

A COMPARITIVE STUDY OF DIFFERNET METHODS OF TEMPERATURE MEASUREMENTS IN NEONATES ATTENDING EMERGENCY ROOM



Pediatrics

KEYWORDS: Infrared tympanic measurement, axillary temperature, Pearson correlation, Bland-Altman analysis.

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ABSTRACT

BACKGROUND:- Accurate measurement of temperature is important in detecting fever and hypothermia in neonates. Hypothermia is an important contributor for neonatal morbidity and mortality in developing countries. Rectal temperature measurement is the gold standard measurement. We studied the correlation and agreement between Axillary, Infrared Tympanic and Infrared Forehead temperature measurement with Rectal temperature measurements, in sick newborn babies at different time intervals newborn emergency room.

METHODS:- This is an observational study, where temperature measurement were taken from rectal site first with digital thermometer, followed by Axillary temperature with digital thermometer, both tympanic and forehead temperature measurements using the Infrared thermometer at 5 minutes, 15 minutes, and 30 minutes from the time of arrival to the Newborn emergency room at Institute of Child Health and Hospital for Children, Chennai. The digital axillary, infrared tympanic and infrared forehead temperature measurements were compared with digital rectal temperature measurements, which is the gold standard temperature measurement. Certain subgroup analysis were done; neonates with low birth weight, Gestational age 32-36 weeks, Gestational age >36 weeks, Normothermic babies, Hypothermic neonates, Hyperthermic neonates, neonates with seizures, respiratory distress and shock. The Pearson Correlation Coefficient(r) and the Bland-Altman Plot Analysis for agreement were obtained.

RESULTS:- A total of 600 measurements were taken from 200 neonates attended the emergency room within the study period. The infrared tympanic temperature measurement showed highest positive correlation when compared with rectal temperature measurement ($r=0.851$, $p<0.0001$). Axillary temperature measurement also showed good correlation($r=0.759$, $p<0.0001$) but is inferior when compared with tympanic measurement. Infrared tympanic measurement also has strong agreement with rectal temperature measurements (Mean difference 0.311, CI 0.339, 0.284). Highest correlation shown by infrared tympanic measurements is sustained in small, sick and normal neonates; Hypothermia ($r=0.872$, $p<0.0001$), Hyperthermia($r=0.931$, $p<0.0001$), shock($r=0.944$, $p<0.0001$), Low birth weight-1500 to 2500 grams ($r=0.852$, $p<0.0001$), Gestational Age-32 to 36 weeks($r=0.815$, $p<0.0001$), Gestational Age>36 weeks($r=0.854$, $p<0.0001$). Right and left infrared tympanic measurements correlated well with each other($r=0.921$, $p<0.0001$) and right tympanic measurements correlated well with rectal temperature measurement($r=0.851$, $p<0.0001$). Forehead temperature measurement showed poor correlation with rectal temperature measurement.

CONCLUSION:- Infrared Tympanic temperature measurement is the most reliable method of temperature measurement in neonates. Tympanic and axillary temperature measurements are reliable in sick, small (>32 weeks and >1500 grams) and healthy neonates.

INTRODUCTION

Accurate measurement of body temperature is important for detecting fever and hypothermia in neonates¹. Low birth weight and sick new born babies are increased risk of developing hypothermia or hyperthermia because they regulate the body temperature less effectively. Nursing a baby in an environmental temperature that is below or above the neutral range of ambient temperature for his postnatal age and maturity will lead to hypoxia and hypoglycaemia. Hypothermia is an important contributor for neonatal mortality in the developing world. Inaccurate temperature measurement by the caregivers results in delay in seeking medical advice, delay in diagnostic workup and delay in initiation of appropriate treatment.

Therefore, it becomes imperative to monitor accurate body temperature in neonates so that appropriate intervention can be made to prevent hypothermia or hyperthermia in neonates. Ideal temperature measurement technique should be safe, easy, non-invasive, time efficient, cost effective and it should measure the core body temperature precisely².

