Original Research Article

Measuring temperature in children, conveniently and accurately: a comparative study on different modalities of thermometry

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ABSTRACT

Background: Fever is one of the most common complaints in children in day-to-day practice. The pattern and grade of fever provide some evidence in determining the etiology of fever. Equally important is the identification and documentation of hypothermia in neonates. Hence there is need for an accurate thermometry mode, which should also be convenient to use in children.
Methods: This was a cross-sectional observation study on all the neonates and children satisfying the inclusion criteria. Infrared forehead thermometer and digital axillary thermometer were used to record temperature and compared with Infrared tympanic temperature which was taken as gold standard.
Results: A total of 240 neonates and children were evaluated. Strong positive correlation was observed between Means of Forehead Thermometer (FT) and Ear Thermometer (ET) with correlation coefficient of 0.777 and p value <0.001. Similar correlation was also observed with Axillary Temperature (AT) with correlation coefficient of 0.944 and p<0.001.
Conclusions: Non-contact Infrared thermometer may be used in neonates and children without causing discomfort. It gives instant and comparable readings which are especially significant in the current coronavirus disease (COVID) pandemic setting.

Keywords: Thermometer, Temperature measurement, Infrared thermometer, Fever, Hypothermia, Thermometry

INTRODUCTION

Humans are homeothermic in nature, meaning they can regulate their core body temperature within a narrow limit. Any change in this regulation can cause elevated body temperature called fever or hyperpyrexia or hyperthermia, or can cause a fall in the temperature called hypothermia.[1] These changes can be due to various causes, infection being the most common one. Fever is one of the most frequent presenting complaints in children, in both emergency department and in outpatient department. The pattern of fever should be observed which gives a clue to make a diagnosis and decide upon treatment. Detecting hypothermia is equally important, and is a feature of sepsis in neonates.

Hence, a device which accurately detects these temperature changes is necessary. There are various sites of temperature measurement including invasive and non-invasive sites. Invasive sites are mostly preferred in anesthetized patients and non-invasive sites are being used in day-to-day life. Among non-invasive sites, rectal temperature has been considered as the most accurate method to predict core body temperature, but its use has been limited due to cumbersome nature and risk of rectal perforation if done improperly.[2]

In our hospital, digital axillary thermometers (AT) are widely used which usually takes around one to two minutes to display the temperature. Measuring the body

temperature using this method is particularly difficult in young children where they become anxious and irritable.

In this pandemic era, infrared forehead thermometer (FT) is being widely used which takes only two seconds to read the temperature, and also its ease of measurement and safety profile make it the better choice if we are assured of its accuracy.[3]

This study was undertaken with the objectives of comparing axillary and forehead thermometry with tympanic membrane infrared thermometry (TT) in terms of accuracy, ease of measurement and safety profile.

METHODS

This study was a cross-sectional observational study. This study was conducted in the pediatric wards and postnatal ward under the Department of Pediatrics, Sri Manakula Vinayagar Medical College and Hospital (SMVMCH). SMVMCH is a 950 bedded tertiary care teaching institute situated in semi-urban area of Puducherry. The study was conducted between October 2016 to May 2019 after obtaining approval from the Institutional Ethics Committee.

Study participants

Children of both sexes in the age group of 0-12 years were recruited in the study.

Sample size

A sample size of 240 was calculated using the software "N MASTER version 2.0" with 95% confidence interval and 5% absolute precision.

Sampling technique

All the newborns and children, admitted to wards who were satisfying the inclusion criteria and who consented to take part in the study were enrolled in the study, till the sample size was reached.

Inclusion criteria

Children from the age of 0-12 years who got admitted in SMVMCH Pediatric wards or post-natal ward.

Exclusion criteria

Children with- suppurative otitis media, otitis externa, large amount of wax, preterm neonates

Data collection procedure

After the clearance by Institutional Ethics Committee, all newborns and children in the wards were recruited in the study. A written informed parental consent was obtained before recruiting them into the study. The socio-demographic and baseline characteristics like age, sex, anthropometry, diagnosis, newborns with hypothermia, and children with fever were recorded.

