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Is There Sufficient Evidence to Support the Use of Temporal Artery and Non-contact Infrared Thermometers in Clinical Practice? A Literature Review

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ABSTRACT

Background and Objective

Accurate measurement of body temperature is a key part of patient observations and can influence important decisions regarding tests, diagnosis, and treatment. For routine measurements in hospitals, non-invasive thermometers such as tympanic infrared ear thermometers are very widely used even though non-invasive thermometers are not as accurate as core thermometry. However, there are known issues regarding the accuracy of these thermometers due to user errors including dirty probe covers and not straightening the ear canal. We were therefore keen to understand if there was evidence to support the use of alternative non-tympanic, non-invasive thermometer that could be easily and widely deployed across Nottingham University Hospitals NHS Trust.

Material and Methods

A search of the published literature via the NICE HDAS was undertaken to identify the evidence on the use of temporal artery (TAT) or non-contact infrared forehead (NCIT) thermometers compared to a core body temperature thermometer in a clinical setting. The relevant literature was identified, appraised and summarized.

Results

Fifteen papers described the use of TAT but only 5 reported results that were considered within clinically acceptable limits of which 2 included febrile patients. Nine of the 10 studies where TAT was considered not to be within acceptable limits included febrile patients. For the NCIT, 3 studies were identified but only 1 reported results within acceptable limits and this did not include febrile patients.

Conclusion

A review of the literature for both TAT and NCIT has indicated that in their current form neither is suitable as a replacement for oral or tympanic thermometers in clinical practice. In particular, the evidence suggests that they are not acceptable methods for detecting temperatures outside the normothermic range and do not detect fever accurately. Known user errors with both TAT and tympanic infrared ear thermometers (IRET) could be detracting from the usefulness of the technology.

Keywords – *Thermometer, infrared, temporal artery, non-contact, forehead, tympanic, oral, core, virus.*

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INTRODUCTION

Body temperature measurement is a key part of routine patient observations in all healthcare settings including secondary care and it is one of the 6 components of the national early warning score (NEWS) system developed by the Royal College of Physicians (<https://www.rcplondon.ac.uk/projects/outputs/national-early-warning-score-news-2>) to standardize the assessment and response to acute illness. Temperature monitoring can influence important decisions regarding tests, diagnosis, and treatment. It is therefore crucial that thermometers are accurate, reliable and easy to use since inaccurate results may lead to a failure in identifying patient deterioration and compromise patient safety. The most accurate measure of body temperature comes from invasive “core” thermometry options such as pulmonary artery (considered gold standard¹) but also bladder, nasopharynx or esophageal thermistors.² However, these methods are invasive, potentially high risk and restricted to patients undergoing specific procedures and not suitable for everyday use in all care settings. There is a range of non-invasive thermometers for obtaining temperatures from peripheral body sites including the tympanic membrane, the mouth or the axilla.

Electronic contact non-disposable thermometers that incorporate probes specific for use in either the oral cavity (sublingual), axilla or rectum, are commonly used in many different healthcare settings, particularly the oral cavity. Infrared sensing thermometers such as IRET or tympanic, which measure the temperature at the tympanic membrane, are also very commonly used across all healthcare settings as well as in a domestic setting. Other infrared thermometers include the non-contact infrared forehead thermometers (NCIT) and the temporal artery thermometers (TAT). There are several chemical thermometry options such as chemical dots or phase change strips though these are generally not as widely used as the electronic thermometry options.

While peripheral body sites are convenient for rapid and easy temperature monitoring, not all thermometers have clinically acceptable accuracy and published studies comparing them to core or oral electronic temperature measurements show substantial variability in the

methodologies, outcomes and patient populations. In particular, the use of peripheral thermometers to detect temperatures outside of the normal range (36–38°C) is crucial to identify patients who are either hyper- or hypothermic and to make the necessary treatment decisions. The wide range of often conflicting data has made drawing firm conclusions from these studies difficult but there have been various systematic reviews and meta-analysis^{2–5} which overall conclude that not all peripheral thermometry options are clinically acceptable. Of all the thermometry options, non-disposable electronic oral thermometers are considered by many to be the most accurate reflection of core body temperature³ and can be considered as the “gold standard” of non-invasive temperature monitoring.⁶

The Royal Marsden Manual of Clinical Nursing Procedures (ninth edition, chapter 11: Observations⁷) includes recommendations on the use of different thermometry devices to determine patient temperature including the use of tympanic thermometers as an acceptable method to measure body temperature. Within the NHS, tympanic thermometers are widely used non-invasive thermometry devices. However, there are issues associated with tympanic thermometers which have been previously described⁸ and by the Marsden Guidelines⁷, such as dirty probe covers and user error (not straightening the ear canal) as factors that could contribute to inaccurate readings being recorded by these devices. In addition, the MHRA also published a Medical Device Alert in May 2003⁹ that highlighted these 2 issues as contributing to low-temperature readings.

