Temperature comparison between contact temporal and non-contact forehead thermometers in paediatric outpatient clinic

ABSTRACT

Objective: To evaluate the performance of two thermometers, non-contact infrared (NCIR) forehead thermometer and contact temporal scanner thermometer, in paediatric outpatients.

Method: Study included normothermic paediatric outpatients (aged between 0 and 17 years) at Le Bonheur Children's Hospital, US. Temperature measurements were taken consecutively by two thermometers in triplicate: TRITEMP™ forehead NCIR thermometer and the TAT-5000 temporal scan thermometer developed by the Exergen Corporation. 231 sets of temperature measurements were recorded; a total of 1,386 body temperature measurement were collected (three readings using the TAT-5000 thermometers and three readings using the TRITEMP™ thermometer). In the majority of cases (~95%), only one set of temperature measurements were taken from each patient.
Feedback from usability study from the nursing staff was collected to record impact of both methods on ease of use, patient comfort and efficiency of nurses' workflow.

Results:
TRITEMP™ forehead temperature results were in agreement with the TAT-5000 temporal artery temperature recordings in the paediatric outpatients. A total of 231 sets of temperatures were recorded (three readings using the TRITEMP™ and three readings using the TAT-5000 thermometer). The mean (± SD) temperature recorded was 36.6 ± SD 0.025 and 36.5°C ± SD 0.045 for the TRITEMP™ and the TAT-5000 thermometer, respectively. Bland-Altmann analysis showed a mean difference of 0.04˚C with the temporal method and the limits of agreement span between -0.23˚C and +0.30˚C. Feedback sought from the nursing staff involved in the study favoured the TRITEMP for measuring temperatures of the children. The non-contact TRITEMP thermometer, minimises anxiety for the children, leading to more efficient workflow for the nurses.

Conclusions:
The results of this study confirm the forehead NCIR thermometer (TRITEMP™) as an alternative to the currently used temporal scanner thermometer (TAT-5000) in detecting body temperature in paediatric outpatients.

What is already known on this topic?

- Body temperature measurement is an essential component of children health assessment in hospital settings and elsewhere.
- Rectal and other internal probe thermometers can cause problems of acceptability and discomfort.
- Only digital axillary and infrared tympanic thermometers are recommended for fever diagnosis in paediatric clinical practice based on existing evidence.
- Alternative less intrusive thermometry methods do exist but data is required to support the use of such methods.
- A non-contact forehead infrared thermometer (TRITEMP™) was found to give similar temperatures and accuracy to a temporal scanner temperature (TAT-5000) in paediatric patients within a Cardiac Centre (unpublished data). Preliminary data also suggested that temperature measurements recorded were comparable to internal probe temperature readings.

What does this study add?

- Further evidence to support the use of the forehead NCIR thermometer (TRITEMP™) as an alternative to the temporal scanner thermometer (TAT-5000) in paediatric outpatients.
- Similar temperatures and accuracy were recorded for both thermometers.
- The TRITEMP™ was the nurses' preferred method choice. The TRITEMPs offers additional benefits to both the patient and the nurse due to its non-contact approach :
  - Reduced patient anxiety – No physical contact eliminates the stress of close proximity and potential discomfort associated with other methods.
  - Faster and less invasive - Quicker temperature readings minimise wait times and disruption for children.
  - Lower risk of cross-contamination - helps prevent the spread of germs in a healthcare setting.

INTRODUCTION

Clinical methods of measuring temperature include invasive, contact and non-contact. Invasive devices, such as rectal[1], pulmonary artery, oesophageal and urinary bladder thermometers[2], are the most accurate and are often used as reference temperatures when evaluating the accuracy of contact and non-contact devices.[1,3-8] However, invasive methods are expensive and can expose patients to risk of complications.[9,10] Furthermore, they are unsuitable for triage, screening and management processes in clinics.

