TITLE: Thermometer Use for Febrile Pediatric Patients: A Review of Clinical Effectiveness, Accuracy, and Guidelines

DATE: 17 March 2016

CONTEXT AND POLICY ISSUES

Elevated body temperature, or fever, is one of the most frequently encountered pediatric problems, accounting for over 25% of pediatric emergency room visits.1-3 There are a variety of methods that are available to record body temperature, including invasive methods to measure the core temperature (such as pulmonary artery thermometry, distal esophagus thermometry, bladder thermometry and nasopharyngeal thermometry), and noninvasive methods to measure peripheral temperature (such as rectal thermometry, axillary thermometry, tympanic thermometry, and temporal artery thermometry, which in turn can be traditional mercury inglass, infrared, digital, skin (contact), or non-contact).4,5 Despite the availability of numerous devices to non-invasively detect fever, the search for an ideal thermometer to measure body temperature in pediatric patients has been a lasting debate among clinicians.6 While many studies have been done to assess the accuracy and reliability of different thermometers in children of all ages,7-11 or under five years of age,12-21 there is lack of evidence with regard to the best thermometer for febrile children under 2 years of age compared with older children, despite different types of thermometers having been used for these two populations in clinical practice.4

This Rapid Response report aims to review the clinical effectiveness of thermometer use for febrile pediatric patients two years of age and older and in patients younger than two years of age. Guidelines associated with the use of thermometers in febrile pediatric patients will also be examined.

RESEARCH QUESTIONS

1. What is the comparative clinical effectiveness of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age?
2. What is the comparative accuracy of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age?

3. What are the evidence-based guidelines associated with the use of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age?

KEY FINDINGS

Limited evidence showed that for febrile children either younger or older than 2 years old, digital temporal artery thermometry correlates well with digital rectal thermometry or traditional rectal glass mercury thermometry for detecting fever, and is more comfortable, offers significant savings in nursing time, and could replace rectal thermometry in a busy emergency room setting. In sick neonates and febrile children up to 2 years old, infrared skin (contact) temporal artery thermometer had low sensitivity and specificity for detecting fever ≥38°C, and a large difference in measurements (and low correlation) with the standard comparators (traditional axillary glass mercury thermometer or traditional rectal digital thermometer), while the infrared tympanic thermometer or digital axillary thermometer had smaller difference (and higher correlation) with the standard comparators. The infrared tympanic thermometry also showed reliability with measurements similar to digital rectal thermometry in both febrile and afebrile children up to 2 years old, and the effect extended to children up to 18 years old.

There was no evidence identified on the comparative clinical effectiveness, or evidence-based guidelines on the use of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age.

METHODS

Literature Search Strategy

A limited literature search was conducted on key resources including PubMed, The Cochrane Library, University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and major international health technology agencies, as well as a focused Internet search. For research question 3, a methodological filter was applied to limit retrieval to guidelines. For all other research questions, no filters were applied to limit the retrieval by study type. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between January 1, 2011 and February 18, 2016.

Selection Criteria and Methods

One reviewer screened the titles and abstracts of the retrieved publications and examined the full-text publications for the final article selection. Selection criteria are outlined in Table 1.
Table 1: Selection Criteria

<table>
<thead>
<tr>
<th>Population</th>
<th>Febrile pediatric patients (≥2 and &lt;2 years of age) presenting to the emergency room, operating room, pediatric units or clinics (including hospital and community)</th>
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</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>Temporal artery thermometer</td>
</tr>
<tr>
<td>Comparator</td>
<td>Tympanic thermometer; Rectal thermometer; Axilla thermometer</td>
</tr>
<tr>
<td>Outcomes</td>
<td>Comparative clinical effectiveness Accuracy (in patients ≥2 and &lt;2 years of age) Guidelines (use of all identified thermometer types in patients ≥2 and &lt;2 years of age)</td>
</tr>
<tr>
<td>Study Designs</td>
<td>Health technology assessments (HTA), systematic reviews (SR), meta-analyses (MA), randomized controlled trials (RCTs), non-RCTs, and evidence-based guidelines</td>
</tr>
</tbody>
</table>

Exclusion Criteria

Articles were excluded if they did not meet the selection criteria in Table 1, if the age groups were mixed and not distinctly divided into >2 or <2 years old, if they were published prior to January 2011, if they were duplicate publications of the same study, or if they were referenced in a selected systematic review.

