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Prevalence and Risk Factors Associated with Temperature Derangement in High-Risk Neonates After Birth Resuscitation and Upon Neonatal Ward Admission: A 5-Year Retrospective, Single-Center, Study

Buranee Yangthara[1]; Jeerapa Poungmalai[2]; Ratchada Kitsommart[1]; Pimol Wongsiridej[1]*

[1]Division of Neonatology, Department of Pediatrics, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand.

[2]Department of Obstetrics and Gynaecology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand.

***Corresponding Author(s): Pimol Wongsiridej**

Associate Professor of Pediatrics, Division of Neonatology, Department of Pediatrics Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Road, Bangkoknoi, Bangkok 10700, Thailand.

Tel: +66-2-419-7000 Ext. 5713, Fax: +66-2-411-3010;

Mail: pimolwong@gmail.com

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Abstract

Objective: Temperature derangement is associated with higher morbidity and mortality in high-risk neonates. The aim of this study was to investigate the prevalence of, and factors associated with temperature derangement in high-risk neonates after birth resuscitation and upon neonatal ward admission.

Methods: Birth and admission records of high-risk infants that were delivered at Siriraj Hospital (Bangkok, Thailand) during 2011-2015 were retrospectively reviewed. A total of 11, 385 infants were included.

Results: Median gestational age and birth weight was 37 weeks and 2,740 grams, respectively. Prevalence of hypothermia and hyperthermia upon admission was 3.5% and 21.4%, respectively. The strongest risk factors for hypothermia upon neonatal ward admission were *birth before arrival*, *hemodynamic support for resuscitation*, and *ventilation support for resuscitation* (8.8 (4.1-19.0), 3.3 (1.8-6.3), and 2.5 (2.1-3.0), respectively]. The strongest risk factors for hyperthermia upon neonatal ward admission were *chorioamnionitis/maternal infection*, *meconium-stained amniotic fluid*, and *pethidine administration* (7.1 (5.2-9.7), 1.5 (1.2-1.9), and 1.5 (1.2-1.8), respectively].

Conclusions: prevalence of hypothermia and hyperthermia was 3.5% and 21.4%, respectively. The identification of improved thermal care strategies is needed, and continuous temperature monitoring is recommended in this high-risk patient population.

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Introduction

Thermal care is critical for postnatal adaptation. Temperature derangement, both hypothermia and hyperthermia, is associated with higher energy expenditure, worsened outcomes, and increased mortality [1-5]. Newly born infants easily transfer heat to the environment via conduction, convection, evaporation, and irradiation due to a large body surface area [6]. Heat loss combined with the limited ability of infants to generate heat via non-shivering thermogenesis can result in the development of hypothermia (body temperature (BT) <36.5 ºC). Preterm infants, infants with skin defects, and infants with perinatal hypoxia are at even greater risk of developing hypothermia. Conversely, hyperthermia (BT >37.5 ºC) can develop secondarily from maternal fever or iatrogenically during birth resuscitation.

The reported prevalence of neonatal hypothermia ranges from 22% to 88% depending on birthweight, gestational age, and level of care [7]. In preterm infants, the occurrence of hyperthermia ranged from 3.5% to 7.5% [3]. Thermal care is one of the fundamental care requirements during birth resuscitation [8]. The current International Liaison Committee on Resuscitation (ILCOR) 2016 guideline outlines specific maneuvers that need to be performed to maintain body temperature between 36.5ºC and 37.5ºC [9].

Despite the adoption and implementation of guidelines designed to maintain normal BT, high-risk infants still frequently develop BT derangement. Factors that contribute to anomalous BT in high-risk infants include large body surface area, more transparent skin, and the higher probability they will receive respiratory support. Improved knowledge about temperature derangement in this high-risk population will improve prevention, treatment, and patient outcomes. Accordingly, the aim of this study was to investigate the prevalence of temperature derangement in high-risk neonates after birth resuscitation and upon neonatal ward admission, and to identify perinatal factors significantly associated with temperature derangement.