By contrast, contact thermometers, such as axillary and tympanic thermometers, offer faster measurement times and reduced discomfort to patients. Nevertheless, they are not as accurate as invasive methods[2,11-13] and still require high levels of staff–patient contact. Additionally, these thermometers have a high level of waste associated with them because of their disposable plastic covers. Other contact thermometers, include temperature measurement over the temporal artery (TAT, temporal artery thermometer), which uses infrared technology to detect the heat that is radiated from the skin surface over the temporal artery. Previous studies have reported mixed results as to the value of temporal artery thermometry.[14] TAT devices are known to differ with technique used. Again, like the axilla and tympanic thermometers, some models require the use of plastic covers.

Non-contact methods of temperature measurements, such as non-contact infrared (NCIR) thermometers, do not contact the patient and offer rapid measurements with mass temperature screening.[15] Non-contact thermometers can measure temperature from different sites of the body including face, forehead and wrists.[11,13,16] Despite increased popularity since the COVID-19 pandemic, little research, has been conducted into NCIR device accuracy or application methods.[15]

The non-contact approach offers potential advantages, including reduced child discomfort and distress, rapid readings, measurement without interrupting sleep, minimal risk of cross-infection, and no requirement for disposable covers.[31] It has been suggested that the lack of data confirming the accuracy of these devices in fever diagnosis has prevented them to be considered useful tools for body temperature measurement in pediatric patients.[9,10]

Body temperature measurement is an essential component of children health assessment in hospital settings and elsewhere. Normal body temperature values of infants range from 36.5°C and 37.5°C depending on physiological variations, patient characteristics and site of measurement.[17,18] Unreliable readings can lead to misdiagnoses, missed or delayed treatments, or unnecessary interventions.[19,20] For these reasons, body temperature measurement should be carried out with valid and reliable devices.[21]

Historically, rectal thermometers were accepted as the gold-standard device for body temperature measurement in daily clinical device; however, there was reluctance for this method to be used both by the child and the parents. Many parents are not uncomfortable with an invasive method of temperature assessment, and the majority of children resent this approach causing discomfort and even distress.[14,22] Alternative devices are available to measure the temperature of children, that are easy to use, cost-effective, non-invasive, and safe.[23,24] Nevertheless, only digital axillary and infrared tympanic thermometers are recommended for fever diagnosis in paediatric clinical practice based on existing evidence.[19,20,25] Correct use of the axilla thermometer requires undressing the child and holding the thermometer under the child's arm for more than 15 seconds.[20] Movement or improper positioning of the thermometer can affect the accuracy of the reading, necessitating additional attempts and further discomfort. Undressing, repositioning and cleaning of the axilla thermometer for each patient can increase the nurses' workload and may require additional resources. Tympanic thermometers are easier to use, but may be inaccurate because of the

presence of ear wax or insufficient straightening of the ear canal[26]; again as with the axilla thermometer, technique and training by healthcare professionals are important when using these thermometers. The poor performance of axillary and tympanic thermometers compared with core body temperature measurements in children has been highlighted in a number of reviews.[26-30] Additionally, both types of device require disposable covers to avoid cross-infection. While the individual cost of a probe is low, the frequent need for replacements can result in a significant ongoing expense for healthcare facilities or families using this type of thermometer.

Reports of agreement between NCIR and conventional thermometers in children have been variable, with larger mean differences reported between NCIR and tympanic thermometers than with NCIR and mercury-in-glass axillary thermometers.[12,32] Although NCIR thermometers are mostly reported to have high sensitivity and specificity in detecting a fever of ≥38°C measured with conventional thermometry[12,32-34], other studies indicate otherwise.[5,35] Most previous studies were conducted in paediatric inpatient populations[5,12,35] or mixed hospital ambulatory care and ward settings.[33,36] Furthermore, NCIR thermometers have been mainly compared with temperature measurement approaches that are not currently recommended for use in children, including rectal measurements[5,33,35,37] and using mercury-in-glass axillary thermometers.[32] However, consensus regarding the ideal method in children is that it should be simple, rapid, non-invasive, reproducible, cost-effective and accurately reflect the children's core body temperature. In practice, many methods have advantages and disadvantages, but none completely fulfil all the aforementioned criteria.

