

Which Site is Better for Skin Sensor Temperature Probe in Newborns Under Open Care System for Prevention of Hypo – Hyperthermia

Abstract

Background: Choosing the right temperature probe location is important, especially in VLBW infants. We aimed to determine five points of the skin surface and compare them with the axillary temperature of potentially suitable locations as well as the best location for skin probe placement. **Methods:** In a cross-sectional study, 400 neonates with gestational age above 26 weeks were enrolled. The axillary temperature was measured using a mercury thermometer at 0 and 30 min. Then, the body temperature was measured using a surface probe on the five skin areas, including the thoracic area, epigastric region, RUQ area, hypogastric area, and left flanking area. Data recorded were compared with the axillary temperature at 0 and 30 min. **Results:** Mean neonatal axillary temperatures at 0 and 30 min were 36.60 and 36.61, respectively. The mean temperature was recorded using skin probes at 0 and 30 min in the thoracic region (36.34 and 36.35) in the epigastric region (36.45 and 36.47), in the RUQ region (36.50 and 36.52), in the Flank region (36.26 and 36.20), and in the hypogastric region (36.24 and 36.26). The lowest mean difference recorded by surface probes with the temperature measured by the thermometer in the axillary region was related to the surface probe RUQ (mean difference: 0.1 and 0.09), which was not statistically significant. **Conclusions:** RUQ area probe has the lowest difference with the temperature calculated using the thermometer in the axillary region and is the best place to put the skin probe for prevention of hypo/hyperthermia.

Keywords: *Hyperthermia, hypothermia, infant, newborn, radiant warmer, temperature probe*

Introduction

The body's normal temperature is the temperature at which the cellular function is optimum.^[1] Neonate's natural skin temperature is 36°C–36.5°C and 36.5°C–37.5°C in the anus; the axillary temperature is 0.5°C–1°C below the central temperature.^[2] Body temperatures lower and higher than the aforementioned amounts are called hypothermia and hyperthermia.^[2] To maintain the body's normal temperature, there should be a balance between heat generation and dissipation. Thermoregulation mechanism is different in neonates and adults; in special cases such as pre-term neonates, low birth weight neonates, and neonates under stressful conditions (e.g., asphyxia cases), thermoregulation becomes more important.^[3]

Body thermoregulation is done by the hypothalamus, which in turn receives the impulse through central heat receptors in the

anterior hypothalamus and the peripheral heat receptors in the skin and mucous membranes and regulates the central heat through peripheral artery diameter change and body behavioral changes.^[4]

Heat dissipation methods in infancy are as follows.^[4] **Radiation:** through placing the neonates in a cold environment and/or near cold things; **Evaporation:** because of delay in drying the neonate's body; **Conduction:** placing the neonate on a cold surface (blanket, sheet, scales) and/or conduction with cold things (hand, phone, etc.); and **Convection:** losing heat through the movement of air across the skin.

Several mechanisms cause neonates to be prone to hypothermia:^[4] a higher surface to weight ratio, limitation of heat generation reserves because of low brown fat and glycogen amount, lack of subcutaneous tissue, immature nervous system (which causes a delay in response to the cold stress), skin permeability increase (which

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This study is a descriptive-analytical cross-sectional study performed on premature neonates born in Alzahra and Shahid Beheshti Hospital of Isfahan University of Medical Sciences in Isfahan.

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causes an increase in evaporation and heat dissipation), excessive manipulation of neonates in intensive care units, potential prenatal asphyxia (which causes norepinephrine effect decrease on nonshivering thermoregulation), and prescribing analgesic and sedatives (which causes heat generation ability decrease).