Critical Appraisal of Individual Studies

The quality of the included diagnostic accuracy studies was assessed using the QUADAS checklist. Numeric scores were not calculated. Instead, the strengths and limitations of the study are summarized and presented narratively.

SUMMARY OF EVIDENCE

Quantity of Research Available

The literature search yielded 408 citations. After screening of abstracts from the literature search and from other sources, 24 potentially relevant studies were selected for full-text review. Five studies were included in the review. The PRISMA flowchart in Appendix 1 details the process of the study selection.

Summary of Study Characteristics

A detailed summary of the included studies characteristics is provided in Appendix 2.

Study design

Five diagnostic accuracy studies were included.

Population
One study included 40 children age 0 to 24 months (mean 10.9 months) with fever higher than 38°C, attending a children hospital. One study included 254 children 1 to 24 months old (median 7 months) with fever higher than 38°C, attending a private pediatric practice. One study included 663 sick newborns (fever status not reported), attending NICU (neonatal intensive care unit). One study included 50 febrile (fever higher than 38°C) and 50 afebrile children aged 2 to 12 years (mean age 6.1 and 6.15 years, respectively), attending the pediatric emergency room of a children’s hospital. One study included 94 febrile (fever higher than 38°C) and 111 afebrile children of all ages (mean age 66 months), attending a general hospital (outcomes were categorized into under or above 2 years old). In the included studies, children were included for assessment when fever was documented in the emergency departments or at some point during hospitalization (types of thermometers used not indicated).

Interventions and comparators

One study compared a digital temporal artery thermometer (Temporal Scanner) with a digital rectal thermometer (Sure Temp). One study compared an infrared skin (contact) temporal artery thermometer (VoiceThermo wdc 6603 B) and an infrared tympanic thermometer (ThermoScan 6022) with a traditional rectal digital thermometer as the standard comparator (brand not indicated). One study compared a digital axillary thermometer (Microlife MT3001), rectal glass mercury thermometer (brand not indicated), infrared tympanic thermometer (First Temp Genius) and infrared skin (contact) temporal artery thermometer (Thermoflash LX-26) with a traditional axillary glass mercury thermometer as standard comparator (brand not indicated). One study compared a digital axillary thermometer (Omron MC-106), infrared tympanic thermometer (Equinox ET 99), and digital temporal artery thermometer (Temporal Scanner) with a traditional axillary glass mercury thermometer (Hicks) as standard comparator. One study compared an infrared tympanic thermometer (ThermoScan PRO 4000) and infrared temporal artery thermometer (Temporal ScannerTM TAT-5000) with a digital rectal thermometer (Sure Temp) as standard comparator.

Outcomes

One study reported the correlation between measurements of the two types of tested thermometers, patient comfort, and required nursing time. One study reported the difference in measurements of the tested thermometers compared to the reference standard (rectal digital thermometer), limits of agreement (the range or scatter in which 95% of the measurement values which are different between the intervention and the comparator lie, relative to the zero-difference line; i.e., the smaller the scatter, the better the agreement), sensitivity and specificity. One study reported the correlation between the tested thermometers to the comparator, and clinical differences (defined as a mean difference of ≥0.2°C to the comparator measurements). One study reported the correlation between the tested thermometers to the comparator, limits of agreement, difference in measurements compared to the comparator, sensitivity, and specificity. One study reported the difference in measurements of the tested thermometers compared to the comparator.

Summary of Critical Appraisal

The included diagnostic accuracy studies have good validity (limited time period between reference and standard tests to minimize the possibility of a change in status between tests; test execution described in sufficient detail to permit their replication) and generalizability (selection criteria clearly described; patients representative of the population in practice) of results, except...
it is unclear whether the index test results were interpreted without knowledge of the results of the reference standard and whether the reference standard results were interpreted without knowledge of the results of the index test. A limitation common to all included studies was the use of rectal or axillary thermometry as standard comparator despite the fact that they do not necessarily reflect core body temperature.

Details of the strengths and limitations of the included studies are summarized in Appendix 3.

**Summary of Findings**

Main findings of included studies are summarized in detail in Appendix 4.

1. **What is the comparative clinical effectiveness of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age?**

There was no evidence found on the comparative clinical effectiveness of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age.