Understanding the performance of NCIR thermometers compared with alternative thermometry methods, such as temporal scanner thermometer, in a paediatric outpatient population, could support introduction of this potentially beneficial technology into routine practice. Recent unpublished data have shown that similar temperature and accuracy were recorded for both a forehead NCIR thermometer (TRITEMP™) and a temporal scan thermometer (TAT-5000) in paediatric patients within a Cardiac Centre. In the same study, preliminary but limited data showed that both thermometers gave comparable readings with internal probe methods. Nurse feedback indicated that the forehead NCIR thermometer was the preferred method choice for taking temperature in paediatric patients, with benefits including rapid and safe method, with minimal disturbance and infection risk to the neonates and children.

This larger study was designed to further evaluate the agreement between a forehead NCIR thermometer (TRITEMP™) with the currently used temporal scan thermometer (TAT-5000) in children within a different hospital setting. The nursing staff working within the area felt that the close contact of the TAT-5000 thermometer required with the forehead caused anxiety in children. Subsequently, anxiously moving children could lead to inaccurate temperature readings, potentially showing lower values than expected. Therefore, this study is aimed at determining whether the forehead NCIR thermometer (TRITEMP™) can be used as an alternative to the temporal scan thermometer (TAT-5000) in this clinical setting.

METHOD

A comparative study was conducted over three months on paediatric outpatients attending the Le Bonheur Children's Hospital, US. The study population comprised roughly 3% neonates (less than 28 days old), 12% infants between 28 days and 1 year, and the remaining individuals were children within the 1-17 age bracket. Following each thermometer manufacturer's instructions, temperature measurements were collected, using thermometers that are traceable to ASTM E 1965-98 and EN60601-1 standards. Temperature measurements were taken using the Exergen TAT-5000 temporal scan thermometer and then the TRITEMP™ forehead NCIR thermometer. Three consecutive readings of the patient's temperature were taken using the Exergen TAT-5000 temporal scanner thermometer followed by three consecutive readings taken using the TRITEMP™ forehead NCIR thermometer. Each set of temperatures was measured by the same nursing staff and in most cases only one set of measurements was taken from the same patient. The nursing staff with varying experience that participated in the study were experienced in the use of the TAT-5000 and were trained on use of the TRITEMP™ prior to the commencement of the study.

As recommended by the manufacturer, the TAT-5000 thermometer works by gently scanning across the forehead, taking multiple individual readings along the way. The highest or peak temperature encountered during the scan is identified. This is assumed to be the most accurate representation of core body temperature. The internal circuitry analyses the peak temperature alongside the arterial and surface temperature. The TAT-5000 thermometer was moved either left or right from the centre of the forehead to the hairline, keeping the sensor flat and in contact with the skin throughout the scan (2-3 seconds). A beeping sound was heard and a red light flashed during the scan indicating that the thermometer was taking measurements. Once the hairline was reached, the thermometer was removed from the head. If the forehead was covered or sweaty, the patient's hair was pushed back and the probe was additionally placed on the soft conical depression behind the earlobe on the neck. Further two temperature measurement were taken by the thermometer, waiting 60s between each measurement to avoid excessive cooling of the skin.

Temperature measurements were then taken using the TRITEMP™ thermometer. This thermometer consists of a lens to focus the IR energy on a detector, which converts the energy to an electrical signal that can be displayed in units of temperature after being compensated for ambient temperature variation. This configuration facilitates temperature measurements from a distance without contact with the object to be measured. Temperature taken from the forehead measures the heat generated from arterial flow and an algorithm converts to body temperature. The thermometer was directed 3-5 cm (or 2 finger widths) from the forehead, ensuring the forehead was exposed, free from obstructions and away from external temperature influences. The reading was displayed on screen within 1 second of measuring temperature. Three temperature readings were taken using the non-contact thermometer, allowing 3-5 seconds between readings.

