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Original Article

Identification the best skin temperature probe attachment place in premature neonates nursed under radiant warmers in NICU: A diagnostic clinical trial study

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ABSTRACT

Background: Optimizing thermal care is essential for premature neonates and is a major problem among researchers. Monitoring of skin temperature in premature neonates is usually done in neonatal intensive care units (NICUs). This study searched the skin temperature at 7 locations and then addressed the correlation of these locations with axillary temperature in order to identify the ideal skin temperature probe (STP) placement.

Methods: This diagnostic clinical trial was performed on 203 premature neonates cared under a radiant warmer (RW) with servo-control mode. STP was placed at different locations, including the chest, forehead, right axillary, arm, right hypochondrium of abdomen, thigh, and foot, in all the neonates. The total duration of measurement for the neonates was seven minutes. Concurrently, a digital thermometer was used at each location, recording 1428 measurements. In addition, agreement of STP with digital axillary thermometer measurements was also assessed. The significance level was $P < 0.05$.

Results: The probe-measured temperature at the right hypochondrium of abdomen was consistent with the digital axillary temperature, compared to temperature measured at other sites.

Conclusion: In premature neonates, proper placement of STP is necessary to monitor skin temperature safely and accurately. NICU nurses have this unique opportunity to determine the best STP placement site and to improve safe practice for optimal outcomes in neonates.

1. Introduction

In neonatal intensive care units (NICUs), it is necessary to manage thermal status in preterm neonates. Thermoregulation management is considered a critical part of neonatal care, as negative physiological effects, including metabolic acidosis, hypoglycemia, increased oxygen use, and increased risk of hypothermia and cold stress may result from changes in thermal stability (Sherman et al., 2006; RL. and DJ., 2010; Koh and CW., 2016; Blackburn et al., 2001a,b). Balance in the lost and produced heat is a key factor in maintaining a constant temperature (neutral thermal environment) (L., 2012).It is necessary to accurately measure the neonates' body temperature, as thermoregulation can influence their survival (Schafer et al., 2014; Sherman et al., 2006). Radiant warmers (RW) are generally employed in NICUs to facilitate passive heat exchange through radiant energy and to ensure stable core body temperature. RWs have major advantages over incubators, including high patient accessibility and minimum thermal environment disturbances (Chaseling et al., 2016). Peripheral sites can be used to determine core temperature instead of direct core-temperature measurements. Continuous monitoring is generally essential in neonates, although episodic measurement of temperature is a basic component in all patients (T., 2003).

Considering the health of infants and children is important (Borji et al., 2018a, 2018b; Kazeminezhad et al., 2018; Otaghi et al., 2017). Continuous monitoring of temperature helps with the early identification of temperature instability and prompt intervention. Consequently, a common procedure is continuous temperature monitoring with skin temperature probes (STPs) in NICUs(Day et al., 1964; Joseph et al., 2017). In RWs, servo-controlled systems are used to regulate heat output considering the sensor's skin measurements. In order to sustain temperature control, RW can reduce and increase the output of the heater (Koh and CW., 2016).

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A list of abbreviations are presented below:

STP	skin Temperature Probe
RW	Radiant Warmer
NICU	Neonatal Intensive Care Unit

Monitoring skin temperature is less invasive and reflective of core temperature. Body temperature monitoring is accomplished through rectal measurements in different NICUs. Despite its reliability, this approach may induce negative effects, considering its invasiveness and contraindications in patients with necrotizing enterocolitis or low platelet count (Van Der Spek et al., 2009). The current study does not include monitoring of rectal temperature due to the potential risk of bowel injury (Joseph et al., 2017; T., 2003; Van Der Spek et al., 2009).