2. **What is the comparative accuracy of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age?**

For children up to 2 years old

**Digital temporal artery thermometer compared with digital rectal thermometer**

One study compared digital temporal artery thermometers with digital rectal thermometers as the reference standard in 40 children 0 to 24 months old (mean 10.9 months) with fever higher than 38°C, attending a children hospital.\(^{23}\)

Temporal artery and rectal measurements had a correlation of 0.776. Temporal artery measurements had a mean difference of +0.03 °C compared to rectal measurements (difference not statistically significant), and 94.7% of measurements differed by less than 1.0°C.

Patients experienced greater discomfort with the rectal thermometry method compared to the temporal artery method (\(P < 0.05\)). Temporal artery measurements required less nursing time for measurement (mean 47 seconds for rectal measurement, and 6 seconds for temporal artery measurement) (\(P < 0.01\)).

The authors concluded that temporal artery thermometry is as effective, more comfortable, and offers significant savings in nursing time when compared to rectal thermometry.

**Infrared skin temporal artery thermometer and infrared tympanic thermometer compared with traditional digital rectal thermometer**
One study compared infrared skin temporal artery thermometers and infrared tympanic thermometers with traditional digital rectal thermometers as the reference standard in 254 children 1 to 24 months old (median 7 months) with fever higher than 38°C, attending a private pediatric practice.  

Tympamic measurement was 0.1°C lower than rectal measurement, and temporal artery measurement was 0.15°C lower than rectal measurement. All differences were statistically significant, however these differences do not exceed the 0.2°C described in other studies as the threshold for clinical significance.  

Temporal thermometer was less sensitive and less specific than tympanic thermometer for detecting rectal fever ≥ 38°C.  

The limits of agreement were -0.73°C to +1.04°C for the tympanic measurement and -0.18°C to +1.64°C for the temporal artery measurement.  

The authors concluded that both the infrared tympanic and infrared skin temporal artery thermometers recorded lower temperatures than the traditional rectal thermometers. The limits of agreement were particularly wide for the temporal artery thermometer, and were recommended not to be used in pediatric practice.  

Digital axillary thermometers, glass mercury rectal thermometers, infrared tympanic thermometers, and infrared contact temporal artery thermometers compared with traditional glass mercury axillary thermometers  

One study compared digital axillary thermometers, rectal glass mercury thermometers, infrared tympanic thermometers, infrared skin temporal artery thermometers with traditional axillary glass mercury thermometers (AGMT) as the reference standard in 663 sick newborns attending NICU. This study did not mention fever as an inclusion criterion for its population, so this may be a confounding factor for the findings.  

Correlations to AGMT measurements were 0.94 for both digital axillary thermometers and tympanic thermometers, 0.74 for temporal artery thermometers, and 0.87 for rectal glass mercury thermometers.  

The mean difference to AGMT measurements was +0.02°C for digital axillary thermometers, +0.03°C for tympanic thermometers, +0.55°C for temporal artery thermometers, and +0.25°C for rectal glass mercury thermometers (all differences are statistically significant). When clinical difference was defined as a mean difference of ≥0.2°C, there was no difference between both mean AGMT vs digital axillary thermometer measurements, and AGMT vs infrared tympanic thermometer measurements.  

The authors concluded that the infrared tympanic thermometer could be a practical method for fever detection for sick newborns.  

For children ≥2 years old  

Digital axillary thermometers, infrared tympanic thermometers, digital temporal artery thermometers compared with traditional rectal glass mercury thermometers
One study compared digital axillary thermometers, infrared tympanic thermometers, and digital temporal artery thermometers with traditional rectal glass mercury thermometers (reference standard) in 50 febrile and 50 afebrile children aged 2 to 12 years attending the pediatric emergency room of a children hospital.26

In febrile children, correlations to traditional rectal glass mercury thermometer measurements were 0.96 for axillary thermometers, 0.92 and 0.93 for right and left tympanic thermometers, and 0.99 for temporal artery thermometers.

The limits of agreement were 0.19 to 1.68 for the axillary measurement, -0.24 to 1.37 and -0.15 to 1.24 for the right and left tympanic thermometers, and -0.24 to 0.26 for the temporal artery thermometer.

Sensitivity for detecting rectal fever was 80% for the axillary thermometer, 98% for the tympanic thermometer, and 80% for the temporal artery thermometer.

Specificity for detecting rectal fever was 100% for the axillary thermometer, 98% for the tympanic thermometer, and 98% for the temporal artery thermometer.

The authors concluded that digital temporal artery thermometry has the potential to replace traditional rectal thermometry in a busy emergency room setting.

