Non-contact forehead infrared agreement with an electronic axillary thermometer for temperature measurements in preterm neonates

ABSTRACT

Objective: To evaluate the performance of a non-contact infrared (NCIR) forehead thermometer in comparison with an electronic axillary thermometer in preterm neonates nursed in either incubator or open cots with or without thermal support and/or phototherapy light.

Method: Study included mainly normothermic neonates nursed in incubators or open cots within a Neonatal Unit, Craigavon Area Hospital. Three temperature measurements were taken consecutively by two different thermometers: TRITEMP™ forehead NCIR thermometer and the Filac™ 3000 AD electronic thermometer in the axilla. A total of 90 sets of temperatures readings were recorded. Feedback was also sought from 23 nursing staff involved, whereby benefits to the patient, nurse and environment were examined.

Results:
TRITEMP™ results were in similar agreement to the axilla temperatures in the preterm neonates. A total of 90 sets of temperatures were recorded (three readings using the TRITEMP™ and three readings using the Filac™). The mean (± SD) temperature recording of the forehead and axilla thermometers was 36.8˚C ± SD 0.092 and 36.7˚C ± SD 0.094 for TRITEMP™ and the Filac™, respectively. Furthermore, the two thermometers showed satisfactory agreement, as the limits of agreement was small. Further analysis indicated similar patterns irrespective of whether the neonate was nursed in an incubator or open cot, with or without thermal support.

Conclusions:
Mean forehead NCIR temperatures was found to be comparable to mean axillary temperature in normothermic preterm neonates. Temperatures were not affected by the neonate's environment (i.e. incubator or cot, with or without thermal support) provided that the thermometers were stabilised prior to use. Temperature measurements obtained with the forehead NCIR thermometer were rapid, safe and showed minimal disturbance to the neonate. Furthermore, the forehead NCIR thermometer improves both the nurses' work-flow and neonate care compared to axillary thermometer. Further studies are required to determine if TRITEMP™ can accurately detect temperature in febrile and hypothermic preterm neonates.

What is already known on this topic?

- In preterm neonates, abnormal temperature on admission to the neonatal intensive care unit (NICU) is associated with adverse outcome.
- The WHO defines normal body temperature for infants as 36.5˚C-37.5˚C.
- Temperature should be measured regularly and readings should be accurate and reproducible, whilst maintaining a normal body temperature, ensuring a stable thermal environment and avoiding cold stress.
- Frequent disturbance of a neonate can lead to hypoxia or deterioration of their condition, therefore the practice for minimal handling is fundamental.
- Important to seek opportunities to minimise the impact of nursing interventions on preterm neonates, promoting sleep and healthy developments through a minimal handling approach to care.

What does this study add?

- Similar temperatures and accuracy were recorded for both the forehead NCIR thermometer (TRITEMP™) and an electronic axillary thermometer (Filac™ 3000 AD) in preterm neonates.
- Temperatures measurements were not affected by the neonates environment (i.e. incubator or cot, with or without thermal support).
- NCITs display benefits and overcome issues encountered with electronic axillary thermometers currently used in NICUs.
  - Non-contact – minimal disturbance to neonate providing a more stable environment and reduces the risk of infection
  - Rapid and easy to use – enables efficient monitoring of neonates
  - No additional consumables, such as plastic probes – no worries about stock and correct waste management.
- Overall, TRITEMP, the forehead NCIR thermometer is the preferred method of choice for taking temperatures in preterm neonates. As well as reproducibility of temperature readings, the thermometer offers additional benefits to neonate, nurse and environment.

INTRODUCTION

Body temperature is one of the most important vital signs in newborns that should be monitored to ensure safe and effective care. Preterm neonates are particularly prone to temperature maintenance problems due to their relatively large body surface area and immature thermoregulatory mechanisms.[1] Newborn preterm infants lose heat rapidly after birth. Despite measures taken to prevent heat loss during stabilisation within the delivery room, many preterm newborns have abnormal temperature on admission to the neonatal intensive care unit (NICU).[2] Abnormalities in temperature is an independent risk factor for morbidity and mortality in very preterm neonates.[3-5]

