal artery and axillary thermometers had similar accuracy	I	IV
Hoffman, R.J., Etwaru, K., Dreisinger, N., Khokhar, A., Husk, G.. (2013). Comparison of temporal artery thermometer and rectal thermometry in febrile pediatric emergency department patients. *Pediatr Emerg Care, 29*(3):301-4. doi:10.1097/PEC.0b013e3182850421.	Purpose: This study compares temporal artery thermometry to rectal thermometry in febrile children in an ED.	Design: retrospective chart review Sample: n= 147 Setting: Urban medical center ED	Measures/ Instruments: Appropriate Statistical Analysis: Bland-Altman plots were created, and differences in mean temperature for mean temporal artery temperature and rectal temperature were calculated. Sensitivity and specificity of temporal artery thermometry in patients with fever of 100.4-F (38-C) or greater and rectal temperature of 102.2-F (39-C) or greater as determined by rectal thermometry were calculated.	A statistically and clinically significant difference between temporal artery and rectal temperature was found. Temporal artery thermometry was 53% sensitive detecting rectal temperature 100.4-F (38-C) or greater, and 27% sensitive detecting rectal temperature of 102.2-F (39-C) or greater. Mean rectal temperature was 102.36-F (39.09-C) (95% confidence interval [CI], 102.14-FY102.58-F); mean temporal artery temperature was 100.36-F (37.98-C) (95% CI, 100.08-FY100.65-F), and mean difference between the two was 1.99-F (1.11-C) (95%CI, 1.75-FY2.23-F). Conclusions: Temporal artery thermometry is poorly sensitive detecting fever and does not accurately reflect rectal temperature. Temporal artery thermometry should not be used for clinical management of children younger than 36 months if detection of fever is of importance.	I	VI