Measuring body temperature at peripheral sites, therefore, represents a compromise between patient acceptance, ease, and speed of recording over temperature accuracy. The Clinical Engineering department at Nottingham University Hospitals NHS Trust (NUH) are responsible for the medical equipment that is used across the Trust including tympanic ear thermometers for patient monitoring. Many of the devices are returned to the department for cleaning and maintenance due to the issues described above. We were therefore keen to understand if there was evidence to support the use of alternative non-tympanic, non-invasive thermometer that could be easily and widely deployed across the Trust to measure

body temperature in patients. There have been 2 horizon scanning/technical scoping articles published covering infrared thermometer use in both children (NCIT¹⁰) and adults (TAT¹¹). The overall conclusions of these 2 reports were that the evidence is somewhat equivocal but that NCIT could be useful in clinical practice but more research is needed. The 2 types of thermometer considered here were the TAT and the NCIT.

MATERIALS AND METHOD

Literature Search Strategy

All searches were performed using the NICE HDAS (Healthcare Databases Advanced Search) and included Pubmed (including Cochrane database), Medline, Embase and Cinahl. Searches were restricted to the English language and in the last 10 years (2008 onwards).

Search terms were as follows: Thermometer; Forehead; Non-contact; Temporal artery; Thermometer AND non-contact; Thermometer AND temporal artery; Non-contact infrared thermometer.

The output was downloaded to Excel and the output reviewed with references being selected according to the inclusion/exclusion criteria and availability (see Table 1).

TABLE 1. Inclusion/Exclusion Criteria for Infrared Non-contact Thermometer Search

Inclusion	Exclusion
Non-contact infrared forehead thermometer (NCIT)	Measurement of temperature in other body locations e.g., skin, corneal, umbilicus
Temporal artery thermometer (TAT)	No comparison to other thermometers
Clinical or professional use in humans	Non-clinical studies i.e., animals or scientific studies, exercise studies
Any age group	Large population scanning studies e.g., traveller studies
Comparison to core or oral thermometers	Use of mercury-in-glass thermometers
Original research published since 2008	

DATA REVIEW

Each paper that was considered to be in scope according to the criteria in Table 1 was reviewed and summarized in terms of populations, setting, devices used, outcomes and detection of hypo/hyperthermia (febrile) patients. The conclusion of the authors regarding whether the device was clinically acceptable or not was also recorded where it was explicitly stated.

FUNDING

No funding was sought for this study.

RESULTS

Literature Search

For the literature search and review, no age groups apart from neonates were excluded to review the widest range of literature. The literature search identified 161 references of which only 16 were considered to be in scope. The 16 original clinical research papers were very varied in their populations, interventions, comparator (or standard reference thermometer), study design, primary outcomes, how the data was analyzed and how the results were reported. However, all papers compared the test devices to a standard reference method (which was presumed to be the most accurate) and most (though not all) concluded whether the test devices returned results within defined clinically acceptable limits. Most papers discussed the limitation of the study which included whether febrile patients were included, whether the study included any device-specific training and whether user technique was considered. Reference methods included invasive core measurements such as pulmonary artery, esophageal and bladder thermometers as well as non-invasive thermometers such as oral or rectal electronic thermometers. As anticipated, no test devices were found to be superior to the standard reference device. Some studies included a range of devices, not just infrared non-contact devices and these were included in the analysis for completeness. The key question we asked of the papers was whether the evidence supported the use of infrared non-contact thermometers in the population being studied and this is summarized in Table 2.

