Non-contact infrared thermometers

Horizon Scan Report 0025
November 2013

Clinical Question: What is the accuracy and utility of non-contact infrared thermometers compared to other methods of measuring temperature in children?

Background, Current Practice and Advantages over Existing Technology:

Temperature is one of the vital signs used by clinicians, parents and carers to assess children during acute illness episodes. It is measured using electronic contact thermometers (rectal, oral, axillary), chemical thermometers (axillary, forehead) or infrared thermometers (tympanic, temporal artery). Mercury-in-glass thermometers are no longer used in the European Union (1) and have not been available for purchase in the UK since April 2009 (2).

Although rectal thermometry is considered to be the most reliable method of measuring temperature in babies and young children (3), the procedure is poorly tolerated, since the thermometer is inserted just over 1 cm into the rectum and left in situ for approximately 10 seconds (4). Some children also find oral temperature measurements uncomfortable or painful (5). To measure oral temperature, the thermometer should be inserted under the tongue and the child's mouth kept closed for around 20 seconds (4).

Axillary thermometers are less invasive than oral or rectal thermometers but need to be placed high in the axilla with the arm held closely to the side for the time required to obtain an accurate measurement, sometimes 30 seconds or longer (4). Infrared tympanic thermometers may provide a more convenient means of measuring temperature in preschool children, as the ear is readily accessible and readings can be obtained within seconds (6). However, a systematic review comparing infrared tympanic thermometry to rectal thermometry reported poor agreement between these two methods, although the review did not evaluate several potential sources of heterogeneity, which may have compromised the accuracy of tympanic temperature measurements, including otitis media, ear wax and insufficient straightening of the ear canal (3).

Non-contact infrared thermometers (NCITs) can be used to measure temperature rapidly and non-invasively, potentially causing less distress to children than conventional methods. Like infrared tympanic thermometers, NCITs can provide temperature readings within seconds. Most NCITs measure temperature over the central forehead area, but temperature over other body surfaces may also be measured if the child's forehead is perspiring or if the child is moving. NCITs can also measure children's temperature while they are sleeping. Since the use of NCITs does not involve any

body surface contact, the risk of cross-infection is negligible and neither disinfection nor disposable probe covers are needed.

Details of Technology:

Table 1 summarises the characteristics of a range of currently available NCITs. The Thermofocus thermometers (Tecnimed, Italy) have received FDA and CE approval for use in clinical settings. The manufacturers recommend that temperature should be measured over body surfaces which are not perspiring or covered by hair in a draft-free room at a constant temperature between 16°C and 40°C.

The most basic model is the Thermofocus 0700A2, which can be used to measure temperature by holding the thermometer over the central forehead. Thermometers in the Thermofocus 01500 series can also be used to measure temperature over other areas of the body, including the neck, umbilicus and axilla.

Temperature measurements are obtained by holding the Thermofocus thermometer approximately 3 cm from the body surface. An LED system emits two tracker light beams, which converge to form a single red spot at the correct measurement distance. The thermometer's internal software applies a correction, taking into account the room temperature, to give a temperature value approximately equivalent to oral temperature. Thermofocus 01500 thermometers can also be programmed to calculate temperature values approximately equivalent to rectal temperature. A temperature reading is obtained within one second and further temperature measurements can be obtained immediately afterwards.

Other NCITs are also available, which can measure temperature when held up to 15 cm away from the child's forehead (Extech IR200, Professional Clinical RY210). The Medisana 76120 (Medisana AG, Germany) and Microlife NC100 (Microlife AG, Switzerland) thermometers give fever warnings for temperatures above 37.5°C. The Syner-Med VeraTemp NCIT (American Scientific Resources Inc, Washington, USA) gives traffic-light-style fever alerts (green if temperature is 36.3 to 37.3°C, orange if temperature is 37.4 to 37.9°C and red if temperature is greater than 38.0°C). The Thermofocus thermometers give high temperature warnings for temperatures above 40°C. The Professional Clinical RY210 (Santa Medical, Tustin, USA) has an adjustable audio alarm for high temperature.