In case the neonate's axillary temperature is higher than 37.4°C or the anus temperature is higher than 37.5°C, the neonate has hyperthermia.^[5] Hyperthermia accompanies the increase of death and disease in infancy. Hyperthermia reasons can be related to peripheral temperature increase; neonates kept in incubator and/or radiant warmer or the neonate exposed to sunlight or near the radiator can suffer from the significant increase in the body temperature. Dehydration, especially in neonates who are not breastfed sufficiently, can also result in hyperthermia. Central nervous system disorder, deprivation syndrome and medications (prostaglandin), neonatal sepsis, transfusion, malignant hyperthermia, neurogenic hyperthermia, and the most important of all, high neonate coverage in warm weather are among the other reasons for hyperthermia. In case the reason for hyperthermia is peripheral temperature increase, the neonate's body and organs will have the same temperature and the neonate will suffer from vascular expansion and start to flush. The hands and feet will be warm and the neonate should be placed in supine position to increase the neonate's heat dissipation. In contrast, in case the reason of hyperthermia is sepsis, because of increasing hypothalamus' thermoregulation threshold, the neonate feels cold peripheral temperature and instead of heat dissipation, the heat generation mechanisms will be activated. In this case, the neonate suffers from vasoconstriction. As a result, the body and organs' skin look pale and blue and the neonate's central temperature is higher than the skin temperature. However, in a neonate that suffers from hyperthermia because of peripheral reasons, the anus temperature may be the same as the skin temperature. Paying attention to the abovementioned points can help to differentiate the hyperthermia reasons.^[6]

Hypothermia is diagnosed by symptoms such as lethargy and decreased activity of the neonate, poor crying, poor sucking, cold hands and feet and the coldness of the whole body, and mottling. In case of progression and failure to take required action, symptoms such as bradypnea and gasping, bradycardia, apnea or respiratory distress, pulmonary hemorrhage, scleroderma, oliguria and death can also appear.^[4]

Generally, it can be said that the most probable reason of neonatal hypothermia and hyperthermia are the exterior and peripheral factors of heat generation and dissipation, and the factors related to the neonate and its disease seldom contribute to hypothermia and hyperthermia. Neonates suffering from hyperthermia in addition to peripheral temperature increase will have symptoms such

as tachypnea, respiratory arrest, tachycardia, hypotension, and perspiration. At first, the neonate becomes restless and the organs become warm and the skin becomes dry and warm. Urine volume and frequency decreases and the neonate may suffer from weight loss. In this phase, the infant tends to drink more and if hyperthermia continues, the neonate will suffer from intense hyperthermia, in which body's temperature reaches 41°C—42°C and the neonate will suffer from lethargy, hypotension, poor crying and eventually consciousness disorder, coma, convulsion, and even death.^[7]

One of the most important reasons of neonatal hypothermia and hyperthermia is using radiant warmer carelessly. Intense hyperthermia in this case is because of temperature control disorder, sensor detachment, and/or not paying attention to device setting.^[8]

Open care systems in which neonates can be accessed easily to take required treatment actions are increasingly used in neonatal intensive care units.^[9] In these systems, the radiant warmer is used to control the neonate's temperature. In this system, special sensors are used that are attached to the neonate's body surface through skin probes to determine the skin temperature and send information to the warmer in order to reach the body's temperature to the predicted point.^[10]

Moreover, placing a transparent protective cover made of polyethylene on the neonate causes imperceptible reduction of water excretion and heat dissipation decrease in convention method, thereby achieving better temperature control, especially in neonates weighing less than 1500 g.^[11]

To use a radiant warmer, the device must first be plugged in and then the ON button must be pressed. Usually, at the beginning, the manual control is selected and the output heat is adjusted at 100% temporarily to make the mattress and sheet on the tray warm in a short time. The manual control at the beginning is to switch the device on to do the preliminary warming or to warm an intense hypothermia neonate; however, the risk of the neonate's over warming should be noticed. Then, the server control mode is selected and the temperature is adjusted to 36.5°C. The neonate is placed on the mattress and the skin probe is attached to its body surface. In this method, using the related probe and sensors, the neonate's skin temperature is determined by these sensors and the skin temperature can be observed on the screen in the control panel.