After use, both thermometers were cleaned in accordance with the manufacturer's guidelines and stored in a clean, dry place where they would not become excessively cold or hot.

Data and Statistical Analysis

Each patient had their body temperature measured three times using both the TRITEMP™ forehead NCIR thermometer and the TAT-5000 temporal scan thermometer. To assess reproducibility, the standard deviation (SD) of the differences between the two sets of measurements (TRITEMP™ vs. TAT-5000) for each patient was calculated. This essentially determines how much, on average, the individual temperature readings from each method differed from each other.

Device readings were also compared using Bland-Altman analysis, assessing the magnitude and detection of mean difference as well as width of the limits of agreement (LOA). The LOA was said to be good if 95% of the data was between 1.96 SD of the mean difference between the methods.[38] Based on previous studies in paediatrics, mean difference was considered good if <0.5˚C, and satisfactory if <0.6˚C.[24,39-42]

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RESULTS

Overall, 231 sets of temperature measurements were recorded; a total of 1,386 body temperature measurements were collected (three readings using the TAT-5000 thermometers and three readings using the TRITEMP™ thermometer). In the majority of cases (~95%), only one set of temperature measurements were taken from each patient. 117 of the patients were female and 113 patients were male; whilst the gender of one patient was not specified. The female/male ratio was 1.104. The age range of the study group was 0-17 years, comprising roughly 3% neonates (less than 28 days old), 12% infants between 28 days and 1 year, and the remaining 85% of individuals were children within the 1 to 17-year age bracket.

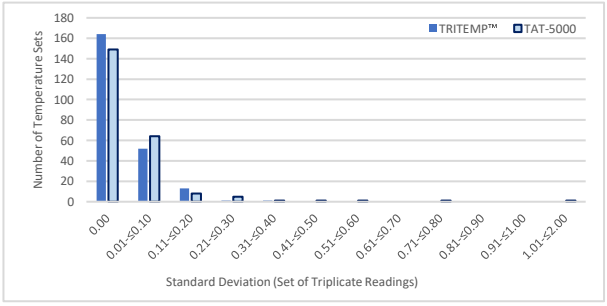
The mean and SD of the triplicate readings for both thermometers were compared. As shown in Table 1 and Figure 1, both the forehead NCIR thermometer (TRITEMP™) and temporal scanner thermometer (TAT-5000) showed similar mean body temperature values and SD of the triplicate readings. i.e. 36.6 ± SD 0.025 and 36.5°C ± SD 0.045 for TRITEMP™ and the TAT-5000, respectively.

Table 1. Summary of temperature variability

Comparison	TRITEMP™	TAT-5000
Total average SD for 231 sets	0.025	0.045
Minimum set SD	0.000	0.000
Maximum set SD	0.320	1.960
Sets with SD (0.00)	164 (71.0%)	149 (64.5%)
Sets with SD (0.01 - ≤0.10)	52 (22.5%)	64 (27.7%)
Sets with SD (0.11 - ≤0.20)	13 (5.7%)	8 (3.6%)
Sets with SD (0.21 - ≤0.30)	1 (0.4%)	5 (2.2%)
Sets with SD (0.31 - ≤0.40)	1 (0.4%)	1 (0.4%)
Sets with SD (0.41 - ≤0.50)	0 (0.0%)	1 (0.4%)
Sets with SD (0.51 - ≤0.60)	0 (0.0%)	1 (0.4%)
Sets with SD (0.61 - ≤0.70)	0 (0.0%)	0 (0.0%)
Sets with SD (0.71 - ≤0.80)	0 (0.0%)	1 (0.4%)
Sets with SD (0.81 - ≤0.90)	0 (0.0%)	0 (0.0%)
Sets with SD (0.91 - ≤1.00)	0 (0.0%)	0 (0.0%)
Sets with SD (1.01 - ≤2.00)	0 (0.0%)	1 (0.4%)

Variability expressed as mean temperature ± SD; SDs calculated based on set of triplicate readings. Both thermometers are traceable to ASTM E 1965-98 with clinical repeatability (or accuracy) within ± 0.2˚C for the range 37˚C - 39˚C.