Table 1: Non-contact infrared thermometers – summary of characteristics

Thermometer	Temperature range (°C)	Optimum distance for measuring temperature	Other comments
£30 to £50			
Medisana® 76120 Infrared Digital Thermometer (Medisana AG, Germany)	34 to 42.2	Up to 5 cm	CE marked. Temperature reading can be obtained within 1 second. Fever alarm for temperatures >37.5°C.
Microlife® NC100 Non-Contact Thermometer (Microlife AG, Switzerland)	34 to 42.2	Up to 5 cm	Takes 3 seconds to obtain reading. Fever warnings if temperature >37.5°C (red LCD backlight, optional alarm).
Syner-Med VeraTemp™ Non-Contact	32 to 42.9	5-8 cm	FDA approved and CE marked. Traffic light style temperature

Thermometer (American Scientific Resources Inc, Washington, USA)			alerts. Display is green if temperature is 36.3 to 37.3°C, orange if temperature is 37.4 to 37.9°C and red if temperature is greater than 38°C.
£50-£70			
Extech® IR200 (Extech Instruments Corporation, Nashua, USA)	30 to 40.3	5 to 15 cm	CE marked. Takes 0.5 seconds to obtain reading.
Thermofocus® 0700A2 (Technimed, Italy)	34 to 42.5	Approx 3 cm	FDA approved and CE marked. Takes less than 1 second to obtain reading. High temperature warnings for temperatures above 40°C. Gives temperature reading approximately equivalent to oral temperature.
Over £70			
Professional Clinical RY210 Large LCD Non Contact Infrared Thermometer (Santa Medical, Tustin, USA)	32 to 43	5-15 cm	Takes less than 1 second to obtain reading. Adjustable audio alarm for high temperature.
Thermofocus® 01500 series (Tecnimed, Italy)	34-42.5	Approx 3 cm	As for ThermoFocus® 0700A2. Can also measure temperature at distance on other parts of the body e.g. neck, umbilicus, axilla. Can give temperature readings approximately equivalent to oral or rectal temperature.

Patient Group and Use:

- Measuring temperature in children who present with fever or acute illness in primary care settings (general practice, out-of-hours primary care centres and emergency departments).
- Screening for fever in children with acute illness during disease outbreaks (e.g. influenza season).
- Monitoring temperature in children being managed at home during an acute illness episode.

Importance:

Fever is one of the commonest reasons for parents taking their child to see a doctor (5). A large prospective cohort study of preschool children in South West England found that, of those who reported having a high temperature, the proportion of children who consulted a doctor ranged between 20% in children under 6 months of age and 39% in children aged 6 to 17 months (7).

Fever has been reported in 31% of preschool and young school aged children presenting in a range of primary care settings including GP surgeries, emergency departments, walk-in centres and out-of-hours centres (8). Fever in children is also a common reason for calls to NHS Direct, a nurse-led telephone health helpline which can be accessed by callers from England and Wales. During a two-year period, NHS Direct received over 270,000 calls regarding fever, of which 67% concerned children under the age of 4 years (9).

A recent systematic review demonstrated that a temperature of 40°C or more has value as a red flag for serious infection in populations where the prevalence of serious infection is low (10). According to UK Hospital Episode Statistics, the incidence of serious infections in children aged 0 to 5 years is 1445 per 100,000 children, the majority of which is due to pneumonia, septicaemia or urinary tract infection (5). As well as being an important measurement in its own right, it is also important for clinicians to take temperature into account when interpreting the significance of heart rate and respiratory rate measurements in children (11).

Previous Research:

Accuracy compared to existing technology

Table 2 summarises the characteristics of studies comparing NCITs to other thermometers. Three studies were conducted in ambulatory settings (12-14), one in a hospital inpatient setting (15) and two in a combination of primary care and hospital settings (16, 17). All except one of these studies (15) compared Thermofocus NCITs with other thermometers. In all studies, NCIT temperature measurements were taken over the central forehead area.