Using another button on the control panel, the desired temperature, which is approximately 36.5°C, is set in the device. In case the neonate's skin temperature is lower than the set temperature, the radiant warmer increases the skin temperature up to the set amount by increasing heat energy; whereas, when the body's recorded temperature by the probe is higher than the set amount, the warmer is turned off automatically so that the body temperature reduces

to the set desirable amount. The server mode method is preferable to control the neonate's temperature in open care systems. If the neonate's skin temperature is more than 0.5°C higher or lower than the set point, the visual/audible alarms are activated and the neonate caregiver will be informed.^[12] The device can radiate 32 mW/cm² of energy with a measurement accuracy of 0.1°C.^[13]

As it is observed, the device's automatic adjustment is based on the skin temperature recorded by the sensor probe. There are some conditions that affect the skin recorded temperature accuracy by the probe. If the probe is detached from the skin surface and has no sufficient conduction, the sensor will record a lower temperature because of the peripheral temperature being colder and the device will use more energy to reach the set temperature, resulting in hyperthermia and over-warming in the neonate. Therefore, it is recommended that the neonate's given skin area is cleaned with alcohol before attaching the probe and the proper probe junction is checked hourly by the caregiver.^[12]

As the location of probe placement has not been constant in different studies and there is no single protocol regarding this in treatment educational centers and also, according to a review of the literature that has been published by Rachel A. Joseph in "Advances in Neonatal Care" magazine, the probe proper placement location using search strategy methods such as Cochrane databases and CPGs has not been determined yet and more research has been recommended in this field.^[14] In this study, we intended to examine five points of the skin surface and compare them with the axillary temperature of proper potential locations and find the best location to place the skin probe.

Methods

This is a cross-sectional study that has been conducted in the infant age group in the intensive care unit in Alzahra Hospital and Shahid Beheshti Hospital of Isfahan University of Medical Sciences. The study inclusion criteria are gestational age higher than 26 weeks, chronological age less than 2 weeks, no skin problems, and not suffering from prenatal asphyxia. The study exclusion criteria are impossibility of neonate follow-up and using phototherapy during the study. Finally, 400 neonates aged 26 weeks and above and chronological age less than 2 weeks were included in the study. This is a descriptive-analytical cross-sectional study performed on 400 neonates in Al-Zahra and Beheshti hospitals (affiliated to Isfahan University of Medical Sciences). This article was extracted from a research project conducted at Isfahan University of Medical Sciences, Isfahan, Iran (code: IR.MUI.REC.1396.3.641). Study Review Board of the university approved the written protocol and informed consent was obtained from all the parents prior to the study.

For the neonates within the study inclusion criteria, after entering the Neonatal Intensive Care Unit (NICU) and after

being placed in the open care system and stability of their conditions while being in the supine position, the probe of Fisher and Paykel type in the NICUs under study was placed in the thoracic area in the right nipple incisors and the skin temperature displayed on the control panel was recorded. At the same time, the neonate's body temperature was measured and recorded using a mercury thermometer, which is normally placed in the neonate's axillary zone for 3 min. After measuring the axillary temperature in the third minute using the mercury thermometer, it was placed in the neonate's axillary zone for another 30 min and the temperature was measured. In case the two figures were identical, the first one was recorded, and if it showed an increase, the thermometer was maintained in position for 5 min and then the temperature was recorded.

The skin temperature in this area (the thoracic area in the right nipple incisors) and the axillary temperature were measured and recorded 30 min later.

This measurement method was used for the other four points of probe junctions, including the epigastric region between the xiphoid appendage and umbilicus, the RUQ area just below the ribs in the mid-clavicular line, the hypogastric area between the umbilicus and the symphysis pubis, and the left flanking area, and the findings were recorded.

Data recorded at each probe junction were compared with the axillary temperature at 0 and 30 min. The values recorded at the five probe binding sites were also compared. Finally, the data were entered into SPSS software version 22 and the data were analyzed with a 5% significance level ($P = 0.05$).

Data collection and analysis

The statistical indicator mean \pm standard deviation was used to describe the quantitative data. T-paired and repeated measure ANOVA tests were used to analyze the data for comparing quantitative data at 0 and 30 min in the two axillary areas and the mean of other probes and to compare quantitative data at 0 and 30 min in the axillary and probe junctions, respectively.