For children 0 – 2 years old compared with >2 years old

Infrared tympanic thermometer and infrared temporal artery thermometer compared with digital rectal thermometer

One study compared infrared tympanic thermometer and infrared temporal artery thermometers with digital rectal thermometers (reference standard) in 205 febrile and afebrile children of all ages attending a general hospital.27 Outcomes were categorized into children 0 to 24 month and >24 month. This study did not separate data for febrile and non-febrile populations which may be a confounding factor for its findings.

In children 0 to 24 months, the mean differences from rectal measurements were -0.06 ± standard deviation (SD) 0.43 for tympanic thermometers, and -0.30 ± SD 0.64 for temporal artery thermometers.

In children >24 to 48 month, the differences were 0.11 ± SD 0.42 for tympanic thermometers, and -0.08 ± SD 0.48 for temporal artery thermometers. In children >4 to 10 years old, the differences were -0.02 ± SD 0.42 for tympanic thermometers, and -0.18 ± SD 0.66 for temporal artery thermometers. In children >10 to 18 years old, the differences were -0.02 ± SD 0.24 for tympanic thermometer, and -0.09 ± SD 0.51 for temporal artery thermometer.

The authors concluded that the infrared tympanic thermometer provides measurements closer to those of a professional grade contact thermometers when compared to the infrared temporal artery thermometer.
3. **What are the evidence-based guidelines associated with the use of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age?**

There were no evidence-based guidelines identified associated with the use of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age.

**Limitations**

One limitation of the diagnostic accuracy studies comparing different types of thermometers is that they used rectal or axillary thermometers measurements as the standard comparators, despite the fact that these thermometers may not reflect the body core temperature. Some studies did not separate data on febrile from afebrile patients, which is a potential confounding factor. The difference in types of thermometers used among included studies made the overall conclusion difficult. There is no evidence on the evidence-based guidelines associated with the use of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age.

**CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING**

Limited evidence showed that for febrile children either younger or older than 2 years old, digital temporal artery thermometry correlates well with digital rectal thermometry or traditional rectal glass mercury thermometry for detecting fever, and is more comfortable, offers significant savings in nursing time, and could replace rectal thermometry in a busy emergency room settings. In sick neonates and febrile children up to 2 years old, infrared skin (contact) temporal artery thermometers against in pediatric practice due to their low sensitivity and specificity for detecting fever ≥38ºC, and large difference in measurements (and low correlation) with the standard comparators (traditional axillary glass mercury thermometer or traditional rectal digital thermometer). Infrared tympanic thermometers or digital axillary thermometers had smaller differences (and higher correlation) with the standard comparators. Infrared tympanic thermometry also showed reliability with similar measurements as the digital rectal thermometry in both febrile and afebrile children up to 2 years old, and the effect extended to children up to 18 years old.

The evidence on the comparative accuracy of different types of thermometers is limited. More studies, especially with core body temperature used as comparator, are needed to draw a conclusive comparison. There was no evidence identified on the comparative clinical effectiveness, or evidence-based guidelines on the use, of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age.

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REFERENCES


Appendix 1: Selection of Included Studies

408 citations identified from electronic literature search and screened

384 citations excluded

24 potentially relevant articles retrieved for scrutiny (full text, if available)

24 potentially relevant reports

0 relevant reports retrieved from other sources (grey literature, hand search)

19 reports excluded (irrelevant population, interventions or outcomes)