One study compared the Thermofocus 0800 with mercury in-glass axillary thermometry(12) (n=251) and another with the Alaris® Tri-Site electronic thermometer (Alaris® Tri-Site, n=855; Thermofocus 0800, n=706), which was used to measure rectal, oral or axillary temperature according to age-appropriate methods (14). Readings from Thermofocus 0800 were strongly correlated with axillary temperatures (r2 = 0.837, p<0.001) (12). The mean difference between Thermofocus and axillary temperatures was 0.07°C and limits of agreement were -0.62°C to 0.76°C (i.e. ±1.96 standard deviations) (12). A moderate Pearson correlation was observed with the Alaris® Tri-Site thermometer (r=0.66, p<0.001) (14).

NCIT temperature readings correlated strongly with rectal temperatures (17) measured using mercury-in-glass thermometers. The mean difference compared to rectal temperature measured using a mercury-in-glass thermometer was 0.029°C; values for limits of agreement were not reported (17). However, another study found only moderate agreement with electronically measured rectal temperature (13). Furthermore, rectal temperature was overestimated in patients with lower temperatures and underestimated in patients with higher temperatures by the Thermofocus 01500 thermometer (r2 = 0.149, p<0.01). In contrast, the Standard ST 8812 NCIT was more likely to underestimate tympanic temperature in patients with lower temperatures (15).

One study reported a weak correlation between temperatures measured using the Thermofocus 01500, the Braun Thermoscan IRT 3020 (an infrared tympanic thermometer), the Exergen TemporalScanner TAT 2000C (a temporal artery thermometer) and the Omron MC-600 (an electronic axillary thermometer) (r = 0.17, r^2 = 0.029, p<0.0001) (16). The strongest agreement between these four methods was observed in children aged 1 to 5 years (r = 0.65, r^2 = 0.37, p<0.0001). Comparisons between the Thermofocus 01500 and each of the other thermometers alone were not reported. The authors reported that statistically significant correlations were observed between Thermofocus temperature measurements taken at different sites (forehead, umbilicus and axilla) and using different models of thermometer (01500, 0900, 0800 and 0700), but did not report on the strength of these correlations.

Table 2: Summary of studies comparing non-contact infrared thermometers to other thermometers

Study (reference) (N = number of participants)	Population and setting	Non contact infrared thermometer	Comparator	Agreement
Chiappini 2011 (12) (N = 251)	Children aged 1 month to 18 years presenting in range of primary care settings[a].	Thermofocus® 0800 (Tecnimed, Italy)	Mercury in-glass axillary thermometer (Thermovedo®, Italy)	$r^2 = 0.837$, $p<0.001$[b]
Fortuna 2010 (13) (N = 200)	Children aged 1 month to 4 years presenting to a tertiary paediatric emergency department.	Thermofocus® 01500 (Technimed, Italy)	Electronic rectal thermometer (Welch Allen SureTemp®, model 678)	$r^2 = 0.48$, $p<0.01$[b]
Selent 2013(14) (N = 855[c])	Children < 18 years old presenting in a paediatric hospital emergency department.	Thermofocus® 0800 (Tecnimed, Italy)	Alaris® Tri-Site electronic thermometer (Alaris Medical Systems Inc, San Diego, California, USA)	$\rho=0.66$, $p<0.001$[d]
Ng 2005 (15) (N = 567)	Children aged 1 month to 18 years admitted to general paediatric ward.	Standard ST 8812 (Standard Instruments Co, Hong Kong SAR, China)	Infrared tympanic thermometer (FirstTemp® Genius, California, USA)	$Z = -27.3$, $p<0.001$[e]
Osio 2007 (16) (N = 90)	Infants and children, inpatients and ambulatory patients.	Thermofocus® 01500 (Tecnimed, Italy)	1)Infrared tympanic thermometer (Braun™ Thermoscan IRT 3020); 2)Temporal artery thermometer (Exergen TemporalScanner™ TAT 2000C); 3)Electronic axillary thermometer (Omron® MC-600)	$r = 0.17$, $r^2 = 0.029$, $p<0.0001$[f]
Teran 2011 (17) (N = 500)	Children aged 1 to 48 months; inpatients or seen in emergency department triage.	Thermofocus® 01500 (Tecnimed, Italy)	Mercury in-glass rectal thermometer (manufacturer not stated)	$r = 0.952$, $p<0.001$[b]