The normal temperature range of infants is narrow, between 36.5˚C and 37.5˚C; therefore, a difference of up to 1˚C in temperature readings may be the difference between normal and abnormal temperatures.[6] Hyperthermia is defined as a temperature >37.5˚C and hypothermia <36.5˚C.[6] Temperature instabilities, namely, fever, cold stress and hypothermia are important markers of potential sickness among neonates. They are often the earliest and only sign of serious illness among neonates.[7] As a result, temperature should be measured regularly and readings should be accurate and reproducible, whilst maintaining a normal body temperature, ensuring a stable thermal environment and avoiding cold stress.[2] Frequent disturbance of a neonate can also lead to hypoxia or deterioration of their condition, therefore, the practice for minimal handling is fundamental.[1] Studies have demonstrated the beneficial effects of development care on brain function and structure in stable preterm neonates.[8,9] In addition, the critical importance of sleep and sleep/wake cycles in preterm neonates play a crucial role in the development of sensory functions, motor coordination and brain growth have been highlighted.[10-12] It is therefore important to seek opportunities to minimise the impact of nursing interventions on preterm neonates, promoting sleep and healthy developments through a minimal handling approach to care.

Numerous temperature measurement methods have been identified for use in neonates, with newer methods including electronic and NCIR thermometers widely used in high-income countries while the traditional mercury-in-glass thermometer remains widely used within low-income countries. A recent search of relevant studies published between January 1949 and May 2021 was performed to identify the current methods available for temperature monitoring in neonates.[13] This review discusses the numerous different methods for temperature monitoring identified. Their accuracies, advantages and disadvantages were compared, the methodological aspects of relevant studies were discussed and further research to address gaps in current literature were suggested. The authors concluded that due to lack of consensus regarding a gold standard method of temperature measurement, as well as suboptimal methodologies used within studies, the accuracies of different thermometers are difficult to determine based on the current research available. However, consensus regarding the ideal method in neonates is that it should be simple, rapid, non-invasive, reproducible, cost-effective and accurately reflect the neonate's core body temperature.[14-15] In practice, every available method has several advantages and disadvantages, but none completely fulfil all the aforementioned criteria.[16] Both electronic and NCIR thermometers have emerged as potential replacements of conventional methods for monitoring of neonates fulfilling several of the listed advantages.

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Electronic thermometers have been reported to provide rapid temperature readings whilst posing minimal risk to the neonate.[17] It has also been suggested that electronic thermometers allow for continuous monitoring when electronic probes are used; yet, their accuracy is variable depending on which sites the temperature measurements are taken from.[18] For neonates, temperature is often measured at the axilla rather than the rectum as rectal thermometry is less accessible, increased risk of infection and risk of rectal perforation.[19] There are conflicting data on how well axillary and rectal temperature measurements correlate when taken with digital thermometers in neonates in the NICU.[20] Electronic thermometers have also been designed for placement on the skin, with these probes commonly used for continuous temperature monitoring of neonates in incubators and under radiant warmers. However, accuracy of skin measurement recorded is variable, as factors such as swaddling, clothing, the environmental temperature, how closely the thermometer is placed to the skin and the peripheral perfusion of the neonate.[18,20] Both the adjusting of clothing to allow access of the probe to be placed under the neonate's arm and the length of time the neonate's arm is held down to keep the probe in position can be uncomfortable and disturb the neonate. There is also a risk of injury and infection to the neonate, if the probe is inserted too far.

NCIR thermometers are newer and more promising devices in terms of speed and the non-contact nature confers on it, the advantage for infection control, especially important for the neonate whose immune system is not fully developed.[21] NCIR thermometers have been used to monitor temperature of neonates, at the axilla and other sites such as the ear, temporal artery, mid-forehead and leg.[22,23] Tympanic thermometers measure the IR energy emitted from the tympanic membrane and surrounding tissue and convert it into a temperature reading using electronic thermal transducers.[24] They are commonly used and have shown to be accurate in both children and adults; however, their use in neonates in currently limited and their accuracy is inconsistent, varying according to the population studied and the specific model used.[13,25]

NCIR thermometers, other than tympanic thermometers, measure the heat that radiates from the subcutaneous blood supply, allowing temperature to be measured without direct contact with the neonate.[26] Temperature measurements taken with IR thermometers have demonstrated less disturbance to the neonates' behavioural states, pain profiles, heart rate variation and partial oxygen saturation.[26,27]