2. Literature review

For a stable core body temperature, RWs are generally applied in NICUs to facilitate passive exchange of heat via radiant energy (Chaseling et al., 2016). RW beds generate heat from electromagnetic waves, which directly transmit energy to the skin of the neonate (Sherman et al., 2006). In a typical RW, the radiant heat output is adjusted considering the servo-controlled feedback signal from a single measurement of local skin temperature (Chaseling et al., 2016). With advances in RW technology, practitioners can improve the maintenance of a therapeutic thermal environment. Recent studies have examined the best approach for temperature measurement and regulation and have evaluated proper STP placement among neonates. In a pilot study by Bolden, reliability and accuracy of skin temperature measurement with axillary skin probe placement were evaluated in extremely premature neonates. The results showed that axillary temperatures were higher than abdominal temperatures (mean difference, 0.44), while no significance was noted (Bolden, 2016).

In another study in term neonates under RWs, Koh et al. compared the accuracy of skin sensor temperature measurements at two sites with axillary temperature. Based on the findings, the measured temperature with the probe at the right hypochondrium of abdomen showed greater consistency with digital axillary temperature, compared to the measured temperature with the probe located at chest (Koh and CW., 2016). A study by Thomas in 2000 also compared abdominal and axillary temperature probes and reported inconsistency in temperature gradient between axillary and abdominal temperatures, and no method was superior (T., 2003). Moreover, Dollberg et al., in 2000 compared neonates in incubators or on RWs and showed no significant differences between axillary and core and abdominal and core temperatures (Dollberg et al., 2000).

Continuous transcutaneous methods, which are known to reduce regular interruptions in the neonate's environment, are applied to monitor core body temperature. In this regard, George and Mishra in 2009 reported the redundancy of routine axillary monitoring in neonates on servo-controlled RW, as abdominal skin temperature is closely associated with digital axillary temperature (George and Mishra, 2009).In another study, Blackburn surveyed the effects of neonatal position and temperature probe placement and found that position and probe placement affect the temperature of skin.

Nursing books, besides products and procedures in the literature, indicate that probe location guidelines should consider avoidance of bony prominences, probe placement on well-perfused tissues, and body surface positioning without any bed contact (i.e., disallowing the neonate to lie on the probe) (Blackburn et al., 2001b). If neonates are in the supine position, most nurses prefer abdominal placement in many settings; generally, it is prohibited to lie on the probe. As earlier noted, these traditional suggestions have been scarcely studied. Considering its relationship with skin integrity, STP placement and changing its site require further research.

Recently, limited studies have examined STP in neonates on RW (Schafer D et al., 2014). Only few articles have aimed to identify the best STP or determine if some sites should be avoided (ST, 2013). Accordingly, this study aimed to clarify a statistically or clinically significant difference between measurements from a digital axillary thermometer and those from STP on the abdomen, chest, forehead, thigh, foot, arm, and axilla. Bedside nurses can improve thermoregulatory care through determining the best skin sensor site for continuous monitoring of temperature.

3. Methods

In this study, patients in two referral NICUs of Rasht (Alzahra and 17-Shahrivar Hospital) with 20 beds were recruited. The method-comparison analysis was applied to evaluate congruence between digital thermometer axillary temperature and skin sensor temperature at different sites.The sample size to determine and select the appropriate temperature control area in premature children referring to the NICU with 95% confidence and 80% strength for comparing a randomized seventh block (seven places of temperature measurement) was determined based on the sample table for variance analysis of 29 people in each group; a total of 203 samples was estimated. Premature infants in a stable post-delivery condition under RW were recruited. All included neonates were in the supine position.On the other hand, the exclusion criteria were as follows: 1) ill, term, or unstable neonates with medical or surgical problems; 2) neonates transferred from other hospitals as they might have other complications; 3) confirmed diagnosis of congenital-neurological disorders and abdominal wall defects; 4) use of vasopressors or phototherapy; 5) isolation precautions; and 6) severe hypoxemia (oxygen saturation $< 75\%$) or skin breakdown. Sampling was done from November 2016 to April 2017.