TABLE 2. Literature Review of Infrared Non-contact Thermometry

Authors	Population	Febrile Patients	Thermometer type and Devices Used in Study	Conclusions
Allegaert ¹²	Pediatric, n=294	Y	Rectal - Filac 3000, Covidien Tympanic - Genius 2 TAT - Exergen NCIT - Thermoflash	YES - TAT agreed with rectal but still not optimal
Barringer ¹³	Adult patients undergoing elective surgery, n=86	N	Oral - WelchAlleyn SureTempPlus Model 690 Axilla - WelchAlleyn SureTempPlus Model 690 TAT - Exergen TAT5000	YES - TAT provided temperature readings closer in agreement with oral readings
Bodkin ¹⁴	Adult patients, n=100	Y	Oral - Dinamap ProCare 400, oral electronic non-disposable TAT - Exergen TAT5000	NO - TAT gave significantly different readings to oral electronic thermometer
Brosinski ¹⁵	Pediatric <3yrs, n=126 geriatric >65 yrs, n=125 unable to use oral thermometer	Y	TAT - Exergen TAT5000 Rectal - WelchAlleyn SureTempPlus	NO - TAT device not accurate enough compared to rectal to be used in the ED
Calonder ¹⁶	Patients undergoing colorectal or gynecology surgery, n=23	N	Esophageal - ES400-18 Level 1 Acoustascope Esophageal Stethoscope Oral - WelchAlleyn SureTempPlus Model 678 TAT - Exergen TAT5000	YES - TAT were accurate for temperature assessment but tended to over-estimate temperature compared to esophageal
Counts ¹⁷	Acutely ill patients aged > 18 years old, n=48	Y	Oral - WelchAlleyn SureTempPlus Model 690 Oral - Disposable digital oral electronic thermometer: Medichoice (Mesure Technology Co, TAT - Exergen TAT5000	NO - TAT was judged to exceed clinically acceptable limits
Forrest ¹⁸	Febrile and afebrile pediatric patients, 36 months and under, n=85	Y	Rectal - WelchAlleyn SureTempPlus Model 690 Axilla - WelchAlleyn SureTempPlus Model 690 TAT - Exergen TAT5000	NO - TAT cannot be recommended to detect fever in pediatric populations
Gates ¹⁹	Adults, multiple myeloma, inpatient unit bone marrow transplantation.	Y	Oral - WelchAlleyn SureTempPlus Model 690 Tympanic - Genius 2 TAT - Exergen TAT5000	NO - TAT over-estimates temperature
Hamilton ²⁰	Adult febrile (n=11) and afebrile (n=8) Pediatric febrile (n=53) and afebrile (n=99)	Y	Oral - WelchAlleyn SureTempPlus Model 692 Tympanic - Braun Thermoscan 4520 NCIT - Visiomed SAS Thermoflash LX-26 Forehead - Beurer FT 60 infrared contact forehead thermometer TAT - Exergen TAT-2000C Forehead - Chicco Thermo Touch Plus contact forehead thermometer	NO - TAT or NCIT (or other forehead thermometers) not considered acceptable

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Authors	Population	Febrile Patients	Thermometer type and Devices Used in Study	Conclusions
Hamilton ²¹	Febrile (n=94) and afebrile (n=111) children	Y	Oral - WelchAlleyn SureTempPlus Tympanic - ThermoScan® PRO 4000 prewarmed tip ear thermometer TAT - Exergen TAT5000	NO - TAT not acceptable. Compared to reference, TAT gave statistically significantly different readings
Langham ²²	Patients undergoing laparoscopic surgery. Aged 18-80 yrs, n=50	N	Bladder - Foley catheter (Mon-a-therm Foley-Temp) Esophageal – esophageal stethoscope with thermistor (Mon-atherm EST) TAT- Exergen TAT-5000 Tympanic - FirstTemp Genius 3000A Skin-surface thermocouple (Monatherm 6130) Skin - Liquid-crystal display strip (Crystalline Moving Line) Oral and Axilla - Electronic thermometer (IVAC TempPlus II 2080A) Deep thermometer (CoreTemp CTM-205 with a PD-51 probe)	NO – TAT only had reasonable correlation to core. Electronic oral thermometry was the most accurate and reliable device compared to the reference
Lunney ²³	Hemodialysis patients	Y	Thermometer in Fresenius 5008 hemodialysis machine, TAT - Exergen TAT5000	NO - TAT method exceeds the clinically acceptable reference method
Marable ²⁴	Adult male patients, critical care unit, n=69	Y	Oral - WelchAlleyn SureTempPlus Model 692 Axilla - WelchAlleyn SureTempPlus Model 692 TAT - Exergen TAT5000, forehead and ear TAT - Exergen TAT5000, forehead only TAT - Exergen TAT5000, ear only	NO – The results do not favour temporal artery scanning in adult critical care patients
Opersteny ²⁵	Pediatric patients aged 0–17 years, inpatient surgical units, n=298	Y	Oral - WelchAlleyn SureTempPlus Model 692 Axilla - WelchAlleyn SureTempPlus Model 692 TAT - Exergen TAT5000	YES - TAT is an acceptable temperature measure that could substitute oral or axillary thermometers
Sollai ²⁶	Healthy term (n=119) and preterm newborns (n=70) nursed in incubators	N	Axilla – Sanitas digital thermometer Tympanic - Thermoscan Pro 4000 NCIT - Thermofocus 800	YES - NCIT is a promising, quick non-invasive and accurate method to measure temperature in newborn and preterm babies
Stelfox ²⁷	18 years or more, expected to stay in ICU for 24hr or more. n=736 readings from 14 patients	Y	Bladder - Level 1® Foley Catheter temperature Sensor, Smiths Group PLC TAT - Exergen TAT5000	YES - TAT closely agreed with the bladder thermometer for normothermic measurements but less agreement for temperatures < 36°C or >38.3°C