The temporal artery is a key site for thermometry due to its connection to the heart, via the carotid artery, thus offering a constant blood flow.[7] As the artery is located superficially and its perfusion remains stable over long periods, it provides a non-invasive and accurate site of core body temperature. Studies have shown the temporal artery thermometers are capable of more accurately predicting temperature among other methods of infants and young children in various settings.[27-30]

NCIR mid-forehead thermometry has been proposed as an alternative to IR temporal artery thermometry as the temporal artery area is small in neonates and hence difficult to use.[27] Several studies have proposed differing results on the use of mid-forehead in neonates.[24,31-35]

When mid-forehead measurements were compared to electronic axillary thermometry in neonates present in incubators, temperatures measured by both methods did not differ to a clinically significant degree.[24] In a recent large study, consisting of 400 neonates, there was good agreement between the forehead NCIR thermometer and the axilla mercury in glass thermometer.[35] The mean temperatures obtained by the two methods of thermometry were similar, simulating a study conducted in children, whereby there was no significant difference between the mean thermometric readings obtained by both axillary mercury in glass and forehead non-touch IR thermometers.[36] The significant positive correlation between the two thermometry methods showed that both thermometers can be used interchangeably.[35,36]

Overall, the use of IR thermometers in neonates is currently limited and there is inconsistent information regarding their accuracy, which varies according to the population studied and the specific model used.[13] Hence, the present study was conducted in preterm neonates to assess the performance and accuracy of the TRITEMP™ forehead NCIR thermometer with Filac 3000 AD, an electronic thermometer in the axilla. The placement of neonates within incubators or open cots with / without thermal support or under phototherapy light was further accessed.

METHOD

This prospective observational study was conducted at the Neonatal Unit, Craigavon Area Hospital, NI (UK). The study subjects included preterm (from 28 weeks gestation) neonates nursed in either incubators or open cots. A majority of the incubators were enclosed in an outer covering, whilst several open cots were equipped with a CosyTherm system, in the form of a warming mattress. The incubator temperature ranged 28.2˚C and 32.2˚C, while the CosyTherm system temperature was maintained at 37˚C. On a few occasions, the additional use of phototherapy light was required.

Temperature measurements were taken in triplicate using the TRITEMP™ forehead NCIR thermometer and the Filac™ 3000 AD, an electronic thermometer in the axilla. Both thermometers are traceable to ASTM standards; the TRITEMP™ is traceable to ASTM E 1965-98 with clinical repeatability (or accuracy) within ± 0.2˚C for the range 37˚C-39˚C and the Filac™ is traceable ASTM E 1112-00 which covers non IR thermometers. These instruments were stabilised before measuring and temperatures were taken in accordance with the manufacturer's recommendations. Calibration of every thermometer was checked before commencing study. Each set of temperatures were measured by the same nurse i.e. three readings using the TRITEMP™ and three readings using the Filac™, respectively. The twenty-eight nurses with varying experience that participated in the study were experienced in the use of the Filac™ and were trained on use of the TRITEMP™ prior to the commencement of the study.

Forehead temperatures were measured first in all cases. The TRITEMP™ was placed in the top corner of the incubator or cot, away from the warming mattress, for at least 30 minutes before taking any measurements and remained in this environment during continuous temperature monitoring of the neonate. 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. For those neonates wearing a hat or nasal continuous airway pressure (NCPAP), it was important that the forehead was still visible. If required, the hat was adjusted or removed, allowing a minimum of 30s for temperature to stabilise. If the overhead phototherapy light was present, the light was moved away to one side and neonate's temperature was taken approximately 1 minute later. The neonates remained at all times inside the incubator or cot, and in some cases were either wrapped in clothing and/or covered with a blanket.

Each temperature reading was displayed on screen within 1 second of measuring the temperature using the TRITEMP™. Three temperature readings were taken using the NCIR thermometer, allowing 3-5 seconds between readings. The TRITEMP™ was returned to the neonate's incubator or cot for the duration of temperature monitoring. The TRITEMP™ was cleaned in accordance with the manufacturer's guidelines prior to taking temperature of different neonate.