The instrument was a digital thermometer to measure the axillary temperature of neonates and a thermometer and humidity gauge for measuring the ambient temperature. The type of axillary thermometer (Beurer Digital Thermometer) was FT15/1 model, manufactured in Germany, with a precision of $\pm$ 0.1 °C. The analogue thermometer and humidity gauge of desktop ambient (MINGLE) showed a range of 20–50 °C and humidity of 0–100%. Its precision was $\pm$ 1 °C for temperatures of 0–30 °C and $\pm$ 2 °C for other temperatures. Its precision for humidity measurement at 40–80% was equal to $\pm$ 5° and $\pm$ 9 °C for other humidity ranges.

Before starting the sampling at the Physics Laboratory of the Faculty of Physics, were calibrated to measure the reliability of the digital thermometer and the humidity meter. In order to harmonize the conditions, the warmers used in this research were identically selected and all of them were warmers of Tosan Mark constructed in Iran. All of the warmers were calibrated before being used by certified medical engineers.

This study was approved by the clinical research review committee of the hospital, as well as the head of NICU and hospital director (ethical code = IR.GUMS.REC.1396.171). This study was registered in the Iranian Registry of Clinical Trials (IRCT code = IRCT2017072512990N8). Participation in this study was voluntary and complete information regarding the objectives of the study gave to mothers of neonates. Parent's informed consent was obtained after getting permission from the Ethics Committee and the research committee of Guilan University of Medical Sciences. All the participants' parents also signed informed consent forms. Participation in the study was completely voluntary and optional. All the participants' parents were assured that the information obtained would be kept completely confidential. The subjects served as their own controls. After confirming the samples' eligibility by the research team, demographic information was collected from the medical records. After selection of neonates with the inclusion criteria, enough explanations were given to parents, and informed consent was obtained if parents were willing. To

begin, the temperature of the warmer was on 37° and this temperature was the same for all neonates. For each neonate, the probe was located in the forehead, chest between the ribs, right axillary, the back of the legs and the upper part of the thigh are attached and bonded to the appropriate and anti-hygienic adhesive, in addition to the probe connection, also has a thermal insulation effect. Then, the neonate's temperature was recorded for two minutes. Therefore, the duration of each probe connection in each area was two minutes. Simultaneously, the temperature of the left axillary was measured and recorded with a digital thermometer. After measuring, the temperature was removed in a probe area and rest for two minutes, and then the probe was connected to the next area. The entire duration of the work on a neonate was 15 min. Each warmer device could attach only on one probe. Two investigators were present at the time of sampling to record information, and another was the management and control of the neonate. Demographic and baseline data such as birth weight, current weight, maternal delivery, childbirth problems, diagnosis, ambient temperature, neonate's position, location of placement of the warmer in the section to the location in place and the window and its mark was recorded. The neonate was placed in the supine position, but redressed or rewrapped; then, the skin sensor was detached. During data collection, the team members continuously monitored the heart rate, temperature, oxygen saturation, and respiratory rate in the neonates.

To determine the temperatures in seven groups and the reference group, mean, standard deviation, and 95% confidence interval were measured. The methods of analysis of variance to compare the accuracy of the temperature measurement locations, and Bland and Altman charts were used to determine the degree of agreement of measurement locations with reference method (left axillary temperature) was used with Willcoxon test. Significant recording of the tests in this study was considered with $P < 0.05$.

4. Results

A total of 203 neonates were evaluated in this study. During data collection, gestational age ranged from 26 to 36 weeks. The neonates' weight ranged from 700 to 2300 g on the day of data collection. Gender of subjects in this study was 53.9% male (n = 110) and 46.1% female (n = 94). The neonates' demographic characteristics are shown in Table 1. Fig. 1 shows the most common reasons for neonatal admission in NICU. Using the Bland-Altman method, agreement was assessed between two methods of measurement. Skin temperatures at seven points were compared with the standard reference (axillary temperature recorded by a digital thermometer). A significant difference was found in the mean temperature of left axillary and other sites ($P < 0.01$ for all). It was also found that there is a high agreement between the temperature of the heat sensor in the left axillary and the location of the heat sensor in the abdominal area as well as the right axillary ($P = 0.0001$ and $P = 0.0001$).