Material and methods

This retrospective chart review included the birth records of high-risk infants that were delivered at the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand during the 1 January 2011 to 31 December 2015 study period. Siriraj Hospital is Thailand's largest national tertiary referral center. Birth resuscitation during the study period was performed according to ILCOR 2010 guideline [10]. Accordingly, all high-risk deliveries as defined by ILCOR 2010 (Table 1) were attended by a dedicated team for birth resuscitation, including at least one pediatric resident and an experienced nurse. In very high-risk cases, such as extreme prematurity or major congenital anomalies, additional experienced personnel and a neonatologist were required to be present in the delivery suit. The protocol for this study was approved by the Siriraj Institutional Review Board. The requirement to obtain written informed consent from study participants was waived due to our study's retrospective design.

Target BT was 36.5ºC to 37.5ºC (normothermia, NormoT). Hypothermia (HypoT) was defined as BT less than 36.5ºC, and Hyperthermia (HyperT) was defined as BT greater than 37.5ºC. Thermal care maneuvers included prewarmed radiant warmer, dry and prewarmed blankets, and room temperature set at a minimum of 25ºC. Additional hat and polyethylene bag were added for preterm infants with a gestational age (GA) less than 32 weeks, and for very low birthweight (VLBW; birth weight less than 1,500 g) infants. There was no exothermic mattress available. Positive-Pressure Ventilation (PPV) during birth resuscitation was administered using bag-and-mask or T-piece ventilation with a gas flow rate of 10 Liters Per Minute (LPM) for both systems. Ventilation gas flow was delivered without a heated-humidified system. A mobile T-piece resuscitator (Neopuff®, Fisher&Paykel Healthcare, Auckland, New Zealand) was used for infants who were transferred with ventilation support (non-invasive ventilation or intubation). According to our local policy during the study period [11], BT was routinely monitored rectally using mercury-in-glass thermometer within 5 minutes post-resuscitation, and before being transferred to a neonatal ward. A transport incubator prewarmed to 35.0ºC was used for all transfers. Upon arrival at the designated neonatal ward, additional measurement of axillary temperature using mercury-in-glass thermometer was obtained immediately after the infant was transferred to a prewarmed incubator.

Statistical analysis

Antenatal and intrapartum risk factors were extracted from maternal antenatal care and intrapartum records, and postnatal factors were retrospectively reviewed. Maternal and infant characteristics are reported as number (percentage) for categorical variables, and as median (interquartile range, IQR) for continuous variables. The primary outcomes were occurrence of temperature derangement (both HypoT and HyperT) at post-resuscitation and upon admission to the neonatal ward. Differences in BT between gestational age groups were Analyzed by One-Way Analysis of Variance (ANOVA). Paired sample *t*-test was used to compare post-resuscitation and neonatal ward admission BT. Infants were identified as being at high-risk if they had one or more of the perinatal factors listed in Table 1. Association between each risk factor and the occurrence of HypoT or HyperT was analyzed using univariate logistic regression, and those results are given as Odds Ratio (OR), 95% confidence interval (95% CI), and *p*-value. Factors selected by backward stepwise elimination based on likelihood ratio were analyzed in multivariate logistic regression, and those results are shown as Adjusted Odds Ratio (AOR), 95% CI, and *p*-value. A *p*-value<0.05 was considered statistically significant. All statistical analyses were performed using SPSS Statistics version 18.0 (SPSS, Inc., Chicago, IL, USA).