Axillary temperature was then measured using the Filac™ 3000 AD electronic thermometer and due attention was given to maintaining asepsis and prevent cross-contamination or disturbance to the neonates. The neonate's arm was raised and probe tip was placed in the axilla. For neonates wearing

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clothing or covered with a blanket, such items were adjusted or removed to help ensure correct placement of the thermometer under the neonate's arm. Ideally, the probe tip was placed horizontally under the same arm when taking the three temperature readings; however, this was not always the case, particularly if there were any doubts about the temperature taken, measurements from the other arm were taken. Furthermore, the probe tip was placed against the neonate's skin in keeping with the manufacturer's recommendations to obtain more accurate temperature readings. The arm of the neonate was then lowered and the neonate had to remain as still as possible while the readings was being measured. The probe was held in position until a long bleep was sounded and the final temperature displayed. Following the three temperature measurements, the used probe was ejected and placed in a bio-waste container and the thermometer was cleaned prior to taking temperature of the next set of readings from the next neonate.

In this neonatal unit, normothermia was defined as axilla temperature between 36.5 and 37.5˚C.[6] For neonates with repeat temperatures above or below this range, another layer is added or removed, and/or the incubator or CosyTherm temperature is increased or decreased, accordingly.

Further sets of temperature reading could be taken from the same neonate following an interval of least three hours between readings.

In addition to recording of the temperatures, each of the nursing staff were asked to complete a feedback survey to determine the acceptability and explore benefits of the TRITEMP™ thermometer for the nurse and patient.

Data and Statistical Analysis

To assess the variability of repeated measurements (reproducibility) of both thermometry methods, each preterm neonate had triplicate measurements of body temperature taken. Repeatability was calculated as a measure of reproducibility of three repeated temperature measurements, defined as the standard deviation (SD) of the differences between the two sets of measurement.

The Bland-Altman method was used to test for the level and limits of agreement between the two thermometry methods. Level of agreement was said to be good if 95% of the data was between 1.96 SD of the mean difference between the two methods.[37] According to previous studies, mean difference was considered good if <0.5, and satisfactory if <0.6˚C. [1,26,33,35,38], and a more recent suggested that an ideal thermometer should be accurate within ±0.1˚C.[39]

The primary outcome was agreement between the forehead NCIR thermometer (TRITEMP™) and the axillary electronic thermometer (Filac™) in preterm neonates. This objective also included the acceptability and exploration of other benefits of the NCIR thermometer through completion of feedback surveys by the nurses after several sets of temperatures were taken. Some were open-ended questions allowing the nurses the freedom to answer in their own words, instead of limiting their response to a set of pre-selected choices. On the other hand, there were closed-ended survey questions, including Likert scale questions, enabling nurses to indicate the extent to which they agree or disagree with a given statement, or express a neutral response. All responses and the quantitative data produced from the Likert scale surveys (total of twenty-three completed) were analysed. For the 5-point Likert scale, the frequency of responses were plotted for each level (i.e. Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree) and the most common response or mode can be determined. Alternatively, each of the levels are assigned a numerical value 1-5, with Strongly Agree assigned 5 and the score for the entire survey was calculated i.e. the numerical value for each level is multiplied by the number of responses and then the mean of the six questions was calculated.

RESULTS

A total of 90 sets of temperatures were recorded (three readings using the TRITEMP™ and three readings using the Filac™ 3000 AD in axilla). One set was excluded due to an incomplete set of temperature measurements. In the majority of cases, several sets of temperature readings were measured from the same neonate, with at least three hours between readings. Approx. 50% of the neonates were nursed either in incubators (48.3%) with the rest in open cots (51.7%). The majority of incubators were enclosed with an outer covering. On some occasions, the open cot had a thermal support (i.e. CosyTherm system). The additional use of phototherapy light was minimal.

The average and SD of the triplicate readings were initially compared. Table 1 and Figure 1 show the SD for the sets of measurements. Similar mean body temperatures were obtained for both methods i.e. 36.8 ± SD 0.092 and 36.7˚C ± SD 0.094 for TRITEMP™ and the Filac™, respectively.