CORE BODY TEMPERATURE

Core body temperature is the operating temperature of an organism, specifically in the deeper structures of the body. Core body temperature is normally maintained in a narrow range so that essential enzymatic reactions occur. Significant core temperature elevation (hyperthermia) or depression (hypothermia), more than the brief period of time is incompatible with human life. The core

temperature is not similar throughout the body². The highest body temperature is recorded and set in hypothalamus.

THE IMPORTANCE OF TEMPERATURE MEASUREMENT²

The presence of hypothermia or fever is a vital indicator. It needs a careful evaluation and prompt treatment. Incorrect temperature detection by caregivers leads to delay in seeking medical care, delay in diagnostic work up and ultimately delayed treatment. The precise measurement of body temperature is important in the following clinical settings.

- To obtain a baseline temperature and to compare with a future temperature recordings.
- To enable close observations in resolving hypothermia or fever.
- When the body temperature is < 300C, the cardiac rhythm disturbances and death can occur.
- Hypothermia has been recognised as important contributor of neonatal morbidity and mortality in the developing countries.
- In new born, the precise body temperature of >380C is associated with serious bacterial infection..
- While measuring temperature, it is necessary to be close to body core temperature³. Ideally the temperature measurement should be
- Safe, comfortable, convenient and easy to use without difficulty by patient and the practitioner.
- Time efficient.
- Reflect the core body temperature, should not be influenced by

the environmental temperature.

- Cost effective
- Not result in cross infection.

Different non-invasive methods of temperature measurement used for measuring temperature

RECTAL TEMPERATURE MEASUREMENTS

Rectal temperature has traditionally been considered as the gold standard for core body temperature measurement in routine clinical practice^{2,3}. Rectal temperature has not been found to be influenced by changes in the ambient temperature and its use is not limited by age³. Rectal temperature measurement with low reading thermometer is considered to be best in clinical practice, when dealing with potential hypothermia such as neonatal cold injury, near drowning and neonatal sepsis. Also rectal temperatures have good agreement with oesophageal temperature measurement⁵.

Disadvantages of rectal temperature measurement are: its time consuming, Rectal temperature varies depending on the depth of insertion of thermometer, the rectal blood flow and the presence of stool and diarrhoea, the rectal temperature measurements lag behind the rapidly rising or falling core body temperature, possibly because of the poor rectal blood flow² very rarely may cause rectal perforation in neonates.

AXILLARY TEMPERATURE MEASUREMENTS

Axillary temperature measurement is one of the earliest methods of temperature measurement^{2,3}. This measurement relies on the thermometer being placed directly over the axillary artery, deep inside the apex of the axilla. It is safe, easily accessible and reasonably comfortable. In neonatal care units, where ambient environmental temperature is maintained, the axillary temperature is found to be as accurate as the rectal core temperature measurements.

Disadvantage to the axillary temperature measurement is, it requires supervision in case of displacement of thermometer and it requires longer time than rectal or oral temperature measurement. Despite its low specificity and sensitivity, the American Academy of Paediatrics recommends axillary temperature measurement as a screening test in neonates with fever⁹, as rectal temperature measurement carries the risk of rectal perforation although, it has been estimated to occur in less than one in two million measurements.

TYMPANIC MEMBRANE TEMPERATURE MEASUREMENTS

Under normal conditions, about 60 per cent of total heat loss from the body occurs in the form of infrared heat radiation and in fever these heat loss also get increased². As the tympanic membrane receives its blood supply from the carotid artery and thus, the temperature measured at this site closely reflects the blood flowing into the hypothalamus thus reflecting the core body temperature.

Modern tympanic thermometers measure the temperature by measuring the thermal radiation emitted from the ear canal and the tympanic membrane. These devices are called Infrared Radiation Emission Detectors (IRED)². Tympanic thermometers accurately measure the temperature because the amount of infrared radiation emitted from the membrane is directly proportional to the membrane temperature.