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Hooper, V. D., & Andrews, J. O. (2006). Accuracy of noninvasive core temperature measurement in acutely ill adults: The state of the science. *Biol Res Nurs, 8*(1):24-34.	Purpose: Compare selected invasive and noninvasive temperature measurement methods in acutely ill, hospitalized adult patients. Questions/ Hypothesis: Are there clinically significant differences between oral, tympanic, and temporal artery noninvasive temperature readings and invasive core temperature readings in acutely ill hospitalized adults?	Design: N/A Method: Integrative review of literature from January, 1982 to March, 2005 Sample: 23 studies met the inclusion/ exclusion criteria of the review Setting: Hospital setting IRB approval: Yes.	Established quality indicators pertaining to evaluating studies included in the integrative review (e.g., number of temperature measurements, data collector training, core settings used for tympanic thermometers) Appropriate Statistical Analysis: Appropriate analysis for integrative review methodology.	Oral temperature taken in the left or right posterior sublingual (buccal) pocket can provide an accurate core temperature measurement. Tympanic thermometry studies are of poor quality, outdated and have insufficient data to support as an accurate measure of core temperature. Insufficient evidence to support the use of temporal artery thermometry as an accurate measure of core temperature.	I	V
Jean-Mary, M., Dicanzio, J., Shaw, J., & Bernstein, H. H. (2002). Limited accuracy and reliability of infrared axillary and aural thermometers in a pediatric outpatient population. *J Pediatr, 141*(5):671-6.	Purpose: To evaluate the accuracy and reliability of axillary and tympanic thermometers in an outpatient setting.	Design: Descriptive, comparative design Method: Three temperature readings were taken sequentially—axillary, tympanic and rectal temperatures. Sample: 198 children, age 3 to 36 months of age --mean age 1.3 years old Setting: Large, urban pediatric clinic	The infrared thermometers were used per user manual directions to obtain axillary and tympanic temperatures. Rectal measures were with IVAC™ digital thermometer (Alaris, San Diego, CA). Statistical Analysis: Regression analyses and receiver operating characteristic (ROC) curve analyses were conducted---appropriate for study.	The mean biases of the axillary and tympanic temperatures were –0.33°F and –0.24°F, respectively. The biases of both thermometers' measurements were significantly correlated with rectal temperature ($P < 0.02$); thus, as rectal temperature increased, the accuracy of axillary and tympanic temperature decreased. Underestimation of rectal temperature was greatest among febrile 1- to 3-year-old children (axillary bias, –1.2; tympanic bias, –0.36). Age was correlated with an axillary temperature bias ($P < 0.01$). Implication: Axillary and tympanic infrared thermometers were comparable, but significantly different than rectal temperatures, particularly as the child's age and rectal temperature increased. Rectal should be used for clinical accuracy.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Kimberger, O., Cohen, D., Illievich, U., & Lenhardt, R. (2007). Temporal artery versus bladder thermometry during perioperative and intensive care unit monitoring. *Anesth Analg, 105*(4):1042-7.	Purpose: Questions/ Hypothesis: To determine if TA temperatures are comparable to bladder temperature in critically ill adults	Design: Prospective, comparative design. Method: Bladder temperature sensor incorporated into urinary catheter for all subjects. Temporal artery (TA) temps recorded on arrival in OR, 30 minutes after anesthesia induction, at the end of surgery, 30 minutes after arrival in PACU. TA measurements taken in ICU by recording 4-times at 1-hour intervals. Sample: 280 total measurements in Neurosurgical intervention patients (n=35) and patients in neurosurgical ICU (n=35) Setting: Surgical and ICU settings.	Measures/ Instruments: Bladder temperature sensor (Smiths-Medical, London, UK) and temporal artery thermometer (TAT-5000 manual) Appropriate Statistical Analysis: Bland and Altman analysis appropriate analysis for this study.	No significant correlation between method discrepancy and magnitude of measurement (p=0.08). Limits of agreement were ~ 3 times greater than the a priori defined limit of +0.05 OC. Sensitivity for detecting fever was 0.89 OC; and sensitivity for detecting hypothermia was 0.29 OC. Results of study did NOT support the use of temporal artery thermometer for perioperative core temperature monitoring.	I	IV
Lawson, L., Bridges, E. J., Ballou, I., Eraker, R., Greco, S., Shively, J., & Sochulak, V. (2007). Accuracy and precision of noninvasive temperature measurement in adult intensive care patients. *Am J Crit Care, 16*(5):485-96.	Purpose: To determine accuracy and precision of four non-invasive temperature measurements (oral, ear-based, temporal artery, and axillary) compared with pulmonary artery (PA) temperature. Questions/ Hypothesis: N/A	Design: Repeated-measures design Method: Sequential temperature measurements on the same side of the body were obtained within 1 minute. Measurements repeated 3 times at 20-minute intervals. Sample: Convenience sample of 60 critical care patients with a PA catheter. Setting: Academic Medical Center Adult ICU	Measures/Instruments: PA measured with Baxter™ PA cath (Baxter HealthCare Corporation, Irvine, CA). Axillary temperature measured using a B-D™ digital thermometer (Becton Dickinson and Company, Franklin Lakes, NJ). Nasopharyngeal and rectal temperatures measured using YSI 400™ (YSI Incorporated, Yellow Springs, OH) probes for continuous temperature measurement. Bladder temperature was continuously measured by foley urinary catheter with thermistor probe (Mallinckrodt). Tympanic temperature obtained with First Temp Genius™ thermometer (Sherwood, St. Louis, MO). ANOVA; Bland & Altman analysis --appropriate analyses.	Rectal, axillary and tympanic temperatures were significantly different from PA temperatures. With mean differences from PA of -0.69, -0.90, and -0.97 respectively. These findings also reflect significant clinical significance. Bladder temp was best estimate of PA temp followed by NP probe. Rectal temp was poor indicator of core temperature.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Marable, K., Shaffer, L., Dizon, V., & Opalek, J. M. (2009). Temporal artery scanning falls short as a secondary, noninvasive thermometry method for trauma patients. *J Trauma Nurs, 16*(1):41-7. doi:10.1097/01.JTN.0000348069.71593.9d	Purpose: identify a minimally invasive, scientifically acceptable alternative to oral thermometry in patients for whom oral measurements were unobtainable. Hypothesis: body temperature assessment using a temporal scanner would be more consistent with oral thermometry than is axillary thermometry.	Design/Method: Prospective, nonrandomized study in which eligible participants served as their own controls. Sample: N=69 Adult males Setting: Adult ICU in Level I Trauma Center, subjects were further categorized as obese or non-obese	Measures/Instruments: Oral and axillary temperatures were obtained using a Sure Temp Plus 692, TA readings were obtained with an Exergen TAT-5000. Each subject had temps measured 5 times, orally, axillary, and with three methods using the TA thermometer Statistical Analysis: Appropriate statistical analysis performed	TA temperatures fell within the accepted range of ± 0.5 ˚F (0.28˚ C) of each other, but showed considerable variability compared to the oral method. The variability was similar to the axillary method. Obese patients had lower readings than non-obese. Fever agreement rates were > 90%. TA thermometry is equivalent to axillary in comparison to oral measurements	I	IV