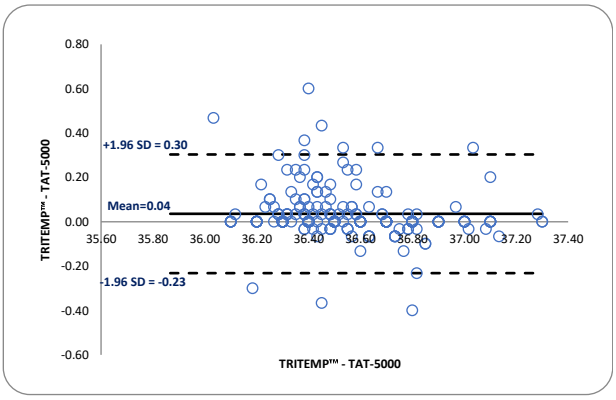
Figure 1. Standard deviation of data sets



The agreement between the measurement techniques (systematic difference) was analysed using a Bland-Altman plot with a limit of agreement of (plus minus) 1.96 SDs. The graphs display the Bland-Altman plots for readings taken by the TRITEMP™ compared to the Exergen TAT-5000 (current method used in hospital). Figure 2 represents all the paediatric results from the study. The difference (y-axis) between the TAT-5000 and TRITEMP™ method is plotted as of a function of the mean of the two measurements (x-axis). Figure 2 demonstrates a mean difference of 0.04°C and limits of agreement between -0.23˚C and +0.30˚C.

Feedback was sought from the nursing staff involved in the study. A Likert scale survey and few open-ended questions were completed by 4 out of 6 nursing staff involved in the study. All

Figure 2. Bland Altman plot showing comparison of forehead NCIR thermometer (TRITEMP™) and temporal scan thermometer (TAT-5000) in paediatric outpatients



Solid lines represent the mean (forehead-temporal) difference and dashed lines represent the 95% limits of agreement

the nursing staff liked the shape and feel of the TRITEMP™, thought that the TRITEMP™ was easy to use and that the training and cleaning was easier than that for TAT-5000. All the nursing staff indicated that the TRITEMP™ was quick and accurate, improving patient care and workflow, resulting in the TRITEMP™ to be the preferred method of choice.

DISCUSSION

Accurate temperature assessment in pediatric practice is of critical importance when diagnosing, treating and monitoring illness. The best method among the various methods of temperature measurement available for pediatric patients has long been debated. While the efficacy and accuracy of temporal artery, tympanic membrane, axillary, and infrared temperature measurement have been studied, the gold standard has been rectal temperature measurement. However, despite its accuracy, this method causes children with non-infectious complaints and their families unnecessary distress and adds significant time to the clinical assessment process.

The TATs or forehead thermometers that use infrared radiation to measure temperature, have been available for approximately 20 years. Despite these innovations and much research on the most accurate and reliable way to measure children's temperature, no conclusive results have emerged. According to a 2008 position statement from the Society of Paediatric Nurses, "Although there are several methods available for measuring temperatures, the goal is to use the most accurate method with the least degree of variance while still recognising the comfort of the patient and ease of use for the health care provider."[43] The same paper stated that temporal artery thermometry "can reliably be used in infants less than 90 days old without fever as well as for all patients greater than 3 months of age with or without fever, ill or well."