5 reports included in review
Appendix 2: Characteristics of Included Studies

<table>
<thead>
<tr>
<th>First Author, Year, Country</th>
<th>Study Objectives</th>
<th>Interventions/Comparators</th>
<th>Patients</th>
<th>Main outcomes</th>
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<tbody>
<tr>
<td>Carr, 2011, US</td>
<td>&quot;This descriptive study compared temporal artery (TA) and rectal temperature measurements, patient comfort during temperature measurements, and nursing time required to obtain temperature Measurements&quot; (p 179)</td>
<td>Digital temporal artery thermometer (Temporal Scanner)</td>
<td>40 children 0 – 24 months old (mean 10.9 months) with fever higher than 38°C, attending a children hospital 900 measurements</td>
<td>Correlation between measurements from the 2 types of thermometers Patient comfort Required nursing time</td>
</tr>
<tr>
<td>Teller, 2013, Switzerland</td>
<td>&quot;To compare infrared tympanic and infrared contact forehead thermometer measurements with traditional rectal digital thermometers.&quot; (p e80)</td>
<td>Infrared contact (skin) temporal artery infrared thermometer (VoiceThermo wdc 6603 B™) Infrared tympanic thermometer (ThermoScan 6022™) Standard comparator: Traditional digital rectal thermometer (brand not indicated)</td>
<td>254 children 1 – 24 months old (median 7 months) with fever higher than 38°C, attending a private pediatric practice Number of measurements not indicated</td>
<td>Difference in measurements compared to comparator (traditional rectal digital thermometer measurements) Sensitivity Specificity Limits of agreement</td>
</tr>
<tr>
<td>Uslu, 2011, Turkey</td>
<td>&quot;We aimed to compare the accuracy of digital axillary thermometer (DAT), rectal glass mercury thermometer (RGMT), infrared tympanic thermometer (ITT) and infrared forehead skin thermometer (IFST) measurements with traditional axillary glass mercury thermometer (AGMT) for intermittent temperature measurement in sick newborns&quot; (p 418)</td>
<td>Digital axillary thermometer (Microlife MT3001™) Glass mercury rectal thermometer (brand not indicated) Infrared tympanic thermometer (First Temp Genius) Infrared skin temporal artery thermometer (Thermoflash LX-26) Standard comparator: Traditional axillary glass mercury thermometer (brand not indicated)</td>
<td>663 sick newborns (fever levels not reported), attending NICU (neonatal intensive care unit) 1989 measurements</td>
<td>Correlation to comparator (traditional axillary glass mercury thermometer measurements)</td>
</tr>
<tr>
<td>First Author, Year, Country</td>
<td>Study Objectives</td>
<td>Interventions/Comparators</td>
<td>Patients</td>
<td>Main outcomes</td>
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</table>
| Batra, 2013, India          | “to compare different methods of temperature measurement available in the emergency room, that is, rectal, axillary, and temporal artery and tympanic membrane” (p 63) | Digital axillary thermometer (Omron MC-106)  
Infrared tympanic thermometer (Equinox ET 99)  
Digital temporal artery thermometer (Temporal Scanner)  
Standard comparator: Traditional rectal glass mercury thermometer (Hicks) | 50 febrile and 50 afebrile children aged 2 to 12 years (mean age 6.1 and 6.15 years, respectively), attending pediatric emergency room of a children hospital  
Number of measurements not indicated | Correlation to comparator (traditional rectal glass mercury thermometer measurements)  
Limits of agreement  
Difference in measurements compared to comparator (traditional rectal glass mercury thermometer measurements)  
Sensitivity  
Specificity |
| Hamilton, 2013 Argentina, US| “This study compared readings from two professional-grade, commercially available infrared (IR) thermometers, the ThermoScan® PRO 4000 prewarmed tip ear thermometer and the Temporal ScannerTM TAT-5000 temporal artery thermometer.” (p 2509) | Infrared tympanic thermometer (ThermoScan® PRO 4000)  
Digital temporal artery thermometer (Temporal ScannerTM TAT-5000)  
Standard comparator: Digital rectal thermometer (Sure Temp) | 205 febrile and afebrile children of all ages (mean age 66 months), attending a general hospital  
Number of measurements not indicated | Difference in measurements compared to comparator (rectal digital thermometer measurements)  
(Differences were categorized according to age range [0 – 24 months and above]) |
## Appendix 3: Summary of Critical Appraisal of Included Studies