Bold indicates Study reference devices.

The results from all 16 papers were collated and summarized by device including which thermometer was used as a reference standard, whether the TAT or NCIT were considered as the next best compared to the standard (a frequently reported outcome) and whether it was considered to be within clinically accepted limits (which was considered to be $\pm 0.5^{\circ}\text{C}$ [1°F]) unless otherwise stated, though it was not always explicitly stated.

Of the 15 papers that included the TAT, only 5 of these studies^{12,13,16,25,27} reported results that were considered to be within clinically acceptable limits or were not statistically significantly different from the reference device and would support the use of TAT in clinical practice. Of these 5 studies, only 2 reported that the TAT could accurately detect fever.^{12,25} Of the remaining 3 papers, Stelfox et al.²⁷ included febrile patients but reported that the TAT was only acceptable for patients within the normal range ($36\text{--}38^{\circ}\text{C}$) as there was less agreement for temperatures below 36°C and temperatures greater than or equal to 38°C . The other 2 papers^{13,16} concluded that TAT was acceptable but they did not include febrile patients in their study.

In the 10 studies where TAT was judged to be not acceptable, 9 of the studies included patients with fever

indicating that TAT did not perform accurately to identify fever in a wide range of patient populations.

There were only 3 studies that compared NCIT to a reference thermometry measurement. The study by Sol-lai²⁶ using the ThermoFocus device reported results that were considered acceptable compared to the reference standard. However, the reference standard was digital axillary in neonates and the study did not include febrile babies. Both studies^{13,20} where NCIT devices were not considered acceptable included febrile patients indicating that the NCIT is not acceptable for detecting temperatures outside the normothermic range.

DISCUSSION

A search and review of the published literature was undertaken to determine if there is sufficient evidence to support the use of non-tympanic non-invasive thermometers in a hospital setting (Table 3). Two types of thermometer were considered: TATs and non-contact infrared forehead thermometers. The literature reviewed focused on the studies comparing TAT and NCIT with either invasive core thermometry or standard oral electronic thermometry.

TABLE 3. Literature Review Summary by Device

Thermometer type: Device	Manufacturer	No . of studies	Used as reference standard	Next best to ref device	Outside accepted limits
Oral: SureTempPlus	WelchAlleyn	8	7	1	
Axilla: SureTempPlus	WelchAlleyn	4	1	2	1
Rectal: SureTempPlus	WelchAlleyn	3	2		
Esophageal: Stethoscope with temperature sensor	Mon-a-therm				
Smiths Medical	2	2			
Bladder: Foley catheter	Mon-a-therm				
Smiths Medical	2	2			
Axilla: Sanitas Dx	Sanitas	1	1		
Oral: Dinamap ProCare 400	Dinamap	1	1		
Rectal: Filac 3000	Covidien	1	1		
Dialysis machine, 5008	Fresenius	1	1		
TAT: TAT5000/2000	Exergen	15		5	10
Tympanic: Genius 2	Covidien	3		1	2
Tympanic: Thermoscan PWT	Braun	2		2	

Despite a decent sized body of evidence, including clinical studies for the TAT, the results do not support their use in a clinical setting with many studies reporting that they were inaccurate outside of the normal body temperature range. This conclusion is in agreement with meta-analyses conducted by Geijer²⁸ and Niven.² The evidence for the NCIT was more limited with very few papers meeting the inclusion criteria and also did not support their use in a clinical setting for the same reasons.