The potential benefits of tympanic thermometry are it is easily accessible, fast, and easy to use without any cross infection. It is not influenced by environmental temperature variations. The presence of ear wax, otitis media or crying does not shown to influence the temperature readings^{2,3}. The thermometer probe must be small and appropriate depth of insertion is necessary into the ear canal such that orientation of the probe should be against the tympanic membrane. The average diameter of ear canal is 4mm at birth and 5 mm at two years of age². It can lead to inaccurate tympanic temperature readings because the meatus is too narrow and are difficult to be used in children less than 2 years old. It has been

suggested that a slight pull of pinna posteriorly to straighten the meatus wall can increase the consistency as well as accuracy of the readings^{2,3}.

MEASUREMENT DEVICES

There are different types of thermometers which are being used in neonatal care units. These are Mercury in- glass thermometer, digital thermometer, Infrared thermometers, and chemical thermometers.

A thermometer is a device which measures the temperature or a temperature gradient using different variety of principles. A thermometer consists of two essential component; a temperature sensor in which some physical changes occur in response to change in temperature and some means to convert this physical changes into numerical values that can be displayed, for example in digital thermometers.

BODY TEMPERATURE IN THE NEWBORN INFANT HYPOTHERMIA¹²

Cold stress – Axillary temperature is 36.0 C to 36.40 C.

Moderate Hypothermia – Axillary Temperature is 32.0 C to 35.90 C.

Severe Hypothermia – Axillary Temperature is < 32.0 C.

HYPERTHERMIA

Axillary temperature is >37.50C.

REVIEW OF LITERATURE

Batraet al⁷, conducted a cross sectional observational study of comparing different methods of temperature measurement available in the emergency department of a tertiary care hospital. This study compared the rectal, axillary, right and left tympanic and temporal artery thermometer measurements. The study concluded that the temporal artery thermometry has the potential to replace the rectal thermometry in the busy emergency room setting.

Hamus Ozdemiret al conducted a prospective, descriptive, and comparative study of comparing the accuracy of digital axillary thermometer, rectal glass mercury thermometer, infrared forehead skin thermometer, infrared tympanic thermometer measurements with traditional axillary mercury thermometer for intermittent temperature measurement in sick newborn babies in a tertiary care hospital. This study suggested that tympanic infrared thermometer could be used as an acceptable and practical method of temperature measurement in sick newborn babies in neonatal units.

Chieh-Yu Liu¹³ et al investigated relationship among five temperature measuring sites in newborn babies. This study used a descriptive-correlation design, employed convenience sampling, and collected data from five temperature measurement site, including rectal, axillary, tympanic-both right and left, and back temperatures using digital thermometers and infrared thermometers in a postpartum clinic. Thirty three babies from one to twenty eight days old were recruited. The study found least differences between right tympanic temperature and rectal temperature, a significant relationship between left tympanic temperatures and rectal temperatures and axillary temperature as the most stable method among the five body temperature reading methods. The study concludes that tympanic temperature can replace the rectal temperature measurements.

Karel Allegaert¹⁴ et al conducted study in real life assessment comparison of tympanic, infrared skin, temporal artery thermometers with rectal measurement in children. The study was conducted in 294 children from heterogeneous group of population from the emergency department, the outpatient clinic, the paediatric day surgery unit and the medical wards.. The study finally concluded that all non-invasive techniques underperformed when compare with rectal temperature measurement, with temporal artery scan deviation is the smallest from the rectal temperature measurement.

Mehmet Yekta Oncel¹⁶ et al performed a study to compare the

accuracy of Digital Axillary thermometer, rectal glass mercury thermometer, and infrared forehead skin thermometer measurements made by mothers and physicians in the health newborns. The body temperature measurements were done in 120 healthy newborn babies on their second day of life, first by the mothers and followed by a designated physician. The study observed that there is no correlation of measurements made by the mothers and the physician using the rectal glass mercury thermometer ($R^2=0.096$), but significant correlation was observed between temperature measurements using digital axillary thermometer and infrared forehead skin thermometer made by mothers and the physician. The study concluded that the difficulty of use and interpretation make rectal glass mercury thermometer less practical than the digital axillary thermometer and infrared forehead skin thermometer also the measurements of temperature using the infrared forehead skin thermometer are obtained in shorter span of time than the digital axillary thermometer, making it a more practical option.