Table 1. Summary of temperature variability

Comparison	TRITEMP™	Filac™
Total average SD for 89 sets	0.092	0.094
Minimum set SD	0.000	0.000
Maximum set SD	0.493	0.416
Sets with SD (0.00)	10	6
Sets with SD (0.01 - ≤0.10)	52	57
Sets with SD (0.11 - ≤0.20)	20	14
Sets with SD (0.21 - ≤0.30)	6	11
Sets with SD (0.31 - ≤0.40)	0	0
Sets with SD (0.41 - ≤0.50)	1	1

Variability expressed as mean temperature ± SD; SDs calculated based on set of triplicate readings.
As indicated in IFU, accuracy of TRITEMP™ and Filac™ 3000 AD ±0.2˚C and ±0.1˚C, respectively.

Figure 1. Standard deviation of data sets

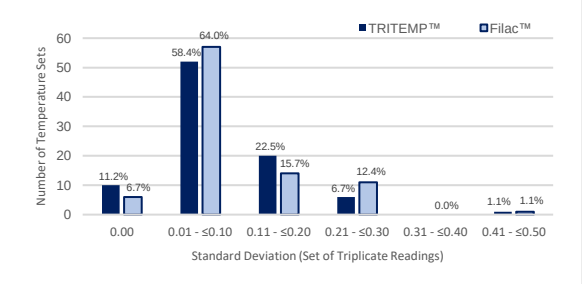

Table 2 summarises the results based on the neonates' environmental conditions i.e. present in an incubator with or without an outside covering or the presence of phototherapy light; alternatively present in an open cot, again the absence or presence of phototherapy light or with the inclusion of a thermal support, such as a CosyTherm system. The incubator temperature ranged from 28.2 - 32.2˚C, while the CosyTherm system temperature was maintained at 37˚C. The mean temperatures recorded for neonates nursed in the incubators were 36.8˚C ± SD 0.091 and 36.7˚C ± SD 0.089, and in open cots were 36.8˚C ± SD 0.092 and 36.7˚C ± SD 0.094 using the TRITEMP™ and Filac™, respectively.

Table 2. Mean temperature variability with neonate environment

Comparison	TRITEMP™	Filac™
Incubator = 46 sets	**36.8˚C (SD±0.091)**	**36.7˚C (SD±0.089)**
Only (n=8)	36.9˚C (SD±0.094)	36.7˚C (SD±0.081)
+ Cover (n=36)	36.8˚C (SD±0.091)	36.7˚C (SD±0.089)
+ *PL (n=2)	36.8˚C (SD±0.085)	36.7˚C (SD±0.078)
Open Cot = 43 sets	**36.8˚C (SD±0.092)**	**36.7˚C (SD±0.094)**
Only (n=31)	36.8˚C (SD±0.092)	36.7˚C (SD±0.094)
+ 'CT (n=2)	36.9˚C (SD±0.062)	36.6˚C (SD±0.052)
+ *PL (n=1)	36.6˚C (SD±0.058)	36.0˚C (SD±0.058)
+ 'CT+ *PL (n= 9)	36.8˚C (SD±0.078)	36.7˚C (SD±0.067)

*Phototherapy light 'CosyTherm

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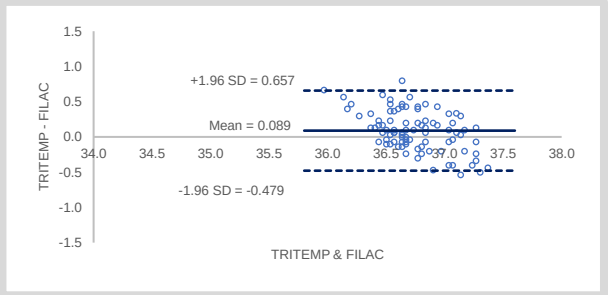
The agreement between the measurement techniques (systematic difference) was analysed using a Bland-Altman plot with a limit of agreement of (plus minus) 1.96 SDs. The graphs display the Bland-Altman plots for readings taken by the TRITEMP™ compared to the Filac™ (reference method). Figure 2 represents all the neonate results from the study. The difference (y-axis) between the Filac™ and TRITEMP™ method is plotted as a function of the mean of the two measurements (x-axis). Figure 2 shows that for the TRITEMP™ 95% of the measurements presented differences between -0.48˚C and +0.66˚C.