Results

During the 5-year study period, there was 56,170 live births at our center. Of those, 11,430 infants (20.3%) had at least 1 of the risk factors listed in Table 1, which made them eligible for inclusion in this study. Forty-five of those infants were excluded due to missing or incomplete post-resuscitation and/or neonatal ward admission BT data. The remaining 11,385 high-risk infants were included. The characteristics of mothers and infants are shown in (Table 2). Preterm gestation accounted for 37% of high-risk deliveries, and 992 of 11,385 infants (8.7%) were born at 32 weeks gestation or less. There were 4,172 low birth weight infants (BW <2,500 g) and 644 very low birth weight infants (BW <1,500g). BT ranged from 35.0 to 40.0ºC, with a median (IQR) BT of 37.3°C (37, 37.5) and 36.9ºC (36.7, 37.1) at post-resuscitation and upon neonatal ward admission, respectively. Five infants died shortly after birth resuscitation, and one infant died upon admission. Body temperature data by gestational age group are shown in (Figure 1). Overall incidence of post-resuscitation HypoT and HyperT was 3.5% and 21.4%, respectively. Seventy-two percent of term infants had post-resuscitation NormoT, and

27% had post-resuscitation HyperT. Preterm infants had a substantially higher rate of HypoT. Only 44% of infants with GA less than 28 weeks were NormoT at post-resuscitation (Figure 1A). The prevalence of temperature derangement upon admission to the neonatal ward was 14%. Regarding post-resuscitation BT, NormoT occurred in 88.3% of term infants, with a far lower rate observed in premature infants. Infants with GA less than 32 weeks were highly susceptible to HypoT (55% in GA <28 weeks, and 20% in GA 28 to 32 weeks) (Figure 1B). The median (IQR) transport time from the delivery suit to the neonatal ward was 20 (10, 30) minutes. Mean (SD) neonatal ward admission BT was significantly lower than at post-resuscitation [36.9°C (0.41) *vs.* 37.2°C (0.47), respectively. Median body temperature compared between post-resuscitation and neonatal ward admission by gestational age group is shown in Figure 2. BT upon admission to the neonatal ward was significantly lower than post-resuscitation BT in all GA groups except for GA <28 weeks. In the GA <28 weeks group, the median BT for both post-resuscitation and neonatal ward admission fell within HypoT range. Seven percent of infants with GA >28 weeks were HyperT at neonatal ward admission, and 5% of infants with GA <28 weeks were HyperT at neonatal ward admission.

Our analysis for association between perinatal risk factors and temperature derangement (Table 3&4). Multivariate analysis revealed requirement for hemodynamic support during resuscitation, birth before arrival, and preterm birth to be strongly associated with both post-resuscitation and neonatal ward admission HypoT (Adjusted Odds Ratio (AOR): 16.6, 95% confidence interval (95% CI): 8.6-32.0, AOR: 12.9, 95% CI: 5.8-28.8, and AOR: 9.2, 95% CI: 6.7-12.5, respectively, for post-resuscitation; and, AOR: 3.3, 95% CI: 1.8-6.3, AOR: 8.8, 95% CI: 4.1-19.0, and AOR: 2.3, 95% CI: 2.0-2.7, respectively, for neonatal ward admission). Other risk factors associated with HypoT were multiple gestation, maternal magnesium sulfate administration, maternal general anesthesia, small for gestational age, and ventilation support for resuscitation (Table 3).

The risk factors shown in (Table 4) were found to be independently associated with occurrence of HyperT. Infection-related condition (maternal chorioamnionitis or infection) was the strongest factor associated with both post-resuscitation and neonatal ward admission HyperT (AOR: 9.1, 95% CI: 6.8-12.3 and AOR: 7.1, 95% CI: 5.2-9.7, respectively). Other risk factors independently associated with HyperT were meconium-stained amniotic fluid, maternal pethidine administration, cesarean section, and large for gestational age (Table 4).

Table 1: Established perinatal factors that qualify an infant to be considered *high-risk.*

Antenatal factors	
Gestational age Multiple gestation Maternal hypertension and/or preeclampsia Maternal gestational diabetes mellitus Chorioamnionitis or maternal infection	Maternal magnesium administration Maternal pethidine administration Oligohydramnios Fetal anomalies
Intrapartum factors	
Maternal general anesthesia Breech presentation Meconium-stained amniotic fluid Non-reassuring fetal heart rate	Cesarean section Forceps-assisted delivery or vacuum extraction Birth before arrival
Post-natal factors	
Requirement for ventilation support (positive- pressure ventilation via face mask, continuous positive-airway pressure application, or endotracheal intubation) Requirement for cardiovascular support (chest compression and/or epinephrine administration)	Small for gestational age (birth weight less than 10th percentile) Large for gestational age (birth weight more than 90th percentile)

Table 2: Characteristics of mothers and infants (N= 11,385).