One of the key issues was the relatively small number of papers meeting the inclusion/exclusion criteria used in our study which then described a wide range of settings, populations, devices, comparator (standard reference) devices, outcomes including detection of fever and how the results were analyzed and reported. This wide variation in reporting and outcomes was also identified and discussed as a drawback in the meta-analysis.²⁻⁵ There was some variability in standard reference methods in the papers reviewed and none of the studies used an intravascular measure of temperature (gold standard) although one study²³ did use the thermometer incorporated in the dialysis machine. Typical invasive thermometry options included in these studies were either bladder or esophageal thermometers. However, the most common reference method was an electronic non-disposable oral thermometer such as the WelchAllyn SureTempPlus. The outcomes, analysis, and reporting also differed between the studies and varied from reporting the mean differences to calculated limits of acceptability. Where febrile patients were included, the reporting varied from false negative or positive rates to misclassification percentages. Due to this variability, we chose to record whether the authors would recommend either the TAT or the NCIT device being studied for use in clinical practice.

Overall, from the 15 papers the described the use of TAT devices, the device was in general considered to be outside the clinically acceptable limits. This is also highlighted and discussed in the recently published meta-analysis and reviews published.^{2,4,5} The majority of studies that found TAT to be acceptable did not include patients outside the normal range and it was shown that there was less agreement for temperatures below 36°C and temperatures greater than or equal to 38°C. These studies indicate that TAT is acceptable for normothermic

patients only as has already been highlighted by the meta-analyses. However, several studies found TAT devices to be more acceptable to patients, especially children, and more likely to record a reading at the first attempt.^{13,25}

There were fewer papers involving the NCIT and these devices were specifically excluded from the meta-analysis of Niven.² Similar to the TAT, these thermometers performed reasonably well in normothermic ranges but not outside this range and the study where the results were within acceptable limits did not contain any febrile patients. A study by Fletcher²⁹ looked at 9 NCITs (all unnamed, 3 groups according to specification) which were calibrated using 2 NPL standard blackbody sources with emissivities >0.999. NCITs from 2 of the groups were shown to give large measurement errors with readings falling far outside both the manufacturer's stated uncertainties. A third group of NCIT performed well, with all the results falling within the stated uncertainties. Overall, more evidence needs to be gathered as to the clinical acceptability of the NCIT devices in all settings but there is potential for NCITs to provide a rapid, hygienic and non-invasive means of measuring temperature, particularly in children.

The evidence indicates that the TAT and NCIT in their current form are not well suited to detecting temperatures outside the normal range. Failure to detect fever has significant consequences for patient care if the fever is missed and the patient is not treated accordingly or if fever is falsely detected, it may result in unnecessary clinical interventions. This is more critical in patients with cancer where detection of fever can be an indication of a potentially life-threatening infection.¹⁹

For both types of thermometer, both calibration and training to reduce user error was discussed as being a key factor in obtaining accurate and consistent readings. Three of the studies^{13,19,24} specifically mentioned device training and 7 of the studies^{16-20,26,27} documented that the devices were calibrated by the Clinical Engineering department. While there was no specific literature on the usability or training for NCIT, there has been a publication detailing the training and use of TAT in clinical practice. Barry et al.³⁰ undertook an observational study to look at the impact of user technique on the accuracy of TAT measurements. Despite documented training on the

correct technique, only 39% of users demonstrated the correct technique and returned acceptable temperature measurements. The remaining 61% failed to demonstrate correct technique and recorded statistically significantly lower temperatures. The most common mistake was to scan only the forehead and to miss either the temple or under the ear. Similar user mistakes have also been documented with tympanic thermometers where users fail to straighten the ear canal to direct the IR beam to the correct quadrant of the tympanic membrane.^{8,9,31} It is interesting to speculate how the manufacturers could use this information to redesign their products to eliminate the user error issues and thereby improve the intuitive use of the device which would in turn reduce the need for regular training to make sure the device is used appropriately. This would then enable a more accurate evaluation to determine whether, when used easily and correctly, the thermometers can measure body temperature within clinically acceptable limits and could be considered as a long-term option for thermometry.

CONCLUSIONS

A review of the literature for both TAT and NCIT has indicated that in their current form neither is suitable as a replacement for oral or tympanic thermometers in clinical practice. In particular, the evidence suggests that they are not acceptable methods for detecting temperatures outside the normothermic range and do not detect fever accurately. Known user errors with both TAT and tympanic IRET could be detracting from the usefulness of the technology.

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