STUDY JUSTIFICATION

- Accurate measurement of temperature is important in detecting hypothermia and fever in neonates.
- Hypothermia is an important contributor for neonatal morbidity and mortality in developing countries.
- Rectal route has been adjudged to have accurately represented the core body temperature as it is not influenced by changes in the environmental temperature.
- Since the rectal route has its own limitations, and it requires some technical expertise to measure it, it become imperative to develop alternative route of temperature measurement that accurately represent the core body temperature.
- The rectal temperature measurement poses significant infectious hazard and without taking proper sterile precaution, there is a risk of transmission of contaminants present in the stool.
- Alternative method of temperature measurement should be safe, cost-effective, non-invasive, time efficient and it should accurately reflect the core body temperature.
- Previous studies on temperature measurement have been done only in healthy newborn babies and also in paediatric age group using mercury in-glass thermometer. The American Academy of Pediatrics discourages the use of mercury in-glass thermometers in children to prevent the pollution caused by incineration of mercury containing devices and also to prevent the inhalational injury caused by accidental exposure of mercury in children.
- There is no study which compares the different methods of temperature measurement done in sick newborn infants using digital thermometers at different time intervals.

OBJECTIVE OF THE STUDY

- To compare the measurement of Axillary, Forehead Skin, and Tympanic temperatures with measurement of Rectal temperatures in Newborn babies attending Newborn Emergency Room in a tertiary care hospital.

MATERIALS & METHODS

- STUDY DESIGN : Observational Study.
- STUDY PLACE : Newborn Emergency Room, Institute of child Health & HC.
- STUDY PERIOD : March 2014 - August 2014.
- SAMPLE SIZE : 600 measurements in 200 Babies.

INCLUSION CRITERIA

- All newborn babies within 28 days of life attending Newborn Emergency Room.

EXCLUSION CRITERIA

- Newborn babies with Ano-Rectal anomalies.
- Newborn babies with ear malformations.
- Newborn babies who required urgent cardio pulmonary resuscitative measures.

STUDY MANOEUVRE

Neonates were enrolled into the study on the basis of the inclusion criteria. Written informed consent was obtained from the parents or the guardians. All the temperature measurement was done in Celsius grade (0C). Temperature was recorded at five sites for each enrolled babies namely, Rectal, Axillary, Right and Left Tympanic and Fore head skin.

Rectal temperature was measured using OMRON Digital thermometer (Model MC - 343F) with flexible tip, after observing sterile precautions. Rectal temperature was measured for 30 seconds at five minutes from time of arrival, 15 minutes from time of arrival, and 30 minutes from the time of arrival. With the baby lying on its back in the warmer, the tip of the thermometer, covered with a probe cover is inserted to a depth of half an inch into the rectum and held in its place for 30 seconds, until the thermometer screen stops blinking. The readings in the thermometer were recorded in centigrade.

Axillary temperature was recorded with a separate OMRON Digital thermometer (Model MC - 343F). After observing sterile precautions, with the infant lying in its back, the Axillary temperature is recorded by placing the tip of the thermometer deep into the apex of the right axilla, parallel to the body plane and held firmly, until the thermometer screen stops blinking. The readings in the thermometer were recorded.

Tympanic temperature was recorded with rossmax (RA600 Infrared ear thermometer). Tympanic temperature from the right ear was first measured and then from the left ear was measured. After observing sterile precautions, the infrared ear thermometer with probe cover was introduced into the ear canal, aimed towards to the tympanic membrane by gently pulling the ear posteriorly to straighten the ear canal. After hearing a long beep from the thermometer, the temperature recorded in the thermometer was noted.