Maxton, F., Justin, L., & Gillies, D. (2004). Estimating core temperature in infants and children after cardiac surgery: A comparison of six methods. *J Adv Nurs, 45*(2):214-22.	Purpose: To examine which temperature monitoring site (rectal, bladder, naso-pharyngeal, axillary and tympanic) most closely reflects core temperature in pediatric patients after cardiac surgery	Design: Descriptive, comparative Method: All temperatures measured/recorded on arrival in PICU and every 30 minutes after for 6 1/2 hours Sample: 19 pediatric postoperative, cardiac surgical patients; mean age of 0.59 months old Setting: Urban, pediatric intensive care unit (PICU	Measures/Instruments: PA measured with Baxter™ PA cath (Baxter HealthCare Corporation, Irvine, CA). Axillary temperature measured using a B-D™ digital thermometer (Becton Dickinson and Company, Franklin Lakes, NJ). Nasopharyngeal and rectal temperatures measured using YSI 400™ (YSI Incorporated, Yellow Springs, OH) probes for continuous temperature measurement. Bladder temperature was continuously measured by foley urinary catheter with thermistor probe (Mallinckrodt). Tympanic temperature obtained with First Temp Genius™ thermometer (Sherwood, St. Louis, MO). ANOVA; Bland & Altman analysis --appropriate analyses.	Rectal, axillary and tympanic temperatures were significantly different from PA temperatures. With mean differences from PA of -0.69, -0.90, and -0.97 respectively. These findings also reflect significant clinical significance. Bladder temp was best estimate of PA temp followed by NP probe. Rectal temp was poor indicator of core temperature.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Moran, J. L., Peter, J. V., Solomon, P. J., Grealy, B., Smith, T., Ashforth, W., … Peisach, A. R. (2007). Tympanic temperature measurements: Are they reliable in the critically ill? A clinical study of measures of agreement. *Crit Care Med, 35*(1):155-64.	Purpose: To compare the accuracy of tympanic, urinary, and axillary temperatures with pulmonary artery (PA) core temperature measurements. Questions/ Hypothesis: 1. What was the agreement between and repeatability of each method, 2. Which covariates modified the performance of temperature measurements? 3. What inferences were afforded by the different methods of analysis?	Design: Prospective, observational cohort study Method: Tympanic, axillary and ear-based temperatures were measured every 4 hours for the first 72-hours and then every 6-hours for an additional 48 hours. Bladder and PA catheters inserted in patients when clinically indicated. Sample: Convenience sample (N=110) of adult patients admitted to critical care over 7-months. Setting: Tertiary, academic medical center	Measures/ Instruments: Axillary temperatures measured with glass mercury thermometers (Livingstone AS2190-1978 C), ear-based temps measured using Sherwood Medical First Temp (Nippon Sherwood Medical Industries, Tokyo, Japan); Bladder temps measured with thermistor foley catheter (Bard, Bard Medical, Convington, GA), PA temps measured with Baxter PA catheters (Baxter Healthcare Corporation, Irvine, CA) Appropriate, used Bland and Altman analysis.	PA temperatures had concordance with tympanic, urinary and axillary temperature (concordance=0.77, 0.92, and 0.83 respectively). None of the modes of temperature had a significant relationship with either APACHE II score or mean arterial pressure. In summary, agreement of tympanic and PA temperatures was inferior to urinary temperature. Patient age, sedation score and dialysis was negatively related to temperature ($p < 0.05$).	I	IV
Myny, D., De Waele, J., Defloor, T., Blot, S., & Colardyn, F. (2005). Temporal scanner thermometry: A new method of core temperature estimation in ICU patients. *Scott Med J, 50*(1):15-8.	Purpose: To evaluate the accuracy and variability of the temporal artery thermometer in ICU-patients. Questions/ Hypothesis: Compare the Temporal artery temperatures to axillary and pulmonary artery (PA) temperatures	Design: Prospective, descriptive design Method: Simultaneous measurements of temporal artery, axillary and PA temperatures within 3 minutes. Sample: Convenience sample of adult patients (N=57) with indwelling PA catheters Setting: Adult Critical Care Unit	Measures/ Instruments: Axillary temps measured with a digital electronic thermistor thermometer (Digital Classic® of Hartmann); TA temps measured with the Exergen Temporal Scanner LXTA® (Exergen), and the PA temperature was measured using the temperature probe of a PA catheter (Thermodilution Catheter®, Baxter Health Care). Appropriate Statistical Analysis: Bland Altman and ANOVA analyses used.	The three temperature measurements were significantly different ($F=9.33$, $df=2$; $p<0.001$). The temporal artery and PA temperatures were not significantly different. 2. The measurements of the temporal artery and axillary temperatures were significantly different; and the PA and axillary temperatures were also significantly different. 3. The use of vasopressor therapy did not significantly affect the accuracy of the temporal artery thermometer.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Odinaka, K.K., Edelu, B.O., Nwolisa, C.E., Amamilo, I.B. & Okolo, S.N.. (2014). Temporal artery thermometry in children younger than 5 years. *Pediatr Emerg Care, 30*(12):867-997. doi:10.1097/pec.0000000000000289	Purpose: This study compares the accuracy of the TA thermometry in children younger than 5 years using the rectal thermometry as the gold standard.	Design: Cross sectional study Method: Temperature measured simultaneously in eligible children Sample: n=156 males=81 females=75 aged 1 day to 59 months mean age of 10.8 + 13.6 months. Setting: Emergency	Measures/ Instruments: The difference between the mean temperatures obtained by the 2 thermometry methods was tested using the paired t test. Pearson correlation coefficient, linear regression, and Bland-Altman plot were also used to test the relationship and agreement between the 2 instruments. The sensitivity, specificity, and positive and negative predictive values were also calculated	Overall, the mean TA temperature (37.80°C ± 1.07°C) was significantly lower than the mean rectal temperature (38.07°C ± 0.95°C), $P < 0.001$. In neonates, however, the mean difference was not significant, 0.02 ± 0.59 ($P = 0.810$). There was a significant positive correlation between the rectal and the temporal temperatures ($r = 0.80$, $P < 0.01$). The Bland-Altman plot showed wide variation in the limit of agreement between the rectal and the TA temperatures which ranged from −1.02°C to +1.56°C. The sensitivity of the TA thermometer was 64.6%	I	VII
Onur, O. E., Guneysel, O., Akoglu, H., Aydin, Y. D., & Denizbasi, A. (2008). Oral, axillary, and tympanic temperature measurements in older and younger adults with or without fever. *Eur J Emerg Med, 15*(6):334-7.	Determine if tympanic digital measurements compare with mercury axillary and oral measurements	Design: Prospective, randomized comparison trial Sample: Convenience sample of 345 adults (17-96, mean 55.63 +/- 19.36). Setting: ED in Academic Medical Center	Measures/Instruments: TM measured with noncontact infrared thermometer (Braun ThermoScan IRT 1020, Germany); Oral and Axillary temps measured with standard mercury-filled thermometer. Statistical Analysis: Appropriate: ANOVA, paired t-test, correlation	No differences in age group comparisons (< 65 y.o. and > 65 y.o.). Differences between sites: • axillary to oral: -0.26 • axillary to tympanic: - 0.41 • axillary to tympanic#2: -0.43 • oral-tympanic: -0.15 • oral-tympanic#2: -0.16 No statistically significant differences between sites.	I	IV

