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Perinatal quality improvement bundle to decrease hypothermia in extremely low birthweight infants with birth weight less than 1000 g: single-center experience over 6 years

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ABSTRACT

Normothermia (36.5°C–37. 5°C) at the time of admission to the neonatal intensive care unit (NICU) in extremely low birthweight (ELBW) infants (birth weight <1000 g) is associated with decreased morbidity and mortality, decreased length of stay and hospital costs. We designed a thermoregulation bundle to decrease hypothermia (<36.5°C) in ELBW infants with a multidisciplinary perinatal quality improvement initiative that included the following key interventions: dedicated delivery room (DR)/operating room (OR) for all preterm deliveries of ≤32 weeks with DR/OR temperature set 24/7 at 74°F by the hospital engineering staff, use of exothermic mattress, preheated radiant warmer set at 100% for heat prior to delivery, servo-controlled mode after the neonate is placed on the warmer, and use of plastic wrap, head cap and warm towels. A total of 200 ELBW infants were admitted to our NICU between January 1, 2014 and December 31, 2019. Hypothermia (<36.5°C) occurred in 2.5% of infants, normothermia (36.5°C–37.5°C) in 91% of infants and transitional hyperthermia (>37.5°C) in 6.5% of ELBW infants. No case of moderate hypothermia (32°C–36°C) was seen in our infants. Our target rate of less than 10% hypothermia was reached in ELBW infants over the last 2 years with no cases of moderate hypothermia in 6 years. Eliminating hypothermia among ELBW remains a challenge and requires team effort and continuous quality improvement efforts.

Significance of this study

What is already known about this subject?

- Hypothermia at the time of delivery in extremely low birthweight, preterm infants is associated with increase in mortality and morbidities.
- Incidence of hypothermia remains high around the globe.

What are the new findings?

- Use of a thermoregulation bundle, involving obstetric and neonatal care providers, and continuous quality improvement efforts decrease the occurrence of hypothermia in extremely low birthweight infants.

How might these results change the focus of research or clinical practice?

- Our study results provide a strong rationale to define normothermia in newborn infants.
- Work collaboratively with perinatal care providers to improve outcomes in this most vulnerable population of extremely low birthweight infants using simple interventions.
- Thermoregulation bundle described in this study is easily reproducible in clinical practice.

INTRODUCTION

Perinatal care practices, including initial stabilization and resuscitation of newborn infants, have improved dramatically over the past five decades. Almost 60 years ago, Silverman *et al*[1] reported that hypothermia is associated increase in mortality in preterm and term infants. Yet, thermal management around the time of birth continues to be a major problem with many newborns admitted with hypothermia (<36.5°C). Normothermia (36.5°C–37.5°C) at the time of admission to the neonatal intensive care unit (NICU) in extremely low birthweight (ELBW) infants is associated with decreased morbidity and mortality, and decreased length of stay and hospital costs. Adverse effects due to hypothermia in preterm infants increase with the degree of hypothermia and immature gestational age at birth. In a retrospective study by Laptook *et al*[2] involving 5277 inborn, very low birthweight (VLBW) infants, mean admission temperature was 35.9°C±1°C, with 46.9% of infants admitted with hypothermia. There was a significant association between admission hypothermia and late-onset sepsis and mortality. For every 1°C drop in temperature below 36.5°C, there was an 11% increase

in the odds of developing late-onset sepsis (OR 1.11, 95% CI 1.02 to 1.20) and a 28% increase in mortality (OR 1.28, 95% CI 1.16 to 1.42). Hypothermia is still a major problem among ELBW infants in high-income countries. Furthermore, in many low-income countries, hypothermia is common even among term infants.[3–5] Maintaining a neonate's temperature in the normothermia range soon after birth remains a challenge due to lower delivery room (DR) or operating room (OR) temperatures preferred by DR staff, heat loss secondary to large surface area in VLBW and ELBW infants, and heat loss during transport from the DR to the NICU. Environmental temperature plays a major role in maintaining normothermia in neonates. Increasing OR temperature from 20°C to 23°C at the time of cesarean section reduces the rate of neonatal and maternal hypothermia.[6] There is no consensus regarding DR/OR temperature settings. The WHO in 1997 recommended a DR/OR temperature of 25°C (77°F).[7] American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc in 2011 recommended DR temperature range between of 68°F and 75°F.[8] Neonatal Resuscitation Program (NRP) guidelines in 2015 recommended a DR temperature of 26°C (79°F) for infants with an estimated fetal weight of <1500 g.[9]

Normothermia

Surprisingly, there is no consensus on what constitutes normothermia, hypothermia or hyperthermia in newborn infants. The WHO in 1997 defined hypothermia as a temperature of <36.5°C with 36°C–36.5°C as mild, 32°C–36°C as moderate and <32°C as severe hypothermia.[7] No upper limit for a normal body temperature in newborns was suggested in this recommendation.[7] On the contrary, hyperthermia also has many adverse effects on the developing brain, including changes in cerebral blood flow and release of neuroexcitotoxic products, such as glutamate and free radicals.[10] Both hypothermia and hyperthermia (>38°C) are associated with adverse outcomes and should be avoided. Maintaining thermal homeostasis using a target range of 36.5°C–37.5°C should be one of the most critical steps during fetal to neonatal transition, in addition to delayed cord clamping, and cardiorespiratory support.

The rate of normothermia in our NICU between 2007 and 2013 was 61%. We wanted to decrease hypothermia rate to <10% in ELBW infants. To achieve this goal, our perinatal quality improvement (PQI) committee members initiated a thermoregulation bundle to target 90% normothermia rate in ELBW infants. We report the results from this multidisciplinary, continuous, and ongoing PQI initiative from our center.

