Horizon Scan Report 0025 **Date: 25 October 2012**

Diagnostic Technology: Non-contact infrared thermometers

Clinical Question:

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

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. Temperature is conventionally 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). Furthermore, the use of rectal and oral thermometers may potentially cause breaches in mucosal integrity, which may act as entry sites for infection (6).

Axillary thermometry is less invasive than oral or rectal thermometry but it may take 30 seconds or more to obtain an accurate measurement (4). Infrared tympanic thermometers are often used to measure temperature in preschool children presenting in primary care, since readings can be obtained within seconds (7). A systematic review comparing infrared tympanic thermometry to rectal thermometry reported poor agreement between these two methods (3). However, 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.

Non-contact infrared thermometers (NCITs) can be used to measure temperature rapidly and non-invasively, 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 Thermometer (American Scientific Resources Inc, Washington, USA)	32 to 42.9	5-8 cm	FDA approved and CE marked. Traffic light style temperature 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 (8).

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 (9). 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 from patients complaining of fever, of which 67% concerned children under the age of 4 years (10).

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 (11). 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, temperature is also a useful factor for clinicians to take into account when interpreting the significance of heart rate and respiratory rate measurements in children (12).

Previous Research:

Accuracy compared to existing technology

Table 2 summarises the characteristics of studies comparing NCITs to other thermometers. Two studies were conducted in primary care settings (13, 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.

NCIT temperature readings were reported to correlate strongly with axillary temperature (13) and rectal temperature (17) measured using mercury-in-glass thermometers. The mean difference between Thermofocus® and axillary temperatures was 0.07°C; limits of agreement were -0.62°C to 0.76°C (*i.e.* ±1.96 standard deviations) (13). 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).

Only moderate agreement with electronically measured rectal temperature was demonstrated (14). Furthermore, rectal temperature was overestimated in patients with lower temperatures and underestimated in patients with higher temperatures by the Thermofocus® thermometer ($r^2 = 0.149$, $p<0.01$). In contrast, the Standard ST 8812 NCIT was more likely to underestimate tympanic temperature in patients with lower temperatures (15).

One study reported that the 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) was statistically significant but weak ($r = 0.17$, $r^2 = 0.029$, $p<0.0001$) (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 did report 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 (13) (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 (14) (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]
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)	$Z = -27.3$, $p<0.001$[c]
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)	$r = 0.17$, $r^2 = 0.029$, $p<0.0001$[d]
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] Wilcoxon signed-ranks test, NCIT reading was significantly lower than tympanic temperature.
[d] Correlation between temperature measurements taken using all four types of thermometer.

Three studies also evaluated NCIT performance in determining the presence of fever (13, 15, 17). Two studies defined fever as a temperature of over 38°C measured using a mercury-in-glass thermometer in the axilla (13) 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).

Table 3 summarises the findings of these three studies. Two studies calculated receiver operating characteristic (ROC) curves to determine the optimum NCIT temperature threshold for predicting fever (13, 15). One study found that a Thermofocus® NCIT temperature threshold of 38°C performed well as a predictor of fever (area under the ROC curve = 0.97, 95% confidence interval 0.95-0.99) (13). Another study found that, for the Standard ST 8812 NCIT, the optimal cut-off point for predicting fever was 35.1°C (area under the ROC curve = 0.87) (15). However, it was acknowledged that using this cut-off value as a screening tool for fever would result in a high false-positive rate.

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(13)[a]	89 (80-97)	90 (86-94)	70 (59-81)	97 (94-99)
Ng 2005(15)[b]	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)[c]	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
[a] Fever defined as axillary temperature > 38°C (mercury-in-glass thermometer)
[b] Fever defined as tympanic temperature > 38°C (infrared thermometer)
[c] 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 (13) or rectal (17) temperature readings measured using mercury-in-glass thermometers (table 2). One study (13) also reported that children found the NCIT significantly more acceptable than the 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 ($p<0.0001$). There was no significant age effect on temperature measurements obtained using the Standard ST 8812 NCIT (15). However, the same study found that Standard ST 8812 NCIT readings were significantly lower than those obtained using infrared tympanic thermometry.

NCIT performance may be improved by allowing sufficient time for children's temperature to stabilise and by not performing invasive procedures before temperature is measured. 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 and obtained NCIT temperature measurements before rectal temperature readings (17). However, 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 and measured rectal temperature before taking NCIT readings (14).

NCIT performance may also be improved by taking an average of repeated consecutive measurements. Two studies which obtained multiple NCIT temperature measurements reported good agreement between NCIT and axillary (13) or rectal (17) temperature readings (table 2). One study obtained three Thermofocus® 0800 temperature readings and two axillary temperature readings (one on each side) (13) whilst the other obtained three consecutive readings with both NCIT and electronic rectal thermometers (17). Chiappini *et al.* (13) 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 (14). 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 performance in relation to 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.

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 costs (less time to obtain readings than axillary thermometry) and material costs (no need for disposable probe covers). If parents and carers are prepared to invest in NCITs and feel confident to use them to monitor children's temperatures at home, this may also result in reduced consultations and health care resource utilisation. NCITs may also indirectly reduce health care burden by reducing disease transmission, particularly in hospital and day care settings.

Research Questions:

- How accurate is the NCIT compared to conventional methods of measuring temperature in children presenting with acute illness in primary care settings?
- How accurate are the different models of NCIT?
- How accurately does the NCIT perform when used over body surfaces other than the forehead?
- How accurate is the NCIT at monitoring changes in temperature?
- What factors improve the accuracy of NCIT readings?
- 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 step:

- Studies validating the use of NCITs against currently used conventional thermometers in primary care.
- 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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