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Paes, B. F., Vermeulen, K., Brohet, R. M., T, & de Winter, J. (2010). Accuracy of tympanic and infrared skin thermometers in children. *Arch Dis Child, 95*(12):974-8. doi:10.1136/adc.2010.185801	Purpose: To evaluate the accuracy and effectiveness of tympanic and infrared skin thermometers. Aims: 1) Evaluate the accuracy of tympanic and infrared skin thermometers and 2) to evaluate the influence of age, sex skin color, and otoscope abnormalities on temperature measurement.	Design: Prospective, comparative design Method: 7-temperature measurements taken: 2-tympanic, 2-pairs of infrared skin, and 1-rectal temperature. Sample: Convenience sample of pediatric patients (N=100); Mean age 3.24 years with range of 2 weeks to 18 years old. Setting: Pediatric unit of hospital	Measures/ Instruments: Rectal temps measured with Terumo digital clinical thermometer (C402; Terumo Corporation, Tokyo). TM temps measured with FirstTemp Genius tympanic thermometer (3000A; Kendall Healthcare, Mansfield, OH). Infrared skin temps measured with the Beurer (FT40; Beurer, Ulm, Germany) and Thermofocus (700A2; Technimed, Varese, Italy) infrared skin thermometers. Appropriate Statistical Analysis: Yes, descriptive, correlational and parametric statistical analyses used.	1. Significant differences of all temperature measurements compared to rectal. The Beurer infrared skin thermometer was the most inconsistent thermometer in comparison to rectal temperature. 2. The tympanic temperature had the best goodness of fit with rectal temperatures (regression coefficient=0.88). 3. The significant differences in the four thermometers evaluated could not be explained by variables of sex, age, skin color, and otoscopic abnormalities.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Penning, C., van der Linden, J. H., Tibboel, D., & Evenhuis, H. M. (2011). Is the temporal artery thermometer a reliable instrument for detecting fever in children? *J Clin Nurs, 20*(11-12):1632-9. doi:10.1111/j.1365-2702.2010.03568.x	Purpose: The primary purpose of this study was to determine the accuracy of the temporal artery thermometer for obtaining temperatures in children in the emergency department who were younger than 4 years.	*Design: Method comparison study design* *Method: Routine rectal temperature recording followed by temporal artery temperature.* *Sample: n=52 boys=31 girls=21* *Setting: Emergency Department & Child Care Center*	Measures/ Instruments: Data were summarized using descriptive statistics. Differences (bias) and limits of agreement (precision) between the test and reference devices were calculated and graphed according tothe Bland-Altman method.33–36 Acceptable ranges of values for bias and precision were determined a priori based on experts' recommendations (bias and precision of ≤±0.5°C) for use of a noninvasive thermometer to substitute for an invasive measure of core body temperature. A total of 52 children (31 boys and 21 girls) younger than 4 years were studied over a 10-month period. Ages of the children ranged from 2 weeks to 35 months, averaging 13.5 ± 8.0 (SD) months. Temperature differences (bias) and limits of agreement (precision) between the test and reference devices. Only the bias and precision values for the temporal artery thermometer were within the range of acceptable values.	Rectal temperatures ranged from 36.6°C to 40.1°C, with 15% (N = 18) of participants having temperatures >37.9°C. Only 4 of the 52 participants had moist foreheads at the time of temporal artery temperature measurement, with 3 of the4 having rectal temperatures >37.7°C. Mean (± SD) temperature, bias and precision, and temperature differences >±1.0°C and >±1.5°C for test temperature devices (axillary and temporal artery) and the rectal electronic temperature device in 52 children younger than 4 years who were admitted to the emergency department Temperature mean ± SD Test device—rectal temperature a Temperature differences >±1.0°C (%) Temperature differences >±1.5°C (%) Rectal 37.8 ± 0.8 Axillary 36.9 ± 0.6 –0.93 ± 0.49 22 (39) 7 (14) Temporal artery 37.4 ± 0.8 –0.46 ± 0.50 8 (15) 3 (6) aBias ± precision. For temporal artery temperatures, the percentage of temperature differences >±1.0°C and >±1.5°C from the reference standard temperatures was 15% and 6%, respectively. For axillary temperatures, the percentage of temperature differences >±1.0°C and >±1.5°C from the reference standard temperatures was 39% and 14%, respectively. Conclusion: Accuracy of TAT is low	I	VII