Results

A total of 400 neonates were examined in this study. The recorded temperatures in different body points were analyzed statistically and the following results were obtained.

From a total of 400 neonates above 26 weeks of gestation with a mean chronological age of 8 days, there were 194 female and 206 male neonates. The temperature shown by the thermometer in the axillary area was in line with previous studies, and it was considered as neonate's standard body temperature in this study. Mean neonatal axillary temperature at 0 min was 36.60°C (SD: 0.27) and the mean of the recorded temperatures at 30 min was 36.61°C

(SD: 0.24), which are not significantly different from each other and it is not statistically significant ($P = 0.15$).

The mean values of the recorded temperatures in the other five areas of the neonate's body that were measured by the skin probe are shown in Table 1. Mean temperature recorded by skin probes at 0 and 30 min were as follows: 36.34°C and 36.35°C in the thoracic region, 36.45°C and 36.47°C in the epigastric region, 36.50°C and 36.52°C in the RUQ region, 36.26°C and 36.20°C in the Flank region, and 36.24°C and 36.26°C in the hypogastric region [Table 1].

In the comparison of recorded temperatures in the axillary area with the other five areas of the neonate's body, the lowest mean difference recorded was related to the RUQ

area (0.09) and the highest was related to the Flank area [Table 2].

According to the following table and variance analysis and regarding (sig: 0.000), there is a significant difference in different points which is shown in Table 3.

The results of the follow-up analysis are observed in the following table, which shows the results of comparing different points in the axillary area in detail [Table 4]. There was a significant difference in other points in the axillary area.

Discussion

Open care systems in which the neonate can be accessed easily to do required treatments are increasingly used in NICUs.^[9] In these systems, a radiant warmer is used to control the neonate's temperature and special sensors are attached to the neonate's body surface through a skin probe to determine skin temperature and send the information to the warmer in order to reach the body temperature to the desired point.^[10] In case the neonate's skin temperature is lower than the set amount, the radiant warmer raising the heat energy amount increases the skin temperature up to the set amount; if the recorded body temperature by the probe is higher than the set amount, the warmer is turned off automatically to reduce the temperature to the desired value.

It is obvious that the base of the device's automatic adjustments is body skin recorded temperature by the probe sensor. There are some conditions that affect the accuracy of recording the skin temperature by the probe.

Another factor affecting the accuracy of recorded temperature by the sensor is the area of placing the skin probe. Lablan emphasized the significance of the area of placing skin probe to examine skin surface temperature and evaluating the body central temperature for the first time.

Table 1: Mean and standard deviation of recorded temperatures at 0 and 30 min in pair form in different body points

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1				
axilla	36.596	400	0.2698	0.0135
axilla30	36.609	400	0.2447	0.0122
Pair 2				
flunk	36.260	400	0.2034	0.0102
flunk30	36.195	400	1.6782	0.0839
Pair 3				
chest	36.342	400	0.2033	0.0102
chest30	36.345	400	0.2055	0.0103
Pair 4				
hypogastric	36.242	400	0.1854	0.0093
hypogastr30	36.264	400	0.2075	0.0104
Pair 5				
epigastric	36.451	400	0.2063	0.0103
epigastric30	36.466	400	0.2289	0.0114
Pair 6				
RUQ	36.499	400	0.2057	0.0103
RUQ30	36.519	400	0.2193	0.0110

Table 2: Comparison of recorded temperatures at 0 and 30 min

	Paired Differences				t	df	Sig. (2-tailed)	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower				Upper
Pair 1								
axilla - axilla30	-0.0130	0.1813	0.0091	-0.0308	0.0048	-1.434	399	0.152
Pair 2								
flunk - flunk30	0.0648	1.6777	0.0839	-0.1002	0.2297	0.772	399	0.441
Pair 3								
chest - chest30	-0.0028	0.1461	0.0073	-0.0172	0.0115	-0.386	399	0.700
Pair 4								
hypogastric - hypogastric30	-0.0220	0.1312	0.0066	-0.0349	-0.0091	-3.354	399	0.001
Pair 5								
epigastric - epigastric30	-0.0148	0.1619	0.0081	-0.0307	0.0011	-1.825	399	0.069
Pair 6								
RUQ - RUQ30	-0.0202	0.1682	0.0084	-0.0368	-0.0037	-2.408	399	0.016