The effect of these factors on the recorded temperature was also considered due to the fact that the location of some RWs was located near the door or window. After analyzing the data, it was found that a statistically significant difference was observed between the mean temperature of the left armpit of the neonates and the other parts of the body of the neonates, in the presence of the warmer located near the entrance (all $P < 0.01$).It was also found that there is high agreement between the temperature of the heat sensor in the left armpit and the location of the sensor in the abdominal area, as well as the temperature area of the left armpit, with the right armpit. In the case where the warmer is far from the entrance, it can be seen (ICC = 0.517 P = 0.0001, ICC = 0.671, P = 0.0001). There was no significant statistical relationship between the recorded temperature and the demographic characteristics (gender, age, weight, etc.) or other environmental factors (humidity and ambient temperature) and physiological characteristics of the premature neonates (heart rate and respiratory rate).

5. Discussion

The present study is first research study and clinical trial study that evaluates skin temperature in different parts of the body in premature neonates. The overall strength of evidence on the ideal site for STP placement on neonates is minimal and lacks transferability. Only two studies were conducted since 2010 (one in full-term neonates) and none provides any evidence for best practice. The neonatal CPGs dated from 2008 to 2016 identified thermoregulation policy of neonates in incubators or RWs; nonetheless, they are unclear on the site for STP placement. The ideal site for STP placement on the neonate must be clarified and an alternate site must be recommended if the ideal site is unavailable (Joseph et al., 2017).In present study, 203 samples were taken to ensure the research strength. But unfortunately, due to the fact that this study was conducted only on Stable Immature neonates and admitted to NICU and the entry criteria were very restrictive, we lost many possible examples. For premature neonates admitted to NICU which are in supine position and are cared in a servo-controlled environment, there are several places to measure skin temperature measurement. One of the limitations of skin temperature testing is that skin sensors need to be removed frequently and periodically attached to other areas of the skin to prevent damage to the skin of premature neonates that is very sensitive and irritable. Our research results showed that of the seven examined places, two right axillary and right hypochondrium places are the most suitable areas for STP placement, and nurses can safely use these points to measure the skin temperature of premature neonates.

According to a pilot study by Bolden, which was conducted to assess the accuracy of skin temperature at the skin of axillary area in extremely premature neonates, no significant difference was found between abdominal area and axillary temperatures (Bolden, 2016). A further study by Schafer et al. was conducted to evaluate skin temperature in three right axilla, right upper abdomen and left flank areas with axillary temperature in term neonates. The results of this study showed that there is no statistically significant difference between the accuracy of skin temperature recorded in three locations with axillary temperature as reference temperature. Therefore, all three locations were recommended as suitable places for measuring skin temperature in term neonates. This study contradicts our study results (Schafer D et al., 2014). A further study by Tomas was conducted to assess the accuracy of skin temperature in the abdominal area with axilla during 24-h monitoring on healthy neonates who were cared for in a home-like environment. There was no significant relationship between the two methods and the superiority of any of the two methods was not determined for measuring the temperature in neonates (T., 2003). According to Blackburn et al., the axillary skin temperature measurement may be appropriate for the continuous measurement of temperature in neonates, which the present study also, confirms this finding (Blackburn et al., 2001b). According to a study by Koh et al. to determine the accuracy of skin temperature of the chest and abdomen with axillary temperature in healthy term neonates, the skin temperature recorded in the abdominal area, has the highest correlation with

Table 1
Demographic characteristic of neonates.

characteristics	Mean	Standard deviation	Minimum	Maximum
Gestational age at birth,d (wk)	31.52	3.01	26	36
Birth weight, g	1214.3	320.6	700	2300
Postnatal age at datacollection, d	6.65	3.54	1	20
Head circumstances, cm	31.44	3.07	25	37
Heart rate,bpm	155.2	14.62	121	180
Respiratory rate	65.64	11.76	43	98