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Rajee, M., & Sultana, R. V. (2006). NexTemp thermometer can be used interchangeably with tympanic or mercury thermometers for emergency department use. *Emerg Med Australas, 18*(3):245-51.	Purpose: To determine level of agreement between chemical dot and mercury or tympanic thermometers	*Design: Prospective observational study. Sample: N: 194 adults, convenience sample. Age 18-91, median 51, 55% male. Setting : ED Australia, 250 bed hospital*	Measures/ Instruments: Chemical dot temps measured with NexTemp thermometer; Oral temps measured with standard mercury-filled thermometers; TM temps measured with Genius Model 300A (Sherwood Medical St. Louis, MO). Statistical Analysis: Appropriate: Bland and Altman analysis, sensitivity, specificity used.	1. No significant bias found between tympanic vs. chemical dot, tympanic vs. mercury, or chemical vs. mercury. 2. Sensitivity/specificity comparisons against mercury: Tympanic: Sens 60%, Spec 97% Chemical: Sens 80%, Spec 100%	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Reynolds, M., Bonham, L., Gueck, M., Hammond, K., Lowery, J., Redel, C., Rodriguez, C., … Craft, M. (2014). Are temporal artery temperatures accurate enough to replace rectal temperature measurement in pediatric ED patients? *J Emerg Nurs, 40*(1):46-50. doi:10.1016/j.jen.2012.007	Purpose: The primary purpose of this study was to determine the accuracy of the temporal artery thermometer for obtaining temperatures in children in the emergency department who were younger than 4 years.	*Design: Method comparison study design* *Sample: n=52 boys=31 girls=21* *Setting: ED*	Measures/ Instruments: Data were summarized using descriptive statistics. Differences (bias) and limits of agreement (precision) between the test and reference devices were calculated and graphed according tothe Bland-Altman method.33–36 Acceptable ranges of values for bias and precision were determined a priori based on experts' recommendations (bias and precision of ≤±0.5°C) for use of a noninvasive thermometer to substitute for an invasive measure of core body temperature. Rectal temperatures ranged from 36.6°C to 40.1°C, with 15% (N = 18) of participants having temperatures >37.9°C. Only 4 of the 52 participants had moist foreheads at the time of temporal artery temperature measurement, with 3 of the4 having rectal temperatures >37.7°C.	A total of 52 children (31 boys and 21 girls) younger than 4 years were studied over a 10-month period. Ages of the children ranged from 2 weeks to 35 months, averaging 13.5 ± 8.0 (SD) months. Mean (± SD) temperature, bias and precision, and temperature differences >±1.0°C and >±1.5°C for test temperature devices (axillary and temporal artery) and the rectal electronic temperature device in 52 children younger than 4 years. Temperature mean ± SD Test device—rectal temperature a Temperature differences >±1.0°C (%) Temperature differences >±1.5°C (%) Rectal 37.8 ± 0.8 Axillary 36.9 ± 0.6 –0.93 ± 0.49 22 (39) 7 (14) Temporal artery 37.4 ± 0.8 –0.46 ± 0.50 8 (15) 3 (6) aBias ± precision. Temperature differences (bias) and limits of agreement (precision) between the test and reference devices. Only the bias and precision values for the temporal artery thermometer were within the range of acceptable values. For temporal artery temperatures, the percentage of temperature differences >±1.0°C and >±1.5°C from the reference standard temperatures was 15% and 6%, respectively. For axillary temperatures, the percentage of temperature differences >±1.0°C and >±1.5°C from the reference standard temperatures was 39% and 14%, respectively. Conclusion: If properly used by ED staff, temporal artery thermometers could be used to obtain temperature in pediatric patients younger than 4 years.	I	VII