All temperature readings were recorded by the principal investigator and counterchecked by one of the consultants from the Department of Pediatrics. The temperature was measured using three thermometers; three readings were recorded with each thermometer after explaining the procedure to the caregiver and getting the consent. Assent is obtained from the child if the child is ≥7 years of age. Temperature was measured during the daytime to decrease the effect of circadian rhythm that was found to interfere with the temperature.[4]

Temperature was measured using the following: IRT 6500 Braun Thermoscan Ear Thermometer, NTF 3000 Braun No Touch Forehead Thermometer, Digital axillary thermometer (Omron).

Analysis of the data

Statistical analysis

Data was entered into Microsoft excel data sheet and was analysed using Statistical Package for social sciences (SPSS) 25.0 version software.

Chi-square test was used as test of significance for qualitative data. Continuous data was represented as mean and standard deviation. Paired sample 't' test was used as test of significance to identify the mean difference between two qualitative and quantitative variables.

Pearson correlation was done to find the correlation between two quantitative variables and qualitative variables respectively.

Graphical representation of data: MS Excel, Medcalc version 18.10.2 (trial version) and MS word was used to obtain various types of graphs such as bar diagram, Pie diagram, Scatter plots.

p value (Probability that the result is true) of <0.05 was considered as statistically significant after assuming all the rules of statistical tests.

Statistical software

MS excel, SPSS version 25 (IBM SPSS Statistics, Somers NY, USA) was used to analyze data, Medcalc version 18.10.2 (trial version).

RESULTS

A total of 240 children were enrolled in the study of which, 121 (50.4%) were males, 119 (49.6%) were females. Neonates were 92 (38.3%) of which 66 (71%) were well babies without any issues, 8 (9%) had neonatal sepsis, 9

(10%) had transient tachypnea of newborn immediately after birth, 9 (10%) had neonatal hyperbilirubinemia. 15 (16.3%) babies found to be hypothermic, 75 (81.52%) babies had normal temperature while 2 (2.17%) babies had hyperthermia. Children were 148 (61.7%) of which 53

(36%) got hospitalised for fever as the main complaint, 45 (31%) presented with respiratory symptoms, 38 (25%) presented with gastro-intestinal symptoms, 12 (8%) presented with seizures. 141 (95.27%) of the children had normal temperature and 7 (9.73%) had fever >380C.

Table 1: Baseline characteristics of study population.

Baseline characteristics		Number n (%)
Gender	Male	121 (50.4)
	Female	119 (49.6)
Study group	Neonates (0-28 days)	92 (38.3)
	28 days-1 year	20 (8.3)
	1-5 years	67 (27.9)
	5-12 years	61 (25.4)
Etiologies for hospitalization in neonates	Inborn, well babies	66 (71)
	Neonatal sepsis	8 (9)
	Transient tachypnea of newborn	9 (10)
	Neonatal hyperbilirubinemia	9 (10)
Etiologies for hospitalization in children	Fever	53 (36)
	Respiratory symptoms	45 (31)
	Gastrointestinal symptoms	38 (25)
	Seizures	12 (8)
Temperature in neonates	Hypothermia (<36.5^{0}C)	15 (16.3)
	Normal temperature (36.5^{0}C - 37.5^{0}C)	75 (81.52)
	Hyperthermia (>37.5^{0}C)	2 (2.17)
Temperature in children >28 days	<38^{0}C	141 (95.27)
	>38^{0}C	7 (4.75)

Table 2: Friedman test for comparison of FT, TT and AT mean.

Parameters	Mean	SD	Mean rank	Chi-square value	P value
FT mean	36.313	0.5678	1.06		
ET mean	36.878	0.5199	2.83	404.369	<0.001*
AT mean	36.726	0.5165	2.12		

Table 3: Pearson's correlation coefficient between FT, TT, AT means.