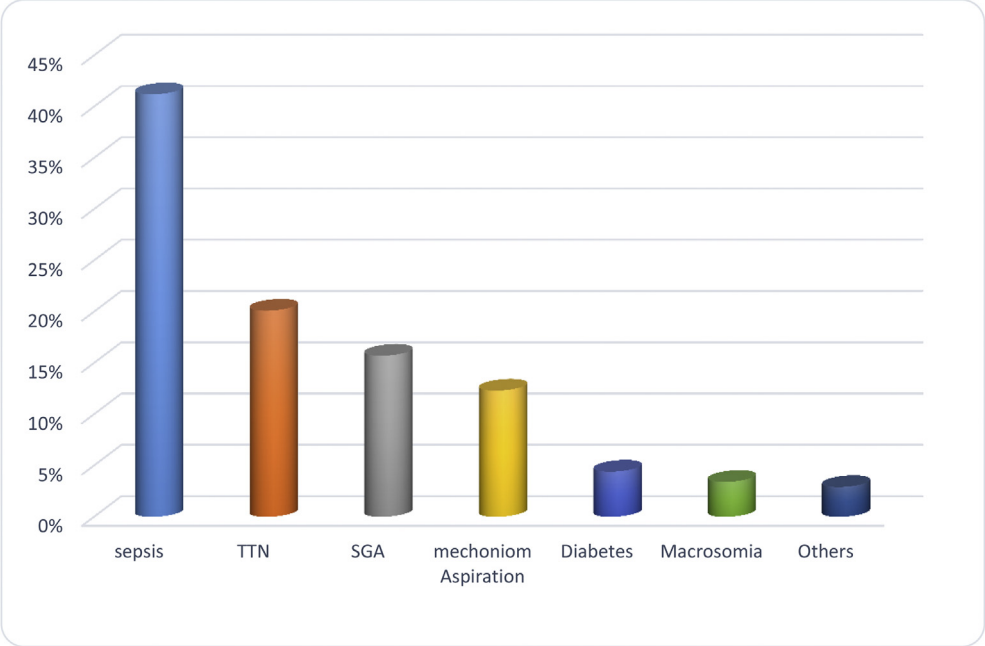

Fig. 1. The most common reason of neonate's admission in NICU.

the axillary temperature compared to the chest, which results of our study confirm this (Koh and CW., 2016).

6. Limitations

There are few limitations in this study. Considering the limited period of skin and axillary temperature monitoring and measurement, the actual trend of temperature readings may not be specified for neonates under RWs for longer period. In addition, premature neonates were studied under limited conditions and were only in one position (supine position). We also used one bed mode (baby control isolette mode). Finally, premature neonates were hemodynamically stable, while unstable neonates were not assessed.

7. Conclusion

The results of this study showed that in premature neonates admitted to NICU, who are in the supine position and are hemodynamically stable, the most suitable place for measuring skin temperature is the right hypochondrium and right axillary areas. In this study, it was found that there is a high correlation between right hypochondrium and right axillary temperature with (left axillary) reference temperature. Based on the findings of this study, nurses can attach skin temperature sensors to this areas and be sure of the accuracy of the temperatures recorded in these areas. Due to the fact that this study was performed only in premature neonates who have a stable hemodynamic and are at supine position, further studies are recommended to conduct in premature neonates unstable and in different positions for future. Skin temperature sites were not examined between the bed and neonate in the present study, which is different from research by Blackburn et al. and Dollberg et al. In the study by Blackburn et al., a significant difference was reported in temperature in the supine and prone positions. Dollberg compared neonates lying and not lying on temperature probes. Since Blackburn and Dollberg showed that “entrapment” changes the temperature gradient of the back and abdomen, it was eliminated from the analysis by examining the samples in the supine position.

Conflicts of interest

The authors declare no conflict of interest in this study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnn.2018.10.001.

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