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Rogers, I. R., Brannigan, D., Montgomery, A., Khagure, N., Williams, A., & Jacobs, I. (2007). Tympanic thermometry is unsuitable as a screening tool for hypothermia after open water swimming. *Wilderness Environ Med, 18*(3):218-21.	Purpose: To determine whether infrared emission detection (IRED) tympanic temperature measurement taken in participants approximately 1 minute following a long-distance open water swimming event is a suitable screening tool for hypothermia.	Design/Method: Quasi-experimental design Sample: N=22, Convenience sample of contestants (15 males, 7 females) Setting: Persons participating in an open water swimming event Only those participants screened as hypothermic received oral temperature measurement (N=19)	Measures/ Instruments: Screening temperature using IVAC Core Check 2090 IRED tympanic thermometers set to core equivalent mode obtained 1 minute after leaving the water. Oral temperatures measured using glass low-temp thermometers. Oral/ tympanic paired temperatures measured 5 minutes after leaving the water Data analysis with SPSS -95% CI, paired t-test.	1. Statistically significant difference between oral and tympanic temperatures. 2. Infrared emission detection tympanic thermometry is unsuitable as a screening tool for hypothermia following prolonged open water swim because it substantially overestimates the incidence and severity of hypothermia in participants.	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Rubia-Rubia, J., Arias, A., Sierra, A., & Aguirre-Jaime, A. (2011). Measurement of body temperature in adult patients: Comparative study of accuracy, reliability and validity of different devices. *Int J Nurs Stud, 48*(7):872-80.	Purpose: To compare a range of alternative devices with core body temperature as measured by Pulmonary Artery Catheter (PAC). Questions/ Hypothesis: The best type of thermometer is a gallium-in-glass.	Design: Comparative design Method: Gallium-in-glass, reactive strip and digital in axilla, infrared ear and frontal thermometers were compared with the pulmonary artery core temperatures. Sample: 201 adult patients (> 18 y.o.) with pulmonary artery catheters. Setting: Intensive care unit in academic medical center in Canary Islands.	Measures/ Instruments: Gallium-in-glass in right axilla for 5min.; Gallium-in-glass in right axilla for 12min; Reactive strip in right axilla; Compact digital in right axilla; Digital with probe in right axilla; Infrared in right ear, core equivalency; Infrared in right ear, oral equivalency; Infrared frontal on right temple; Gallium-in-glass in right axilla for 5min.; Gallium-in-glass in right axilla for 12min.; Reactive strip in right axilla; Compact digital in right axilla; Digital with probe in right axilla; Infrared in right ear, core equivalency; Infrared in right ear, oral equivalency; Infrared frontal on right temple compared with PAC. Appropriate Statistical Analysis: Student's paired t-tests between PAC and other temperature readings and regression analysis.	1. The difference between PAC temperature and the other temperatures increased by 0.1-0.2 °C for each additional 1 OC. on PA reading. 2. Age, weight, level of consciousness, male gender, environmental temperature and vasoconstrictive medications all increased the difference in the readings. 3. The reliability with the lowest inter-rater and intra-rater reliability was the infrared ear thermometer and highest for the gallium-in-glass thermometer. 4. The gallium-in-glass thermometer for 12 minutes attained the highest score (i.e., validity, reliability, accuracy, external influence, waste, ease-of-use, speed, durability, security, comfort, and cost).	I	IV