Characteristics	Median (IQR) or n (%)
Maternal age (years)	29 (24, 34)
Delivered by cesarean section	7,340 (64.5%)
Gestational age (weeks)	37 (35, 39)
Less than 28	150 (1.3%)
28 to 32	842 (7.4%)
33 to 36	3,231 (28.4%)
37 or above	7,162 (62.9%)
Male gender	6,164 (54.1%)
Birth weight (grams)	2,740 (2,270, 3,140)
1-minute Apgar score	8 (8, 9)
5-minute Apgar score	10 (9, 10)
Ventilation support during birth resuscitation[a]	1,479 (12.9%)
Hemodynamic support during birth resuscitation[b]	62 (0.5%)

[a]Bag-and-mask ventilation, non-invasive ventilation, or intubation
[b]Chest compression, fluid bolus, or epinephrine administration
Abbreviation: IQR: Interquartile Range

Table 3: Risk factors significantly associated with hypothermia (body temperature <36.5°c).

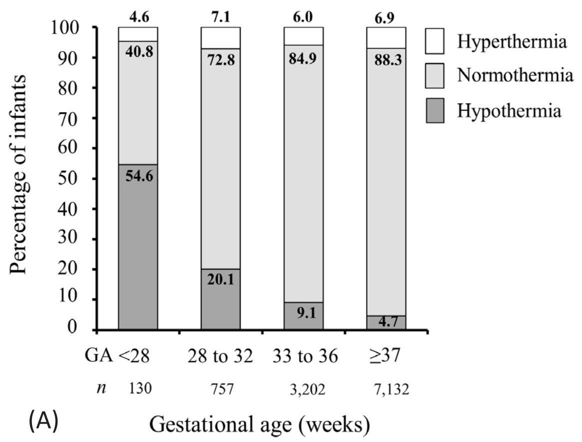
	Post-resuscitation (n=11,381)				Neonatal ward admission (n=11,221)			
Risk factors	**n**	**OR (95% CI)**	**AOR (95% CI)**	***p***	**n**	**OR (95% CI)**	**AOR (95% CI)**	***p***
Preterm birth	339/4,216	11.3 (8.5-15.1)	9.2 (6.7-12.5)	*<0.01*	515/4,088	2.9 (2.5-3.4)	2.3 (2.0-2.7)	*<0.01*
Multiple gestation					214/1,602	2.2 (1.8-2.6)	1.2 (1.0-1.5)	*0.02*
$MgSO_4$	170/2,034	5.7 (3.0-4.6)	2.6 (2.1-3.3)	*<0.01*	263/1,991	2.2 (1.9-2.6)	1.7 (1.4-2.0)	*<0.01*
General anesthesia	73/931	2.7 (2.1-3.5)	1.7 (1.2-2.3)	*<0.01*				
BBA	15/41	16.7 (8.8-31.8)	12.9 (5.8-28.8)	*<0.01*	16/39	8.6 (4.5-16.4)	8.8 (4.1-19.0)	*<0.01*
SGA	106/2,077	1.7 (1.3-2.1)	2.7 (2.1-3.5)	*<0.01*	258/2,059	2.1 (1.8-2.4)	2.4 (2.0-2.8)	*<0.01*
Ventilation support for resuscitation	155/1,479	4.7 (3.8-5.8)	3.2 (2.5-4.2)	*<0.01*	219/1,454	2.6 (2.2-3.0)	2.5 (2.1-3.0)	*<0.01*
Hemodynamic support for resuscitation	34/62	37.0 (22.2-61.7)	16.6 (8.6-32.0)	*<0.01*	20/50	8.3 (4.7-14.7)	3.3 (1.8-6.3)	*<0.01*

A *p*-value<0.05 indicates statistical significance
Abbreviations: OR: Odds Ratio; CI: Confidence Interval; AOR: Adjusted Odds Ratio; $MGSO_4$: Magnesium Sulfate; BBA: Birth Before Arrival; SGA: Small For Gestational Age

Table 4: Risk factors significantly associated with hyperthermia (body temperature >37.5°c).