Parameters	Mean	SD	Pearson's correlation coefficient	P value
FT mean	36.313	0.5678	0.777	< 0.001*
TT mean	36.878	0.5199		
TT mean	36.878	0.5199	0.944	< 0.001*
AT mean	36.726	0.5165		
FT mean	36.313	0.5678	0.801	<0.001*
AT mean	36.726	0.56165		

All these above mentioned baseline characteristics and the number (n) and its percentage are summed up in Table 1.

The Friedman test results shows that there is a significant difference between the mean of FT (Forehead thermometer), TT (Tympanic thermometer) and AT (Axillary thermometer) values (Chi-square value=404.369, p<0.001) as shown in Table 2.

The Pearson's correlation test results shows that there is a strong positive correlation between FT mean and TT mean (Pearson's correlation coefficient=0.777, p≤0.001). There is a strong positive correlation between TT mean and AT mean (Pearson's correlation coefficient=0.944, p≤0.001). There is a strong positive correlation between FT mean and AT mean (Pearson's correlation coefficient=0.801, p≤0.001) as depicted in Table 3.

The one way ANOVA result shows that there is a significant difference in FT, TT and AT means with respect to age with FT F value of 4.632 and p value 0.004, TT F value 4.802 and p value 0.003 and AT F value 4.433 and p value 0.005.

The independent sample 't' test result shows that there is no significant difference in FT, TT and AT means with respect to sex; with FT t value of 0.749 and p value 0.454, TT t value of 1 and p value of 0.318 and AT t value of 1.599 and p value of 0.111.

DISCUSSION

Newborn male infants have a lower baseline body temperature than newborn females, as newborn females have more body fat mass in the form of brown adipose tissue (BAT) and they tend to increase or sustain more BAT during their life than males. A subtle, but constitutional gender-related metabolic difference can be hypothesized in human neonates, although the difference in body temperature looks too small (only 0.27%) to have clinical significance.[5,6] In our study, the mean temperature in neonates was 36.840C in males and 36.900C in females. In pediatric age group, the mean temp in males was 36.870 and 36.970 in females.

There are numerous studies in the literature that concluded as no thermometry route being ideal.[7,8] Intra-corporeal thermometry methods were considered best as they measure temperature of blood vessels that perfuse head and trunk organs. As these methods are difficult to perform, and have their own limitations, high risk for complications and are expensive, their usage is limited only to particular conditions.

Rectal temperature measurement by mercury-in-glass thermometer has been considered gold standard for years in most clinical settings.[9] But its use has many problems such as risk of cross contamination, perforation or discomfort for the patient. The use of mercury-in-glass thermometer has been banned since 2010 as it has risk of toxicity associated with the direct contact with the skin and mucosa. Hence, to combine patient's safety and comfort with satisfactory accuracy of core body temperature in clinical practice, non-invasive thermometry methods have been introduced. Non-invasive thermometry methods include oral, tympanic, temporal artery (TA), forehead and axillary temperature measurement by digital electronic thermometers, which display estimated core body temperature values according to conversion algorithms.[10]

Infrared tympanic thermometers are ideal as they yield core body temperature and are practical to use.[11] The blood supply of the tympanic membrane is shared with the hypothalamus, from the common carotid artery. The blood supply to the ear canal and the tympanic membrane is from the maxillary and middle meningeal arteries, which are branches of the external carotid artery. Tympanic thermometers seem to be optimal for use with the elderly population. Owing to the ease of application, safety, and tolerability in the elderly; their use in routine practice seems to be advantageous. A study by Robertson and Hill suggested that tympanic thermometer is the right equipment and the correct route of measurement for obtaining accurate temperature reading.[12] Considering all these, tympanic thermometry was taken as the gold standard in our study.

Oral temperature is as accurate as axillary temperature and easy to use in older children and adults. But use of oral thermometer is not feasible, particularly in young children as sealing of mouth is difficult in them. As our study includes neonates and children less than 5 years of age, temperature measurement by axillary thermometer has been chosen.