<table>
<thead>
<tr>
<th>First Author, Publication Year</th>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Critical appraisal of included diagnostic accuracy studies (Quadas</strong>—<strong>:)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carr,** 2011</td>
<td>Validity: the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests; the execution of the index test described in sufficient detail to permit replication of the test; the execution of the reference standard described in sufficient detail to permit its replication</td>
<td>Validity: Unclear whether the index test results were interpreted without knowledge of the results of the reference standard; unclear whether the reference standard results interpreted without knowledge of the results of the index test.</td>
</tr>
<tr>
<td></td>
<td>Generalizability of results: spectrum of patients representative of the patients who will receive the test in practice; selection criteria clearly described</td>
<td>A limitation of this study was the use of rectal thermometry as standard comparator because it does not necessarily reflect core body temperature.</td>
</tr>
<tr>
<td>Teller,** 2013</td>
<td>Validity: the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests; the execution of the index test described in sufficient detail to permit replication of the test; the execution of the reference standard described in sufficient detail to permit its replication</td>
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<td>Generalizability of results: spectrum of patients representative of the patients who will receive the test in practice; selection criteria clearly described</td>
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<td>Uslu,** 2011</td>
<td>Validity: the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests; the execution of the index test described in sufficient detail to permit replication of the test; the execution of the reference standard described in sufficient detail to permit its replication</td>
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</tr>
<tr>
<td></td>
<td>Generalizability of results: spectrum of patients representative of the patients who will receive the test in practice; selection criteria clearly described</td>
<td>A limitation of this study was the use of axillary thermometry as standard comparator because it does not necessarily reflect core body temperature.</td>
</tr>
<tr>
<td>Batra,** 2013</td>
<td>Validity: the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests; the execution of the index test described in sufficient detail to permit replication of the test; the execution of the reference standard described in sufficient detail to permit its replication</td>
<td>Validity: Unclear whether the index test results were interpreted without knowledge of the results of the reference standard; unclear whether the reference standard results interpreted without knowledge of the results of the index test.</td>
</tr>
<tr>
<td></td>
<td>Generalizability of results: spectrum of patients representative of the patients who will receive the test in practice; selection criteria clearly described</td>
<td>A limitation of this study was the use of rectal thermometry as standard comparator because it does not necessarily reflect core body temperature.</td>
</tr>
</tbody>
</table>
Table A2: Summary of Critical Appraisal of Included Study

<table>
<thead>
<tr>
<th>First Author, Publication Year</th>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamilton, 2013</td>
<td>Validity: the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests; the execution of the index test described in sufficient detail to permit replication of the test; the execution of the reference standard described in sufficient detail to permit replication. Generalizability of results: spectrum of patients representative of the patients who will receive the test in practice; selection criteria clearly described.</td>
<td>Validity: Unclear whether the index test results were interpreted without knowledge of the results of the reference standard; unclear whether the reference standard results interpreted without knowledge of the results of the index test. A limitation of this study was the use of rectal thermometry as standard comparator because it does not necessarily reflect core body temperature.</td>
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</table>
Appendix 4: Main Study Findings and Authors’ Conclusions