[a] One paediatric emergency department, three paediatric clinics and one primary care centre.
[b] Linear regression was used to determine the correlation between methods.
[c] Temperature readings were obtained from 855 children using the Alaris® Tri-Site electronic thermometer and 706 children using the Thermofocus® 0800 thermometer.
[d] Pearson correlation was used to determine the correlation between methods.
[e] Wilcoxon signed-ranks test, NCIT reading was significantly lower than tympanic temperature.
[f] Correlation between temperature measurements taken using all four types of thermometer.

Table 3 summarises the results of four studies, which evaluated NCIT performance in detecting fever (12, 14, 15, 17). Two studies defined fever as a temperature of over 38°C measured using a

mercury-in-glass thermometer in the axilla (12) or an infrared tympanic thermometer (15). One study defined fever as a rectal temperature of 38°C or higher, measured using a mercury-in-glass thermometer (17). One study defined fever as oral or rectal temperature >=38°C or axillary temperature >=37°C, measured using the Alaris Tri-Site electronic thermometer(14). These studies found that NCITs had high sensitivity and specificity for detecting fever.

Table 3: Performance of non-contact infrared thermometers in determining presence of fever

Study (reference)	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive predictive value, % (95% CI)	Negative predictive value, % (95% CI)
Chiappini 2011(12)[a]	89 (80-97)	90 (86-94)	70 (59-81)	97 (94-99)
Selent 2013(14)[b]	77 (71-82)	79 (75-83)	55* (49 to 62)	91* (88 to 94)
Ng 2005(15)[c]	89.4 (83.1-93.6)	75.4 (74.5-76)	33.7 (31.4-35.3)	98.1 (96.9-98.8)
Teran 2011(17)[d]	97 (92.7-98.8)	97 (93.9-98.6)	95.2 (90.6-97.7)	98.1 (95.3-99.3)

CI = Confidence Interval. *Values calculated from published data.
[a] Fever defined as axillary temperature > 38°C (mercury-in-glass thermometer)
[b]Fever defined as oral or rectal temperature >=38°C or axillary temperature >=37°C (measured using Alaris® Tri-Site electronic thermometer).
[c] Fever defined as tympanic temperature > 38°C (infrared thermometer)
[d] Fever defined as rectal temperature >= 38°C (mercury-in-glass thermometer)

Impact compared to existing technology

Based on currently published data, Thermofocus NCIT temperature readings correlate strongly with axillary (12) or rectal (17) temperature readings measured using mercury-in-glass thermometers (table 2). One study (12) also reported that children found the NCIT significantly more acceptable than a mercury-in-glass axillary thermometer. Trained physicians or nurses assessed children's discomfort during both types of temperature measurement using a five-point scale. The mean distress score was significantly lower using the NCIT than the mercury in-glass axillary thermometer ($p<0.0001$). However, comparisons with electronic axillary thermometers, which provide more rapid temperature readings, may have provided different results.

NCIT performance may be improved by allowing sufficient time for children's temperature to stabilise and by avoiding taking children's temperature when they are distressed. However, this may not be realistic in many clinical settings. For example, one study, which demonstrated good agreement between NCIT and rectal temperatures ($r = 0.952$, $p<0.001$), allowed at least 15 minutes for children's temperature to stabilise (17), whereas another study, which only demonstrated moderate agreement between NCIT and rectal temperatures ($r^2 = 0.48$, $p<0.01$), did not report whether or not children's temperatures were allowed to stabilise (13). One study reported that Thermofocus 0800 temperatures were significantly higher in unhappy children (14).