Appendix 1: Evidence Table

Reference	Research/Purpose Questions/Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Schuh, S., Komar, L., Stephens, D., Chu, L., Read, S., & Allen, U. (2004). Comparison of the temporal artery and rectal thermometry in children in the emergency department. *Pediatr Emerg Care, 20*(11):736-41.	Identify agreement between temporal artery temperature measurement and rectal measurement in children less than 24 months of age.	Design: Prospective, cross-sectional study. Sample: 327 with temperature measurements by both methods, 313 had parent's measure temperature as well. Exclusion criteria: abnormal anorectal anatomy, immunosuppression, multiple trauma, airway instability, thermoregulatory abnormalities, unable to understand English. Setting: Tertiary care pediatric ED, 55000 annual visits.	TA professional model and TA consumer models used to measure TA temperatures Bland-Altman, 95% CI, ROC for fever detection of > 38 or 38.3 °C. Sensitivity, specificity, PPV, NPV, OR, LR	1. Reliability between professional model (TAPM) and rectal temperature was +0.19 +/- 0.66 and between the home model (TACM) was -0.11 +/- 0.47. The ability to detect fever of greater than 38.0 °C or 38.3 °C in the professional model was 90% (CI: 0.83-0.94) and 97% (CI: 0.92-0.99) and for the home model: 67% and 73%.	I	IV
Titus, M. O., Hulsey, T., Heckman, J., & Losek, J. D. (2009). Temporal artery thermometry utilization in pediatric emergency care. *Clin Pediatr, 48*(2):190-3. doi:10.1177/0009922 808327056.	Purpose: Compare measurements obtained via rectal and temporal artery thermometry. Questions/ Hypothesis: To determine the effectiveness of temporal artery temperature measurement in children 1 to 4 y.o.	Design: Prospective, cross-sectional Method: Rectal and temporal artery temperatures measured in subjects. Sample: Convenience sample (N=42) of children age 1-4 y.o. Setting: Tertiary Emergency Department	Measures/ Instruments: Temporal artery temperature measured with Exergen Temporal Scanner® (model TAT 5000); Rectal temperature measured with the Turbo Temp® (Alaris) Appropriate Statistical Analysis: Pearson correlations & multiple regressions conducted.	1. Pearson correlation between TAT and rectal temperatures was 0.91 ($p < 0.0001$). 2. The ROC analysis indicated that a cutoff of 37.7 O. or greater for TAT was equivalent to rectal temperatures > 38.3 OC --100% sensitivity; 93.5% specificity. 3. TAT is an effective screening tool in identifying fever in children age 1 to 4 years of age.	I	IV
Washington, G. T., & Matney, J. L. (2008). Comparison of temperature measurement devices in post anesthesia patients. *J Perinesth Nurs, 23*(1):36-48. doi: 10.1016/j.jopan.2007.10.001	Purpose: To determine if there was a relationship between oral and axillary temperature measurements to patient core temperatures obtained in the operating room (OR). Questions/ Hypothesis: To determine if there was sufficient agreement between each device and last OR core temperature to allow the devices to be used interchangeably.	Design: Descriptive, correlational Method: Subjects had oral and axillary temperatures measured consistently throughout PACU as compared to the core temperature obtained in OR prior to transfer to PACU Sample: 727 physiologically stable patients Setting: Postsurgical patients admitted to one of four PACU's.	Measures/ Instruments: Core temperatures measured in OR by anesthesiologist using esophageal temperature probe. Oral temperature measured using 3M Tempa-Dot® Single-use chemical thermometer (3M, St. Paul, MN) and axillary temperature measured with Alaris TURBO TEMP®. Appropriate Statistical Analysis: Descriptive and inferential statistics, as well as the Bland-Altman analysis was used.	1. Axillary temperature was approximately 0.5 °C lower than the OR core temperature--which was significantly different ($t=11.8$, $p < 0.001$); and the oral temperature was approximately 0.5 °C ° higher than the OR core temperature. 2. The axillary temperatures were significantly correlated with OR core temperatures ($r=0.53$, $p<0.001$); similarly oral temperatures were significantly correlated with OR core temperatures ($r=0.6$, $p<0.001$). 3. The use of a consistent device to assess patients' temperature can help to assure continuity of measurement.	I	IV