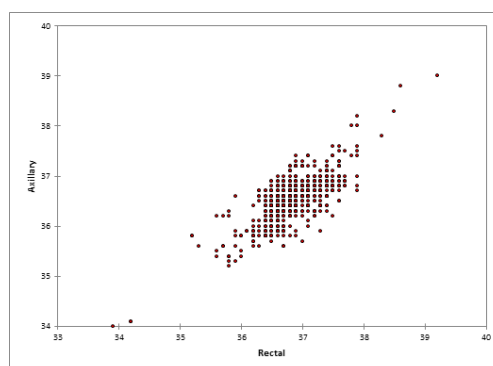
Fore head skin temperature was measured using rossmax (HA500 Infrared thermometer). The forehead skin temperature was recorded by placing the probe of the thermometer over the forehead after removing the hair and dirt. The temperature recorded in the thermometer was noted after hearing a long beep sound.

STATISTICAL ANALYSIS

- Statistical Analysis was done for 600 measurements taken from 200 babies.
- Data were entered in the Microsoft Excel spread sheet and analysed using the IBM SPSS version 20 for Windows, Pearson coefficient correlation, and Bland-Altman plots were obtained.
- Total of 209 babies were enrolled in the study, out of which 9 newborn babies were excluded from the study based on the exclusion criteria.

RESULTS & OBSERVATIONS

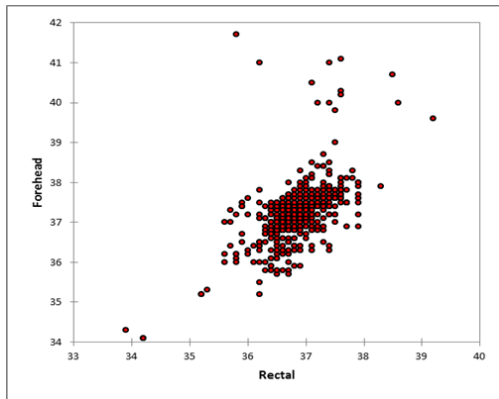
CORRELATION BETWEEN RECTAL AND AXILLARY TEMPERATURE MEASUREMENTS



The Pearson coefficient correlation is $r=0.759$ ($p<0.0001$, $n=600$). There is significant positive correlation of 75.9% between rectal and

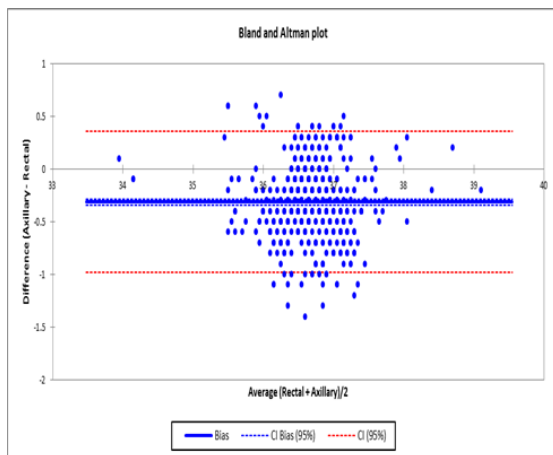
axillary temperature measurements

CORRELATION BETWEEN RECTAL AND FOREHEAD TEMPERATURE MEASUREMENTS



- The Pearson coefficient correlation is $r = 0.576$ ($p < 0.001$, $n = 600$). There is a weak correlation of 57.6% between Rectal and Forehead temperature measurements.

AGREEMENT BETWEEN RECTAL AND AXILLARY TEMPERATURE MEASUREMENTS

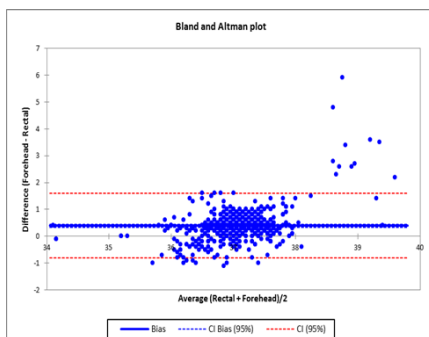


Bland-Altman Analysis:

Bias -0.311
Standard error 0.341
CI(95%) [-0.339, -0.284].