Table 3: One-way variance analysis to compare the measured temperature in different body areas

site	Mean	Std. Deviation	F	sig
axilla	36.596	0.2698		
flunk	36.260	0.2034		
chest	36.342	0.2033	61	0.000
hypogastric	36.242	0.1854		
epigastric	36.451	0.2063		
RUQ	36.499	0.2057		

Table 4: Results of follow-up analysis

(I) site	(J) site	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
axilla	flunk	0.37438*	0.000	0.2991	0.4496
	chest	0.25841*	0.000	0.1832	0.3337
	hypogastric	0.34950*	0.000	0.2743	0.4247
	epigastric	0.24463*	0.000	0.1694	0.3199
	RUQ	0.09263*	0.006	0.0174	0.1679

He pointed out that the placement area of the skin probe and recording the temperature at that point must adapt the axillary temperature as the standard area of temperature measurement and patient management.^[15]

Bolden compared the accuracy of probe sensors in two areas on preterm infants with birth weights lower than 1250 g. He placed the probe in the abdominal area 2 cm below and to the right of the umbilicus and then in the axillary area. He finally concluded that axillary probe temperature is higher than skin probe temperature although no significant statistical difference was found.^[16]

In a study by Schafer *et al.* on 36 neonates in 30–36 weeks of gestation age, the probe sensor was placed in three areas: the upper right abdominal area, left Flank region, and right axillary. He concluded that the temperature recorded by the sensor in all three areas was equal to the axillary temperature measured by the thermometer.^[17]

In Blackburn's study on 83 neonatal centers, it was found that the probe placement area was different at each center and it was determined based on the unit's protocols.^[18] He also studied 23 infants with 27–37 weeks of gestation age and showed that the skin temperature at the sensor probe that had been placed in the upper right abdominal area was significantly different from the temperature recorded by the skin probe placed in the back area in the prone position and the recorded temperature by the thermometer in the axillary area.^[19]

In a study conducted by Thomas on infants with 5–9 weeks of gestation age, an inconsistency was observed between the recorded temperature of the abdominal skin probe with axillary recorded temperature.^[20]

In the study by Bell, the probe sensor was placed in mid-epigastric between xiphoid and umbilicus and it was

shown that placing the probe in this area is highly accurate in recording body temperature and the results are in line with axillary temperature.^[21]

Koh *et al.* conducted a study on 148 term infants less than 2 weeks of gestation age. The skin probe was placed in the right hypochondrium for 73 infants and it was placed in the chest area for the other 75. At 0 (at the beginning of enrollment), 15, and 30 mi after enrolling the infant, the temperature of the aforementioned areas was recorded and compared with axillary temperature measured by a digital thermometer (in total, the temperature was recorded 880 times). Finally, it was concluded that the recorded temperature by the abdominal skin probe compared to the chest skin probe is more precise and is more in line with the axillary temperature.^[22]

Limitations

One of the limitations of this study was related to the sample size. To evaluate the best site for skin sensor temperature probes in newborns under open care system, further studies are needed.

Conclusions

In this study, the temperature recorded in the axillary area was considered as the standard temperature, and five accessible and practical areas were chosen as the skin probe placement areas. The neonate's body temperature measurement was done. As mentioned before, the skin probe in the RUQ area showed the highest affinity and the lowest mean difference with the axillary area. This shows that the area is a trustworthy one for neonate's body thermoregulation and regulating the neonate's peripheral temperature and prevention of hypo or hyperthermia.

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Conflicts of interest

There are no conflicts of interest.

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