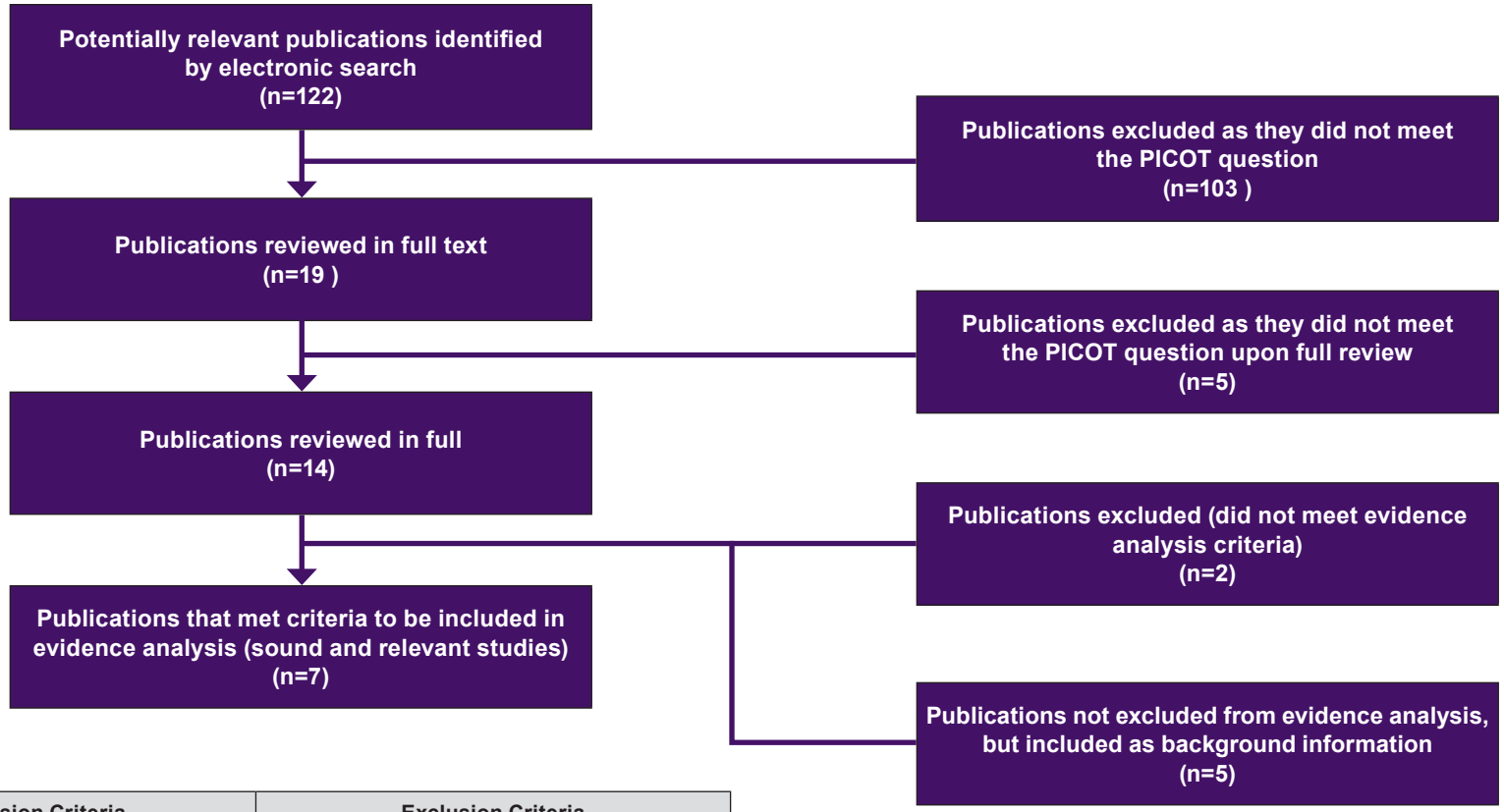
Appendix 2: Other Resources Table

Reference	Description	Conclusions
Apa, H., Gozmen, S., Bayram, N., Catikoglu, A., Devrim, F., Karaarslan, U., Gunay, I., … Devrim, I. (2013). Clinical Accuracy of tympanic thermometer and noncontact infrared skin thermometer in pediatric practice. *Pediatr Emerg Care, 29*(9): 992-7. doi:10.1097/pec.0b013e3182a2d419	Purpose: The aim of this study was to compare the body temperature measurements of infrared tympanic and forehead noncontact thermometers with the axillary digital thermometer	Temperatures With Ranges Tympanic n=1639 Mean= 36.8 (SD) =(0.92) Range=34.1-39.5 Forehead n=1639 Mean=37.0 (SD) =(0.66) Range=34.6-39.6 Axillary n=1639 Mean= 36.6 (SD) =(0.85) Range=34.3-39.8 There was not a high correlation of measured temperatures
Basak, T., Acikson, S., Tosun, B., Aygul, A., Acikel, C. (2013). Comparison of three different thermometers in evaluating the body temperature of healthy young adult individuals. *Int J Nurs Pract, 19*(5):471-8. doi:10.1111/ijn.12097	Purpose: Aim of this study was to compar the measurement values obtained with a non-contact infared thermometer, a tympanic thermometer and a chemical dot thermometer.	The agreement limits for non-contact infrared and chemical dot was between-1.30 and 0.32 o C; for non-contact infrared and typanic was between -1.26 and 0.13o C; and for chemical dot and typanic -0.89 and 0.74o C. It was determined that, although the measurement values of the typanic membrane and chemical dot thermometers conformed with each other, the conformity of the non-contact infrared thermometer was weak.
Bodkin, R., Acquisto, N., Zwart, J., Toussain, S. (2014). Differences in noninvasive thermometer measurements in the adult emergency department. *Am J Emerg Med, 32*(9):987-9. doi:10.1016?j.ajem.2014.05.036.	Purpose: Primary objective of the study was to compare temperature measurements from 2 commonly used noninvasive thermometer devices. Secondary objective was to determine if there was a larger discrepancy betweenthese devices in patients who were measured as febrile (defined as a temperature >38o C) by 1 or both devices	A total of 100 patients were identified. Mean oral temperature was 37.51 o C (SD +-1.25), and mean TA temperature was 37.03o C (SD +-0.94). Overall, 49% of patients had a difference in temperature measurements greater than or equal to 0.5o C. A total of 57% of fevers recorded by the oral thermometer were not recorded by the TA thermometer. There was a statistically significant difference in measured temperatures between oral and TA thermometers and a clinically significant difference in 49% of patients. Febrile patients had a greater discrepancy and variability between noninvasive temperature measurements. Caution should be taken when evaluating temperature measurements with these noninvasive devices.
Carleton, E., Fry, B., Mulligan, A., Bel, A., Brossart, C. (2012). Temporal artery thermometer use in the prehospital setting. *CJEM, 14*(1):7-13. doi:10.2310/8000.2011.110484	Purpose: The primary objective of this study was to assess the usefulness of the TAT in the prehospital setting.	A total of 818 patients had their temperatures taken with both thermometers in the prehospital setting. The relationship between the TAT and digital thermometer measurement was positive and moderate; however, there was poor agreement between the two devices.\Sixty-nine charts were reviewed, and a positive correlation was found between the TAT and the emergency department digital thermometer, with good agreement between the two devices. No extraneous factors were found to have a noticeable effect on the temperature measurement; the TAT performed well in cold weather and the EMS personnel reported it to be easy to use.
Crawford, D., Hicks, B., & Thompson, M. (2006). Which thermometer? Factors influencing best choice for intermittent clinical temperature assessment. *J Med Eng Technol, 30*(4):199-211. doi:10.1080/03091900600711464	Purpose: Evaluate the multiple methods available to intermittently measure temperature Research Questions: a) review the current technologies, b) examine comparative costing data for six selected representative devices and, c) discuss clinical factors related to the selection of devices for intermittent temperature measurement.	Mercury-in-glass thermometers have accuracy that can be verified by calibration. However they have long reading times and cannot be used orally in uncooperative patients or children. Chemical thermometers have a faster thermal response time than for mercury-in-glass thermometer. Has accuracy between 37 - 39 °C. Electronic contact thermometer and infrared sensing devices have fast reading times and easily accessible measurement sites. Contact/metallic liquid-in glass thermometers were the most cost-effective and the infrared sensing (ear) were the most costly.
El-Rhadi, A.S. & Patel, S. (2006). An evaluation of tympanic thermometry in a paediatric emergency department. *Emerg Med J, 23*(1):40-1. doi:10.1136/emj.2004.022764	Purpose: Determine the accuracy and usefulness of tympanic thermometers compared with axillary and rectal in infants.	Findings: tympanic more significantly correlates with rectal (r= 0.87), than axillary (r= 0.69). Similar findings in febrile infants: tympanic: r = 0.83, axillary: r = 0.67 both compared to rectal. Sensitivity to predict fever is 76% with tympanic of temp 38-38.9 °C and 100% with fever greater than 39 °C. Axillary is 24% of temps 38-38.9 °C, and 89% for temp 39 °C and greater

Appendix 2: Other Resources Table

Reference	Description	Conclusions
Gasim, G.I., Musa, I.R., Abdien, M.T., Adam, I.. (2013). Accuracy of tympanic temperature measurement using an infrared tympanic membrane thermometer. *BMC Res Notes, 6*(194). doi: 10.1186/1756-0500-6-194	Purpose: The aim of this study was to compare the accuracy of infrared tympanic thermometers in comparison to mercury thermometers in measurement of body temperature.	In total, temperature was measured in 174 patients, 95 of whom (54.6%) were male. The mean (SD) patient age and weight was 33.18 (25.07) years and 52.13 (69.85) kg. There was no significant difference in mean (SD) temperature measurement between mercury and infrared tympanic membrane thermometers, 37.29°C (0.91) versus 37.38°C (0.95), P = 0.373, respectively. There was a significant positive correlation between axillary and tympanic body temperature measurements (r = 0.697, P < 0.001). The mean difference between the two readings (with limits of agreements) was - 0.093 (−0.20; 0.02) °C. Conclusion: Tympanic membrane thermometry is as reliable and accurate as axillary mercury glass thermometry.
O'Grady, N., Barie, P., Bartlett, J., Bleck, T., Carroll, K., Kalil, A., & ... Masur, H. (2008). Guidelines for evaluation of new fever in critically ill adult patients: 2008 update from the American College of Critical Care Medicine and the Infectious Diseases Society of America. *Crit Care Med, 36*(4):1330-49. doi:10.1097/CCM.0b013e318169eda9	Purpose: Summarized guidelines/recommendations system for measuring temperatures in an adult patient in ICU who has previously been afebrile and in whom the source of fever is not initially obvious.	1Choose the most accurate and reliable method to measure temperature based on the clinical circumstances. Temperature is most accurately measured by an intravascular, esophageal, or bladder thermistor, followed by rectal, oral, and tympanic membrane measurements. Axillary measurements, temporal artery estimates, and chemical dot thermometers should not be used in the ICU. Any device used to measure temperature must be maintained and calibrated The site of temperature measurement should be recorded in the chart.

Appendix 3: Study Selection Flowchart and Inclusion/Exclusion Criteria



Inclusion Criteria	Exclusion Criteria
Studies published in English	Studies not published in English
Studies involving human subjects	Non-human studies
November 2011- October 2015	Studies not in the timeframe listed
Studies addressing the PICOT question	Studies not addressing the PICOT questions

The following databases were searched: PubMed, Google Scholar, CINAHL, Cochrane Library, BioMed Central-Open Access, Agency for Healthcare Research and Quality, and the National Guideline Clearinghouse.

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".

Appendix 4: 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.