- Axillary temperature showed good agreement with rectal temperature with mean difference of 0.311 (Confidence Interval 0.339, 0.284).

AGREEMENT BETWEEN RECTAL AND FOREHEAD TEMPERATURE MEASUREMENT



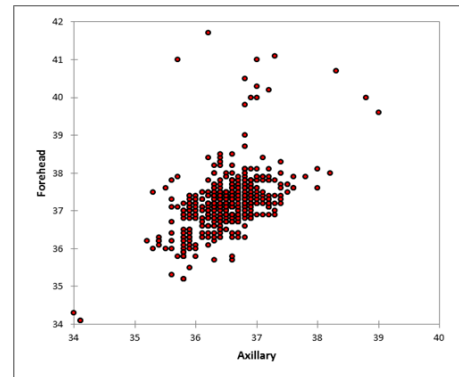
Bland-Altman Analysis

Bias 0.389

Standard error 0.615
CI Bias (95%) 0.339] 0.438[

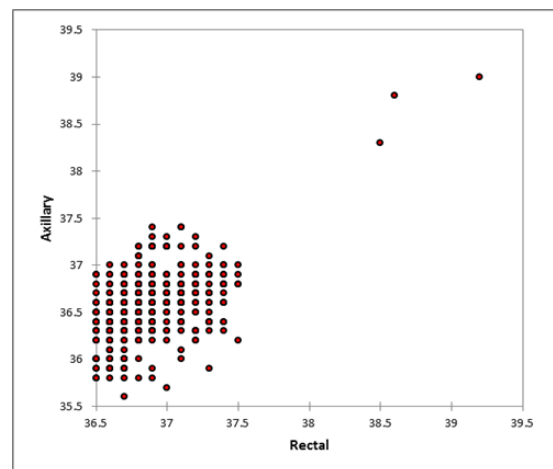
The forehead temperature measurements have good agreement with rectal temperature measurement with mean difference of 0.389 (Confidence Interval 0.339, 0.438).

CORRELATION BETWEEN AXILLARY AND FOREHEAD TEMPERATURE MEASUREMENTS



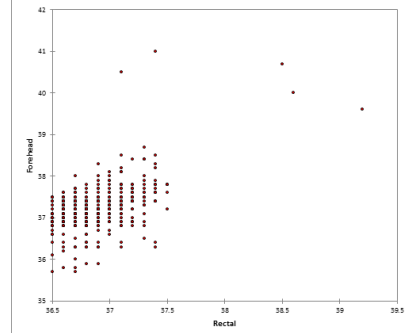
- The Pearson Correlation Coefficient is $r = 0.525$ ($p < 0.001$, $n = 600$). There is a weak correlation of 52.5% between Axillary and Forehead temperature measurements.

CORRELATION BETWEEN RECTAL AND AXILLARY TEMPERATURE MEASUREMENTS IN NORMOTHERMIC NEWBORN



- The Pearson Correlation Coefficient is $r = 0.533$ ($p < 0.0001$). There exists a positive correlation of 53.3% between Rectal and Axillary temperature measurements in Normothermic Newborns.