	Post resuscitation (n=11,381)				Neonatal ward admission (n=11,221)			
Risk factors	**n**	**OR (95% CI)**	**AOR (95% CI)**	***p***	**n**	**OR (95% CI)**	**AOR (95% CI)**	***p***
Meconium-stained AF	366/1,153	1.8 (1.6-2.1)	1.4 (1.2-1.6)	<0.01	119/1,146	1.8 (1.4-2.1)	1.5 (1.2-1.9)	<0.01
Chorioamnionitis / maternal infection	150/232	7.1 (5.4-9.4)	9.1 (6.8-12.3)	<0.01	79/227	8.3 (6.2-11.0)	7.1 (5.2-9.7)	0.02
Pethidine	702/2,440	1.7 (1.5-1.9)	1.5 (1.4-1.7)	<0.01	246/2,429	1.9 (1.6-2.2)	1.5 (1.2-1.8)	<0.01
Cesarean section	1,743/7,338	1.5 (1.4-1.7)	1.9 (1.7-2.1)	<0.01				
LGA	150/548	1.4 (1.2-1.7)	1.6 (1.3-2.0)	<0.01	492/541	1.4 (1.1-1.9)	1.5 (1.1-2.1)	0.02

A *p*-value<0.05 indicates statistical significance
Abbreviations: OR: Odds Ratio; CI: Confidence Interval; AOR: Adjusted Odds Ratio; AF: Amniotic Fluid; LGA: Large For Gestational Age.



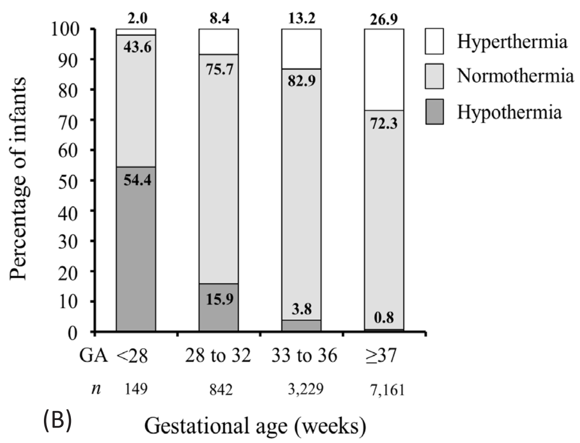


Figure 1: Distribution of body temperature by gestational age group in high-risk neonates. (A) post-resuscitation (n=11,381); (B) neonatal ward admission (n=11,221). (*hypothermia* = body temperature <36.5°c; *normothermia* = body temperature 36.5 to 37.5°c; and *hyperthermia* = body temperature >37.5°c)

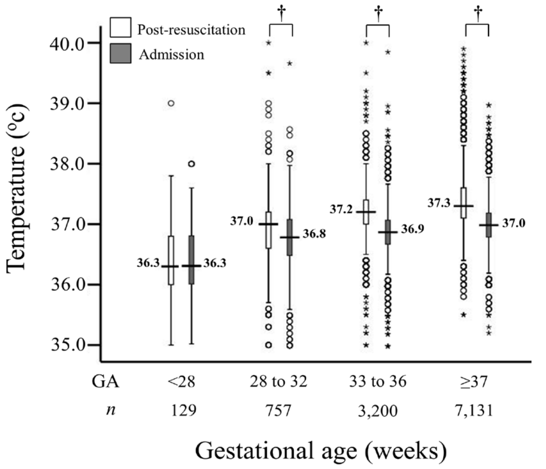


Figure 2: Median body temperature compared between post-resuscitation and neonatal ward admission by gestational age group. († indicates statistical significance; $p<0.05$).