The axillary temperature is a favored site for temperature measurement by parents, children and caregivers because of its ease of use and low risk of injury. However, these measurements can be affected by ambient temperature and by changes in skin perfusion. Axillary thermometry is a safe and non-invasive method whose results correlate well with rectal temperature.[13] Axillary temperature monitoring with digital thermometers has been reported as the most reliable, appropriate, and accurate method when compared to mercury-in-glass thermometers, which were accepted as a criterion standard for years in the literature.[14]

Romano et al concluded in their study in pediatric ICU that infrared tympanic thermometer estimated core body temperature better than digital axillary thermometer and it performed similar to the rectal probe with a mean bias of -0.13 and a variability of 0.39.[15]

Sethi et al conducted a study on accuracy of non contact infrared thermometry and axillary digital thermometry in neonates in Ahmedabad, India and stated that the temperature measurement by digital axillary and non-contact forehead thermometer do not agree well with a mean difference of -1.5 ,95% limits of agreement.[16] A study by Chiappini et al on pediatric population found a good agreement (mean difference =0.07C, 95% CI) between infrared forehead thermometry and axillary thermometry by using a glass thermometer.[17] Similarly, our study shows good agreement between non-contact infrared forehead thermometer and digital axillary thermometer with a mean difference of -0.414 and SD 0.346.

Paramita et al compared axillary and tympanic membrane to rectal temperatures in children aged 6 months to 5 years with fever, and concluded that axillary temperature measurement and tympanic membrane temperature measurement are equally good and can be used in daily clinical practice or at home.[18] In our study, strong agreement is noticed between tympanic and axillary temperature measurements with a mean difference of 0.152 and SD 0.173.

A prospective cohort study by Nimah et al on pediatric and cardiac intensive care units at a tertiary care children's hospital found that ITT (Infrared tympanic thermometer) measurements agreed more closely with core temperature than rectal, forehead, and axillary measurements during both febrile and non-febrile conditions in children. ITT measurements performed well with an area under curve of 0.855 (95% confidence interval, 0.797-0.913) in comparison with rectal temperature area under curve of 0.777(95% confidence interval, 0.701-0.853), forehead measurement area under curve of 0.710 (95% confidence interval, 0.715-0.888), and axillary measurement area under curve of 0.664 (95% confidence interval, 0.579-0.750). The study concluded that ITT is a reliable, practical, and accurate method of detecting fevers in children and a less invasive substitute for bladder or rectal measurements. Use of axillary and forehead temperature measurements should be discouraged in assessing fever in critically ill children.[19]

Our study shows a strong positive correlation between tympanic and forehead with Pearson's correlation coefficient of 0.777, p<0.001. Also there is a strong positive correlation between tympanic and axillary with Pearson's correlation coefficient=0.944, p<0.001.

Duran et al conducted a study on preterm infants of birth weight <1500 g to compare temporal artery, mid-forehead and axillary temperature recordings in them. The mean mid- forehead temp was 36.72±0.08, axillary was 36.71±0.07 and stated that there is no statistically significant difference between the means of mid-forehead and axillary temperatures. The study concluded that mid-forehead is a valid and useful device measurement of temperature.[20] In our study, the mean ear temperature is 36.878±0.52, axillary 36.726±0.517 and forehead 36.313±0.568. Though there is a statistically significant difference between the means of all three measurements, these differences are negligible in absolute terms and correlation coefficient was found to be strong positive.

There are certain limitations to the study which include the exclusion of preterm neonates as their hemodynamic status may be affected during the recording of temperature. Also, critically ill children have not been included, but the implications of the study may be significant in them as we need an accurate and non-invasive method to rapidly record their temperature.

CONCLUSION

Axillary temperature is as good as tympanic temperature except for the fact that it is a cumbersome procedure, time consuming, influenced by skin perfusion, and clothes should be removed which makes the child anxious. Ear temperature is being used in western countries as an ideal device. But while taking temperature in newborns, the probe might disturb the child which increases heart rate, and in children less than 6 months of age, they get apprehensive when a probe is placed in their auditory canal. Non-contact infrared forehead thermometer is convenient, gives immediate readings, accuracy is comparable to other forms of thermometry, and may be preferred in all settings especially due to the current COVID-19 pandemic.

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