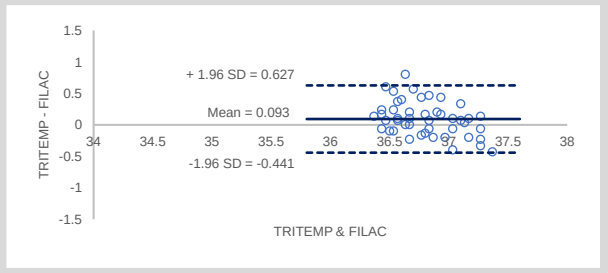
Figure 2. Bland Altman plot showing comparison of forehead NCIR thermometer (TRITEMP) and electronic axillary thermometer (FILAC) in preterm neonates within incubators and open cots



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

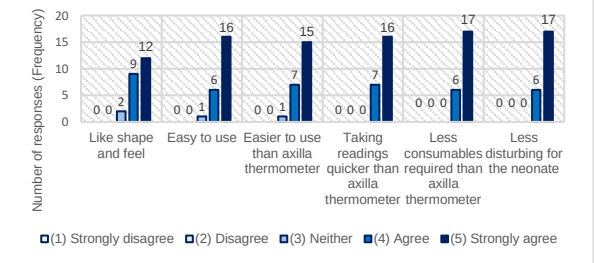
Figure 3 represents results for the neonates nursed in incubators only. The difference (y-axis) between the Filac™ and TRITEMP™ method is plotted as a function of the mean of the two measurements (x-axis). Figure 3 shows that for the TRITEMP™ 95% of the measurements presented differences between -0.44˚C and +0.63˚C.

Figure 3. Bland Altman plot showing comparison of forehead NCIR thermometer (TRITEMP) and electronic axillary thermometer (FILAC) in preterm neonates within incubators only



A Likert scale survey was completed by 23 nurses during the study. Figure 4 shows the nurses' responses regarding the features and benefits of the TRITEMP™. Alternatively, results from the 5-point Likert scale survey have been tabulated (Table 3).

Figure 4. Bar chart showing responses of the Likert scale survey



The plot shows that the mode or most common response for each question is that the nurses strongly agree with the TRITEMP™ features highlighted. Furthermore, the mean score for the Likert survey was 4.65 indicating that the nurses have positive attitudes towards the use of the TRITEMP™ for measuring temperature in neonates.

Table 3. Responses from the Likert scale survey

Level	Value	TRITEMP™					
		Like shape & feel	Easy to use	Easier to use than axilla	Taking readings quicker than axilla	Less consumables required than axilla	Less disturbing for neonate
Strongly disagree	(1)	**0** [0]	**0** [0]	**0** [0]	**0** [0]	**0** [0]	**0** [0]
Disagree	(2)	**0** [0]	**0** [0]	**0** [0]	**0** [0]	**0** [0]	**0** [0]
Neither	(3)	**6** [2]	**3** [1]	**3** [1]	**0** [0]	**0** [0]	**0** [0]
Agree	(4)	**36** [9]	**24** [6]	**28** [7]	**28** [7]	**24** [6]	**24** [6]
Strongly agree	(5)	**60** [12]	**80** [16]	**75** [15]	**80** [16]	**85** [17]	**85** [17]
	Mean	**4.43**	**4.65**	**4.61**	**4.70**	**4.74**	**4.74**

Note: Score = numerical value for each level is multiplied by the number of responses e.g. 12 nurses strongly agreed that they liked the shape and feel of the TRITEMP™: [12] responses x (5) value for strongly agree = **60** score

The nurses responses to a few open-ended questions further supported the use of the TRITEMP™ or taking temperatures in neonates. The level of disturbance when using the axilla thermometer was measured in terms of neonate crying, moving or looking uncomfortable. Almost 80% of the nurses indicated that the main issue with the Filac™ axilla thermometer is the disturbance and upset of the neonate either by the necessity to adjust the neonate's clothing, determining the correct position of the probe under the neonate's arm, making contact with the neonate's skin, and then holding the neonate's arm down to ensure that the probe remained in position whilst the temperature was being measured. In this study, 68.5% of the neonates were wearing clothing (i.e. baby grow) and 60.7% of the neonates were wrapped in muslin blankets. Furthermore, almost 83% of the neonates were reported to be disturbed (neonate crying, moving or looking uncomfortable) when taking their temperature using the axilla thermometer.