<table>
<thead>
<tr>
<th>First Author, Publication Year</th>
<th>Main Study Findings</th>
<th>Authors’ Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research question 1 (comparative clinical effectiveness of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age)</td>
<td>There was no evidence found on the comparative clinical effectiveness of temporal artery thermometers with tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age</td>
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<tr>
<td>Research question 2 (comparative accuracy of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age)</td>
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</tbody>
</table>
| Carr, 2011 | Pearson’s correlation between digital temporal artery and digital rectal measurements: $r = 0.776$  
Mean difference: 0.03°C (temporal artery measurement higher than rectal measurement)  
94.7% of measurements differ by less than 1.0°C  
Patient comfort (from pain assessment scores)  
Greater discomfort experience with the digital rectal thermometry method compared to the digital temporal artery method ($P < 0.05$)  
Nursing time  
Digital rectal measurement: mean 47 seconds  
Digital temporal artery measurement: 6 seconds (87% nursing costs savings) | "The findings of this study support that TA thermometry is at least as effective, more comfortable, and offers significant savings in nursing time and associated nursing cost when compared to rectal thermometry" (p 183) |
| Teller, 2013 | Measurements compared to traditional digital rectal measurements (median; range)  
Infrared tympanic measurement: median 0.1°C (-0.1 to -0.4; $P < 0.1$) lower than rectal measurement  
Infrared contact temporal artery measurement: median 0.15°C (-0.3 to -0.7; $P < 0.05$) lower than rectal measurement  
Sensitivity for detecting rectal fever $\geq 38^\circ C$  
Infrared tympanic: 0.72 (95% confidence interval CI 0.62 to 0.80)  
Infrared contact temporal artery: 0.42 (95% CI 0.32 to 0.52)  
Specificity for detecting rectal fever $\geq 38^\circ C$  
Infrared tympanic: 0.97 (95% confidence interval CI 0.93 to 0.99)  
Infrared contact temporal artery: 0.42 (95% CI 0.92 to 0.99)  
Limits of agreement (95% CI; Bland-Altman plot)  
Infrared tympanic measurement: range -0.73°C to +1.04°C  
Infrared contact temporal artery measurement: range -0.18°C to +1.64°C | "Both the tympanic and forehead devices recorded lower temperatures than the rectal thermometers. The limits of agreement were particularly wide for the forehead thermometer and considerable for the tympanic thermometer. In the absence of valid alternatives, because of the ease to use and little degree of discomfort, tympanic thermometers can still be used with some reservations. Forehead thermometers should not be used in paediatric practice.” (p e80) |
| Uslu, 2011 | Pearson’s correlation to traditional axillary glass mercury thermometer (AGMT) measurements  
Digital axillary thermometer: $r = 0.94$  
Infrared tympanic thermometer: $r = 0.94$  
Infrared temporal artery skin thermometer: $r = 0.74$  
Glass mercury rectal thermometer: $r = 0.87$  
Difference to traditional glass mercury axillary thermometer | "Our study suggests that tympanic thermometer measurement could be used as an acceptable and practical method for sick newborn in neonatal units.” (p 418) |
<table>
<thead>
<tr>
<th>First Author, Publication Year</th>
<th>Main Study Findings</th>
<th>Authors’ Conclusions</th>
</tr>
</thead>
</table>
| (AGMT) measurements (mean) | Digital axillary thermometer: +0.02°C  
Infrared tympanic thermometer: +0.03°C  
Infrared contact temporal artery thermometer: +0.55°C  
Glass mercury rectal thermometer: +0.25°C  
(all differences are statistically significant) | "Temporal artery thermometry has the potential to replace rectal thermometry in a busy emergency room setting." *(p 63)* |
| Batra, 2013 | Pearson’s correlation to traditional rectal glass mercury thermometer measurements *in febrile children*  
Digital axillary thermometer: \( r = 0.96 \)  
Infrared tympanic thermometer  
- Right: \( r = 0.92 \)  
- Left: \( r = 0.93 \)  
Digital temporal artery thermometer: \( r = 0.99 \)  
95% limits of agreement (Bland-Altman plot) *in febrile children*  
Digital axillary thermometer: 0.19 to 1.68  
Infrared tympanic thermometer  
- Right: -0.24 to 1.37  
- Left: -0.15 to 1.24  
Digital temporal artery thermometer: -0.24 to 0.26  
Pearson’s correlation to traditional rectal glass mercury thermometer measurements *in afebrile children*  
Digital axillary thermometer: \( r = 0.77 \)  
Infrared tympanic thermometer  
- Right: \( r = 0.74 \)  
- Left: \( r = 0.72 \)  
Digital temporal artery thermometer: \( r = 0.91 \)  
Limits of agreement (95% CI; Bland-Altman plot) *in afebrile children*  
Digital axillary thermometer: -0.14 to 0.96  
Infrared tympanic thermometer  
- Right: -0.17 to 0.92  
- Left: -0.20 to 0.91  
Digital temporal artery thermometer: -0.36 to 0.30  
Sensitivity for detecting rectal fever  
Digital axillary thermometer: 80%  
Infrared tympanic thermometer: 98%  
Digital temporal artery thermometer: 80%  
Specificity for detecting rectal fever  
Digital axillary thermometer: 100%  
Infrared tympanic thermometer: 98%  
Digital temporal artery thermometer: 98% | |
| Hamilton, 2013 | Measurements compared to rectal measurements (mean ± SD)  
0 – 24 months  
Infrared tympanic thermometer: -0.06 ± 0.43  
Digital temporal artery thermometer: -0.30 ± 0.64 | "This study indicates that the ThermoScan PRO4000 provides measurements closer to those of a professional grade contact thermometer when compared to the Temporal Scanner TAT-5000." *(p 2509)* |
Table A3: Main Study Findings and Authors’ Conclusions

<table>
<thead>
<tr>
<th>First Author, Publication Year</th>
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<th>Authors’ Conclusions</th>
</tr>
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</table>
| >24 – 48 months                | Infrared tympanic thermometer: 0.11 ± 0.42  
                              | Digital temporal artery thermometer: -0.08 ± 0.48 |                      |
| >4 – 10 year                   | Infrared tympanic thermometer: -0.02 ± 0.42  
                              | Digital temporal artery thermometer: -0.18 ± 0.66 |                      |
| >10 – 18 year                  | Infrared tympanic thermometer: -0.02 ± 0.24  
                              | Digital temporal artery thermometer: -0.09 ± 0.51 |                      |

Research question 3 (evidence-based guidelines associated with the use of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age)

There were no evidence found on the evidence-based guidelines associated with the use of temporal artery, tympanic, rectal, or axilla thermometers in febrile pediatric patients two years of age and older and in patients younger than two years of age.