Agreement between NCIT and conventional thermometer readings may also be improved by taking an average of repeated consecutive measurements. One study, which obtained three NCIT

temperature readings and two axillary temperature readings (one on each side) (12), and another study, which obtained three consecutive readings with both NCIT and electronic rectal thermometers (17), reported good agreement between NCIT and conventional thermometer readings. Chiappini et al. (12) reported similar clinical reproducibility and no significant inter-operator differences for both NCIT and axillary thermometers.

However, a study which found only moderate agreement between NCIT and rectal temperatures did not perform repeat measurements (13). In addition, although six different staff members were involved in taking readings, no measure of inter-operator variability was reported. Another study, which obtained three readings from NCIT, tympanic, temporal artery and axillary thermometers but only demonstrated weak to moderate agreement between these methods, also did not report any measures of clinical or inter-operator reproducibility (16). Ng et al. (15) found that removing repeated temperature measurements from the same patient had little impact on the NCIT's diagnostic accuracy for detecting fever other than widening 95% confidence intervals.

Guidelines and Recommendations

The NICE guideline on feverish illness in children (5) recommends that in infants under the age of 4 weeks body temperature should be measured with an electronic thermometer in the axilla. However, in children aged 4 weeks to 5 years, temperature should be measured using an electronic or chemical dot thermometer in the axilla or an infrared tympanic thermometer. The guideline recommends that health care professionals should avoid using disposable chemical dot thermometers if multiple temperature measurements are required. The guideline recommended that health care professionals should not use forehead chemical thermometers because they are inaccurate and have poor sensitivity at detecting fever, and that oral and rectal routes should not routinely be used to measure temperature in children aged 0 to 5 years. The Canadian Pediatric Society (18) recommends that definitive temperature should be measured using an electronic rectal thermometer and screening temperature using an electronic axillary thermometer in children aged 5 years or younger. Tympanic thermometers may be used for screening temperatures in children aged over 2 years. Neither guideline makes any recommendations about NCIT use.

Cost-effectiveness and economic impact:

There is currently no literature on the cost-effectiveness or economic impact of using NCITs to measure temperature in children. Although some models of NCIT are considerably more expensive than most conventional thermometers, the use of NCITs by health care professionals may lead to long-term cost savings in terms of reduced staff time (quicker to obtain readings than axillary thermometry) and material costs (no need for disposable probe covers). Time required to obtain temperature readings has already been established as an important driver of total costs associated with using different types of thermometer (5).

Research Questions:

- How accurate are NCITs compared to other thermometers for measuring temperature and detecting fever in children presenting with acute illness in primary care settings?
- How accurate are the different models of NCIT?
- How accurate is the NCIT at monitoring changes in temperature?

- What factors improve the accuracy of NCIT readings, including child characteristics and ambient temperatures?
- How acceptable is the use of NCITs to health care professionals, parents and carers?
- Is the NCIT a cost-effective method of measuring temperature in children in the community?

Suggested next steps:

- Studies comparing the accuracy of different models of NCIT against currently used conventional thermometers.
- Studies evaluating the acceptability of NCIT use among health care professionals, parents and carers.
- Studies evaluating the cost-effectiveness of NCIT use in primary care settings.

Expected outcomes:

- NCITs may provide a rapid, hygienic, non-invasive and accurate means of measuring children's temperature in the community (home and primary care settings).
- NCITs may be useful in detecting fever in children in the community (home and primary care settings).
- NCITs may be more cost-effective than conventional methods of measuring temperature.

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Acknowledgements:

The authors would like to thank Nia Roberts for helpful discussions. This work is supported by the National Institute for Health Research (NIHR) Diagnostic Evidence Co-operative Oxford at Oxford Health NHS Foundation Trust. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

This report was prepared by the Primary Care Diagnostic Horizon Scanning Centre Oxford
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