Other issues reported with the axilla method included temperature variability (with differences between arms), and probe cover stock and wastage. Furthermore, all but one nurse indicated that the TRITEMP™ thermometer improves both their work-flow and neonate care compared to the Filac™. Moving forward, 19 out of the 23 nurses would prefer to use the TRITEMP™ to measure neonates' temperatures, whilst 3 out of 23 require further use of this thermometer as they remain undecided.

DISCUSSION

The ideal method of temperature measurement in neonates should be simple, rapid, non-invasive, reproducible, cost-effective and accurately reflect the neonate's core body temperature.[14-15] There are several methods for temperature monitoring in neonates currently available, each with their own advantages and disadvantages, but none completely fulfil all of the aforementioned criteria.[13,16] Furthermore, due to the lack of consensus regarding a gold standard method of temperature measurement, as well as suboptimal methodologies used within studies, the accuracies of different thermometers are difficult to determine based on the current research available.[13] Accuracy has been found to vary according to the population studied and the specific model used. Both electronic and NCIR thermometers have emerged as potential replacements of conventional methods for monitoring of neonates fulfilling several of the advantages listed previously. In NICUs, temperature is often measured at

the axilla rather than the rectum as is more accessible and less invasive.[19] The present study was conducted to evaluate the performance of forehead NICR thermometer TRITEMP™ in comparison with the currently used electronic axillary Filac 3000™ AD thermometer in preterm neonates. The neonates were nursed in either incubator or open cots with or without thermal support and/or phototherapy light.

In this study, the TRITEMP™ demonstrated high accuracy when compared with the reference method i.e. the axillary Filac™. The mean difference of +0.089˚C with the reference method meets the criterion that an ideal thermometer should be accurate within ±0.1˚C.[39] On further analysis, similar mean difference of +0.093˚C was obtained between the two methods irrespective of the neonates' environment i.e. incubator (range 28.2˚C-32.2˚C) or open cot (at ambient temperature or at 37˚C if thermal support used). This finding supports a previous study conducted in neonates nursed in incubators, whereby the forehead and axillary temperatures measured did not differ to a clinically significant degree.[24] Some current studies show that mid-forehead measurements were inaccurate due to various factors that influence the readings, including the neonate's environment.[34] Allowing adequate stabilisation of the thermometers before measuring may have produced different conclusions.

During the present study, it was evident that the TRITEMP™ displays many benefits or compared to the Filac™, for both the neonate, nurse and environment. Unlike the TRITEMP™, the axilla thermometer method led to disturbance and upset of the neonate, which can lead to hypoxia or deterioration of their condition.[1] Almost 83% of the neonates were reported to be disturbed (neonate crying, moving or looking uncomfortable) when taking their temperature using the axilla thermometer. Disturbance was associated with adjusting clothing to aid correct positioning of the thermometer probe under the neonate's arm and holding the neonate's arm down to ensure that the probe remained in position while temperature was being measured.

On the other hand, the forehead thermometer caused minimal disturbance to the neonate. On some occasions, the neonate's hat or NCPAP was adjusted to obtain visibility of their forehead. Minimal neonate handling or nurse intervention provides a more stable environment preventing deterioration of the neonate's condition, promoting sleep and healthy developments (e.g. brain growth, function and structure, sensory function and motor coordination).[8-12]

During this study, other issues reported with the axilla method included temperature variability (with differences between arms), and probe cover stock and wastage. These issues affect the efficiency of the nurses' work-flow and ultimately affect the neonate's care. Furthermore, in addition to cost, the excess use of plastic places additional pressure on management to ensure stock availability and safe disposal of waste.

Some nurses perceived that there was some variability between forehead measurements; however, the triplicate temperature measurements recorded by the TRITEMP™ do not support this comment. Furthermore, all but one nurse recorded that the TRITEMP™ improves their work-flow and neonate care, and the majority would prefer to use TRITEMP™ rather than the current axilla thermometer.

The main limitation of the present study is that there were no febrile neonates. It may be beneficial to include measurements of preterm neonates either prior to or on admission to the NICU.

CONCLUSION

Based on a sample of preterm neonates present in a NICU, the infrared forehead NCIR thermometer is a suitable alternative to the electronic axilla thermometer. It is accurate, quick, easy to use, cost effective and environmentally friendly as well as causing minimal disturbance to the neonate.

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