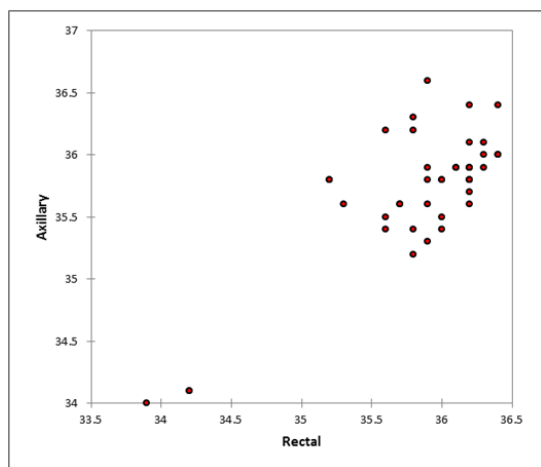
CORRELATION BETWEEN RECTAL AND FOREHEAD TEMPERATURE MEASUREMENTS IN NORMOTHERMIC NEWBORNS



- The Pearson Coefficient of Correlation is $r = 0.523$ ($p < 0.0001$). There exists a positive correlation of 52.3% between Rectal and

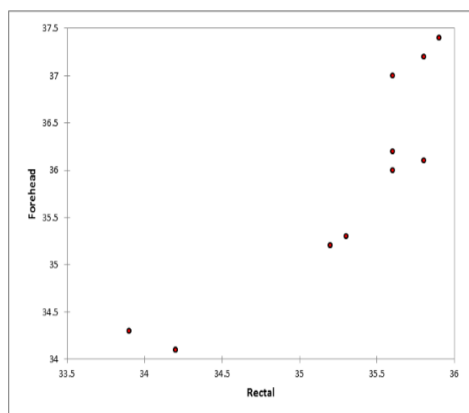
Forehead temperature measurements in Normothermic newborns.

CORRELATION BETWEEN RECTAL AND AXILLARY TEMPERATURE MEASUREMENTS IN HYPOTHERMIC NEWBORNS



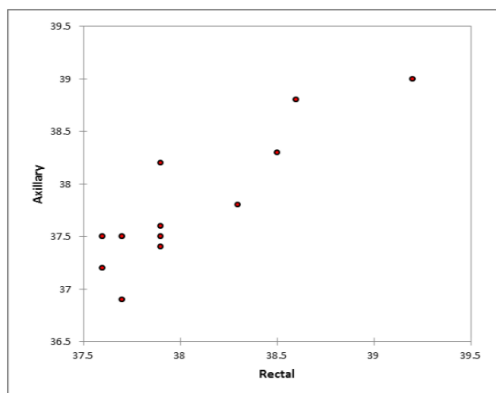
- The Pearson Coefficient of Correlation is $r=0.801$ ($p<0.0001$). There exists a significant positive correlation of 80.1% between Rectal and Axillary temperature measurements in hypothermic newborns.

CORRELATION BETWEEN RECTAL AND FOREHEAD TEMPERATURE MEASUREMENTS IN HYPOTHERMIC NEWBORNS



- The Pearson Correlation Coefficient is $r=0.499$ ($p=0.001$) and there exists a correlation of 49.9% between Rectal and Forehead temperature measurements in hypothermic newborns.

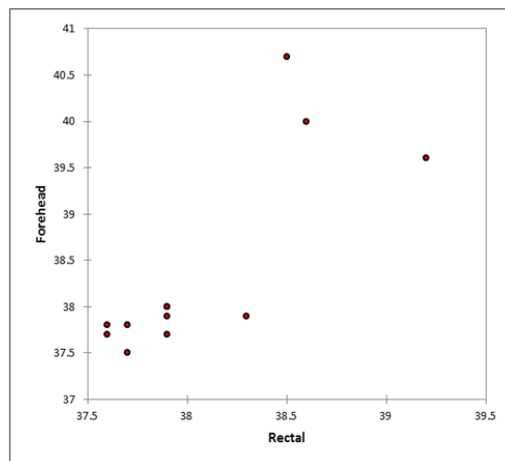
CORRELATION BETWEEN RECTAL AND AXILLARY TEMPERATURE MEASUREMENTS IN HYPERTHERMIA



- The Pearson Correlation Coefficient is $r=0.889$ ($p<0.0001$). There exists a significant correlation of 88.9% between Rectal and

Axillary temperatures in Hyperthermic Newborns.