Discussion

The results of this study revealed a prevalence of post-resuscitation temperature derangement and temperature derangement at neonatal ward admission of 24.8% and 14.2%, respectively. HypoT was significantly more prevalent than HyperT in both term and preterm infants. Physiological stress caused by HypoT leads to increased oxygen consumption, hypoglycemia, hypoxia, and metabolic acidosis, which explains why several studies reported association between hypothermia and death in neonates [12]. Post-resuscitation HypoT demonstrates the physiologic vulnerability of newly born infants to heat loss via all active mechanisms (i.e., conduction, convection, evaporation, and irradiation). Without the strategies associated with standard birth resuscitation, evaporation and radiation comprise the greatest expense of total heat loss at birth [13]. Consistent with the findings of previous study [14], we found birth before arrival to be one of the risk factors most strongly associated with HypoT. We encourage standard neonatal resuscitation training for all potentially involved healthcare personnel so that they will be able to initiate steps of thermal care, including maintenance of suitable environmental temperature and thorough drying of the infant [14]. Preterm infants are susceptible to heat loss via several physiologic limitations. Large surface area, thin keratinized skin, and lack of subcutaneous fat promote transepidermal heat loss. Additional factors that promote a heat deficit include limited intrinsic heat production from brown fat metabolism, and poor vasomotor response to cold environment. We found preterm infants to be 9 times more likely to have HypoT after birth resuscitation, and 2 times more likely to have HypoT upon neonatal ward admission than term infants. As expected, the prevalence of HypoT was highest among extremely preterm infants (<28 weeks GA) (54%), which was consistent with the findings of a large study conducted in a developed country [3]. The current ILCOR 2016 guideline suggests additional thermal mattress and body coverage with polyethylene material for heat protection in this group. However, it is a challenge to prevent heat loss in very preterm infants because they often present with certain degree of respiratory insufficiency that requires ventilation support [15]. We found that infants who received ventilation support were 3 times more likely to have post-resuscitation HypoT, and 2.5 times more likely to have neonatal ward admission HypoT than infants who did not receive ventilation support, independent of gestational age. Significant heat loss via respiratory mucosa plays a significant role in facilitating heat loss, so heated-humidified gas flow during ventilation support should be implemented [16].

In the present study, infants that required hemodynamic support during birth resuscitation were found to be at the highest risk for developing HypoT. This is due to the fact that these infants are unable to generate heat due to hypoxia. Moreover, these infants are more likely to require more advanced and longer duration resuscitation maneuvers. Resuscitation steps, including dry ventilation circuit, unwarmed fluid or medications, and prolonged exposure to cold environment during resuscitation, all contribute to massive heat loss during intensive resuscitation. Therefore, continuous temperature monitoring during resuscitation in early postnatal period for high-risk infants is recommended.

Neonatal ward admission BT was significantly lower than the post-resuscitation BT, and the median transportation time was 20 minutes. It can, therefore, be concluded that the transport incubator protocol that is currently being used is inadequate for maintaining BT within the target range. The effectiveness of and risks associated with the use of a higher preset transport incubator temperature and a humidified environment deserves further study [17,18]. Additional maneuvers, such as continuous temperature monitoring, exothermic mattress, and heated-humidified ventilation gas [19], are also necessary during transfer [20]. Previous studies demonstrated association between low admission temperature and high mortality rate [3,4]. Most of the risk factors that influenced post-resuscitation HypoT in this study were also found to be associated with admission HypoT. Taken together, these findings highlight the need to identify strategies to continuously improve thermal care in routine practice.