Further studies show favourable results of the temporal artery thermometer in children subpopulations.[44-47] In 2015, a group of emergency department staff nurses at a multihospital health system conducted an evidence-based quality improvement project to determine the best practice for accurate temperature measurement in children younger than five years who presented to the emergency department.[48] The project included an exhaustive literature search, a review of relevant studies, the development of a table of evidence, a presentation of the findings, and recommendations for practice change. This article also described the adoption of temporal artery thermometry, a painless, non-invasive screening method that provided consistently accurate temperature measurement as well as increased patient and nurse satisfaction and a shorter triage process.

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The temporal thermometer, TAT-5000 has been adopted in clinical paediatric settings. In a recent unpublished study, the forehead NCIR thermometer (TRITEMP™) was compared with the temporal scan thermometer (TAT-5000) in paediatrics within the Cardiac Centre, Nemours Children's Hospital, Florida. TRITEMP™ results were in agreement with the Exergen TAT-5000 temperature recordings in the paediatric patients. A total of 120 sets of temperatures were recorded (three readings using the TRITEMP™ and three readings using the TAT-5000 thermometer). The mean (± SD) temperature recorded was 36.6 ± SD 0.09 and 36.7˚C ± SD 0.11 for the TRITEMP™ and the TAT-5000 thermometer, respectively. Bland-Altmann analysis showed a mean difference of -0.07˚C with the temporal method and the limits of agreement spanned between -0.68˚C and +0.53˚C also indicating a reasonable level of agreement. Overall, results suggested that the two thermometers can be used interchangeably with a reasonable level of confidence. In the same study, feedback from the nursing staff indicated that the TRITEMP™ offered many benefits compared to the TAT-5000 thermometer, for both the paediatric and the nurse. Nurses reported disturbance of the paediatric patients when using the TAT-5000 thermometer; this was particularly important when ~60% of paediatrics in the study were less than 1 years of age. TRITEMP™ non-contact reportedly caused minimal disturbance to the paediatric patients. Minimal patient handling or nurse intervention, in parallel reduces risk of infection. The ease of use and rapidness of measuring temperature using TRITEMP™ improved the nurse workflow. Minimal training requirements would also aid departments whereby the turnover of staff or reliance of bank nurses is required.

In parallel, to the previous study mentioned, this study was conducted and again showed favourable use of the TRITEMP™. The study allowed us to further evaluate the interchangeability of the forehead NCIR thermometer with the currently used temporal scan thermometer in a different children's clinical setting.

In this study, the TRITEMP™ demonstrated good agreement when compared with the current method i.e. TAT-5000, the temporal scanner thermometer. The Bland-Altman analysis demonstrates a mean difference of 0.04˚C with the temporal method indicating a small difference between the two methods but meets the criterion that an ideal thermometer should be accurate within ±0.1˚C.[49] The limits of agreement span between -0.23˚C and +0.30˚C also indicating a reasonable level of agreement. Despite, a small systematic difference and some variability, results show the two thermometers can be used interchangeably with a reasonable level of confidence.

Again, feedback from the nursing staff involved in the study preferred the TRITEMP™ rather than the currently used TAT-5000. In addition to the obvious benefits of being a non-contact thermometer, all the nursing staff liked the shape and feel of the TRITEMP™, thought that the TRITEMP™ was easy to use and that the training and cleaning was easier than that for TAT-5000. All the nursing staff also felt that the TRITEMP™ was quick and accurate, improving patient care and workflow, and hence resulting in the TRITEMP™ to be the preferred method of choice.

The results of this study confirm the forehead NCIR thermometer (TRITEMP™) as an alternative to the currently used temporal scanner thermometer (TAT-5000) in paediatric outpatients.

LIMITATIONS OF THE STUDY

The strengths of this study included a larger sample size of paediatric patients, and again the measurement of body temperature in a real clinical setting, and the use of appropriate statistical methods of analysis. However, there were no febrile or hypothermic paediatrics among this population. It may be beneficial to extend this study to address this limitation.

CONCLUSION

The results of this study confirm the forehead NCIR thermometer (TRITEMP™) as an alternative to the currently used temporal scanner thermometer (TAT-5000) in detecting body temperature in paediatric outpatients.

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