CORRELATION BETWEEN RECTAL AND FOREHEAD TEMPERATURE MEASUREMENTS IN HYPERTHERMIA



- The Pearson Correlation coefficient is $r=0.796$ ($p<0.0001$) and there is a significant correlation of 79.6% between Rectal and Tympanic temperature measurements in hyperthermic newborns.

CORRELATION BETWEEN RECTAL, AXILLARY, TYMPANIC RIGHT & LEFT, FOREHEAD MEASUREMENTS AT 30 MINUTES

	AXILLARY	TYMPANIC(RT)	TYMPANIC(LT)	FOREHEAD
RECTA L	$r=0.734$ n-200 $p<0.0001$	$r=0.845$ n-200 $p<0.0001$	$r=0.779$ n-200 $p<0.0001$	$r=0.546$ n-200 $p<0.0001$

The right infrared tympanic temperature measurement correlated well with digital rectal temperature measurement at 30 minutes.

MEAN FOR AGE WEIGHT AND GESTATIONAL AGE DESCRIPTIVE STATISTICS

	N	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
WEIGHT	200	1250	3950	2694.20	518.886
GESTATION	200	33	40	38.02	1.453
AGE(<72HRS)	82	1	72	19.66	18.714
AGE(>72HRS)	118	3	31	14.07	8.552

The mean weight is 2694.2 grams; the mean age of gestation is 38.02 weeks. The mean age at presentation 19.66 hours in neonates presented within 72 hours and 14.07 days in neonates presented more than 72 hours.

CONCLUSION

- Of the three different methods available to measure peripheral temperature in neonates (Axillary, Tympanic & forehead measurements), when compared against the gold standard (Core temperature – rectal temperature measured by digital thermometer),
 - Tympanic measurement using Infrared thermometer has the highest positive correlation ($r=0.851$, $p<0.0001$).
 - Axillary measurement using the digital thermometer also has the good correlation ($r=0.759$, $p<0.0001$), but it is inferior to infrared tympanic temperature measurements.
 - Forehead measurements using Infrared thermometer cannot be relied upon for use in neonates as it shows a weak correlation ($r=0.576$).
- Tympanic measurements using Infrared thermometer not only showed a good correlation, but also have a strong level of agreement with rectal temperature measurements (Mean difference 0.311, CI 0.339, 0.284).
- Highest correlation shown by Tympanic Infrared readings

against rectal temperature measurements is sustained in various subgroups of sick, small, and normal neonates as shown below.

1. Hypothermia($r=0.872$, $p<0.0001$).
 2. Normothermia($r=0.712$, $p<0.0001$).
 3. Hyperthermia($r=0.931$, $p<0.0001$).
 4. Shock($r=0.944$, $p<0.0001$).
 5. Respiratory Distress($r=0.793$, $p<0.0001$).
 6. Seizures($r=0.614$, $p<0.0001$).
 7. Low Birth Weight – 1500 to 2500 grams($r=0.852$, $p<0.0001$).
 8. Gestational Age – 32 to 36 weeks($r=0.815$, $p<0.0001$).
 9. Gestational Age – more than 36 weeks($r=0.854$, $p<0.0001$).
- Infrared tympanic temperatures measured in right and left ears correlate well with each other($r=0.921$, $p<0.0001$). But when compared with rectal measurements, right tympanic measurements performed better than the left tympanic measurements.

RECOMMENDATIONS

- Tympanic temperature measurement using Infrared thermometer is the most reliable method for temperature measurement in neonates.
- In the absence of the Infrared thermometer, Axillary measurement using digital thermometer should be used.
- Infrared forehead thermometer should not be used for measuring temperature in neonates.
- Tympanic and Axillary measurements are reliable in healthy as well as sick and small neonates (>1500 grams and >32 weeks of gestation).
- Tympanic Infrared thermometry is not reliable in infants with birth weight <1500 grams. It may be because of small size of auditory canals in them. Further studies are needed in this scenario.