Although the prevalence of HyperT was lower than that of HypoT, its consequence included worsening neurological outcomes in high-risk neonates, particularly for preterm infants and infants with perinatal hypoxia [1,21]. Post-resuscitation HyperT occurred in 27% of our high-risk term infants, and in 12% of our high-risk preterm infants. Interestingly, the prevalence rates of HyperT upon neonatal ward admission ranged from 5% to 7% across GA groups, which is comparable with the findings reported by Laptook, *et al.*, [3]. This finding is worrisome and warrants further clarification, and it highlights a need to identify strategies to lower the rate of HyperT. We found maternal infection or chorioamnionitis to have the strongest association with HyperT at both post-resuscitation and upon admission in the neonatal ward. Fetal temperature appears to be dependent on maternal temperature via functional uteroplacental circulation [22]. Therefore, maternal fever or conditions with uteroplacental insufficiency are risk factors for the development of neonatal HyperT. The same explanation is applicable to other conditions that occur secondarily to uteroplacental insufficiency, such as meconium-stained amniotic fluid. Certain factors that we identified as risk factors for temperature derangement were associated with unpredictable direction of BT changes; thus, development of a single protocol that is compatible with all clinical settings of infants is very challenging. We, therefore, suggest continuous temperature monitoring in all high-risk deliveries from birth until BT stability is achieved in the neonatal ward. Ideally, thermal control maneuvers should be initiated early enough to prevent severe derangement of BT during the early postnatal period.

The findings of our study represent temperature outcomes in real-life clinical practice while in full compliance with standard guideline-based recommendations. BT measurement values were available for all included infants, and all measurements were taken by trained clinicians. Moreover, the large size of the study population in this study gave it the statistical power needed to identify all statistically significant differences and associations between evaluated groups.

This study also has some mentionable limitations. First, the retrospective nature of this study makes it vulnerable to missing or incomplete data. Second, this was a single-center study. That limitation is mitigated by the fact that our center routinely handles pregnancies that range from completely routine to the most complex possible. Third, different methods of temperature measurement were used, including rectal measurement in the delivery suits, and axillary measurement upon admission to the neonatal ward. We acknowledge the reported poor agreement between the two anatomical sites of measurement in neonatal infants [23]. However, the two measurement sites were demonstrated to be comparable [11]. Moreover, we used mercury-in-glass thermometers, which are widely accepted due to their consistent precision and reliability [23]. Fourth, we did not explore association between temperature derangement and neonatal outcomes. However, previous study reported association between admission temperature and poor outcomes [1,3]. Fifth and last, other potential confounders, including maternal temperature, duration of resuscitation, on-going BT, and air temperature in the transport incubator, were not included and adjusted for in our analysis. Although these potential confounding factors may affect infant BT, our results reflect the overall effectiveness of the existing protocol across different types of high-risk infants in two different post-natal settings.

Conclusion

Temperature derangement occurred in 24.8% and 14.2% of high-risk infants at post-resuscitation and neonatal ward admission, respectively. Several risk factors were found to be significantly associated with each measured parameter. The strongest risk factors for hypothermia were hemodynamic support for resuscitation and birth before arrival for post-birth resuscitation and neonatal ward admission, respectively. The strongest risk factor for hyperthermia was chorioamnionitis/maternal infection for both post-birth resuscitation and neonatal ward admission. The identification of improved thermal care strategies is needed, and continuous temperature monitoring is recommended in this high-risk patient population.

References

1. Lyu Y, Shah PS, Ye XY, Warre R, Piedboeuf B, et al. Association between admission temperature and mortality and major morbidity in preterm infants born at fewer than 33 weeks' gestation. JAMA Pediatr. 2015; 169: e150277.

2. Degorre C, Decima P, Degrugilliers L, Ghyselen L, Bach V, et al. A mean body temperature of 37 degrees C for incubated preterm infants is associated with lower energy costs in the first 11 days of life. Acta Paediatr. 2015; 104: 581-588.

3. Laptook AR, Bell EF, Shankaran S, Boghossian NS, Wyckoff MH, et al. Admission temperature and associated mortality and morbidity among moderately and extremely preterm nnfants. J Pediatr. 2018; 192: 53-59.

4. de Almeida MF, Guinsburg R, Sancho GA, Rosa IR, Lamy ZC, et al. Hypothermia and early neonatal mortality in preterm infants. J Pediatr. 2014; 164: 271-275.

5. Wilson E, Maier RF, Norman M, Misselwitz B, Howell EA, et al. Admission hypothermia in very preterm infants and neonatal mortality and morbidity. J Pediatr. 2016; 175: 61-67.

6. Lunze K, Hamer DH. Thermal protection of the newborn in resource-limited environments. J Perinatol. 2012; 32: 317-324.

7. Mullany LC. Neonatal hypothermia in low-resource settings. Semin Perinatol. 2010; 34: 426-433.

8. World Health Organization. WHO Recommendations on Interventions to Improve Preterm Birth Outcomes. Ed. Geneva, Switzerland: WHO press. 2015.

9. American Academy of Pediatrics. Preparing for resuscitation. 7th ed. Weiner GM. Elk Grove Village (IL): American Academy of Pediatrics. 2016.

10. American Academy of Pediatrics. Overview and principles of resuscitation. 6th ed. Kattwinkel J. Elk Grove Village (IL): American Academy of Pediatrics. 2011.

11. Jirapaet V, Jirapaet K. Comparisons of tympanic membrane, abdominal skin, axillary, and rectal temperature measurements in term and preterm neonates. Nurs Health Sci. 2000; 2: 1-8.

12. Soll RF. Heat loss prevention in neonates. J Perinatol. 2008; 28: S57-S59.

13. Hammarlund K, Nilsson GE, Oberg PA, Sedin G. Transepidermal water loss in newborn infants. V. Evaporation from the skin and heat exchange during the first hours of life. Acta Paediatr Scand. 1980; 69: 385-392.

14. Kamath-Rayne BD, Thukral A, Visick MK, Schoen E, Amick E, et al. Helping Babies Breathe, Second Edition: A Model for Strengthening Educational Programs to Increase Global Newborn Survival. Global health, science and practice. 2018; 6: 538-551.

15. Yangthara B, Horrasith S, Paes B, Kitsommart R. Predictive factors for intensive birth resuscitation in a developing-country: a 5-year, single-center study. J Matern Fetal Neonatal Med. 2018.

16. McGrory L, Owen LS, Thio M, Dawson JA, Rafferty AR, et al. A Randomized Trial of Conditioned or Unconditioned Gases for Stabilizing Preterm Infants at Birth. J Pediatr. 2018; 193: 47-53.

17. Trevisanuto D, Testoni D, de Almeida MFB. Maintaining normothermia: Why and how? Semin Fetal Neonatal Med. 2018.

18. Russo A, McCready M, Torres L, Theuriere C, Venturini S, et al. Reducing hypothermia in preterm infants following delivery. Pediatrics. 2014; 133: e1055-e1062.

19. Meyer MP, Hou D, Ishrar NN, Dito I, te Pas AB. Initial respiratory support with cold, dry gas versus heated humidified gas and admission temperature of preterm infants. J Pediatr. 2015; 166: 245-250.

20. Maletzki J, Adzikah S, Ruegger C, Bassler D. Admission hypo- and hyperthermia are associated with increased mortality and morbidity in very preterm infants. Acta Paediatr. 2017; 106: 519.

21. Lee AC, Kozuki N, Blencowe H, Vos T, Bahalim A, et al. Intrapartum-related neonatal encephalopathy incidence and impairment at regional and global levels for 2010 with trends from 1990. Pediatr Res. 2013; 74: 50-72.

22. Martin R, Fanaroff AA, Walsh MC. Fanaroff and Martin's neonatal-perinatal medicine. 9th ed. Missouri: Elsevier. 2011.

23. Hissink Muller PC, van Berkel LH, de Beaufort AJ. Axillary and rectal temperature measurements poorly agree in newborn infants. Neonatology. 2008; 94: 31-34.