METHODS

PQI bundle for prevention of hypothermia (SQUIRE 2.0)

We established a thermoregulation bundle consisting of the following elements: (1) perinatal quality improvement (QI) study; (2) staff education, including nurses in labor and delivery and NICU, obstetricians, neonatologists, neonatal nurse practitioners (NNPs) and team members (composed of NICU nurse, respiratory care practitioner and neonatologist/NNP) attending the deliveries; (3) dedicated DR/OR for all preterm deliveries of ≤32 weeks with DR/OR temperature set 24/7 at 74°F by the hospital engineering staff; (4) use of exothermic mattress; (5) preheated radiant warmer set at 100% for heat prior to delivery (Panda Warmer, GE Healthcare); (6) use servo-controlled mode after the neonate is placed on the warmer; (7) use of plastic wrap (Saran wrap, Dow Chemical, USA), head cap and warm towels; (8) axillary temperature recorded every 5 min in the DR/OR as a sixth Apgar score and prior to leaving the DR/OR; (9) stabilize temperature in the normothermia range (36.5°C–37.5°C) prior to transport to NICU if baby is stable; (10) transport from DR/OR to NICU in a servo-controlled unit with temperature probe placed on the neonate; (11) keep the admitting bed in the NICU warm; (12) record the first temperature within 15 min of admission to the NICU; (13) continue recording temperature every 15 min until reaching temperature between 36.5°C and 37.5°C; (14) document the DR/OR temperature, baby's temperature prior to leaving DR/OR, and the first temperature in the NICU in the admission history and physical record; (15) no umbilical vessel catheterization in the DR/OR except for resuscitation; (16) no surfactant administration in the DR/OR; and (17) share the results in graphical format to all perinatal staff and review the results at our monthly PQI meetings. No infants were excluded after admission to the NICU, including those who died in the NICU.

This study was conducted in a 28-bed level III non-academic NICU with average deliveries of 4000 neonates per year. DRs/ORs are located on the same floor, and it takes about 5 min to transport a baby from the DR/OR to the NICU. Neonatologists provided 24/7 coverage in the NICU. Our center has no pediatric or neonatal trainees rotating in the NICU.

RESULTS

During the period between January 1, 2014 and December 31, 2019, 24,685 newborn infants were delivered in our center. A total of 200 ELBW infants (0.81%) were admitted to our NICU. Demographic data and short-term outcomes are shown in table 1. Nine out of the 200 (4.5%) ELBW infants were <500 g; 24/200 (12%) were <24 weeks gestational age; and 4/200 (2%) infants received epinephrine in the DR/OR. All infants delivered during this study period were included, except for babies who died in the DR/OR. Smallest baby admitted during this study period was born at 26 weeks gestational age, weighing 270 g with an admission temperature of 36.8°C.

We achieved normothermia in 182/200 (91%) of ELBW infants (figure 1). Five out of 200 (2.5%) ELBW infants were hypothermic, and 13/200 (6.5%) infants were hyperthermic (figure 2) on admission to NICU. However, hyperthermia rate in the last 2 years was only 2% (4/55). Ninety-seven out of 200 (48.5%) infants were intubated in the DR/OR and 83/97 (85.6%) were normothermic; 4 (4.1%) were hypothermic; and 10 (10.3%) infants were hyperthermic. Of the four infants who received epinephrine and/or chest compressions in the DR/OR, one baby was hypothermic and one baby was hyperthermic. In all infants, temperature returned to normal within 1 hour of admission to NICU. Maximum rate of hyperthermia (15.7%) was observed in the year 2017. The highest temperature recorded in this group was 38.8°C in one of the infants.

Table 1 Demographics and short-term outcomes of the study population

	ELBW (<1000 g) (n=200)
Birth weight (g)	767±148 (270-990)
Gestational age (weeks)	26.0±1.9 (23–33.4)
Race, W/H/B/A %	22/52/18/8
Cesarean delivery, n (%)	154 (76%)
Male, n (%)	106 (53%)
1 min Apgar, median	5
5 min Apgar, median	8
Intubated in the DR/OR	97 (49)
Admission temperature in the NICU (°C)	37.0±0.40 (range 36.0–38.6) (Median 37.0)
IVH	
No IVH	71%
IVH grades 1–2	10.5%
IVH grades 3–4	14.5%
Bronchopulmonary dysplasia	53%
Death before discharge	15%

Data are mean±SD, unless otherwise specified.
A, Asian; B, black; BW, birth weight; DR, delivery room; ELBW, extremely low birthweight; H, Hispanic; IVH, intraventricular hemorrhage; NICU, neonatal intensive care unit; OR, operating room; W, white.

Review of placental pathology (by Drs Bhatt and Ruiz) in these cases of hyperthermia revealed histological chorioamnionitis in 4/13 (31%) were ELBW infants. Eight of the mothers underwent spinal anesthesia; one mother underwent epidural anesthesia; one mother had general anesthesia; and three mothers had no anesthesia during delivery. Only one mother had a temperature of >37°5C at delivery and also had histological chorioamnionitis. She underwent spinal anesthesia. None of the infants with hyperthermia had positive blood cultures, and there were no deaths in this group. Overall mortality among the ELBW infants was 15% (29/200) during the study period. DR/OR temperature was recorded in 75% (150/200) of the deliveries.

DISCUSSION

We were able to achieve our goal of <10% hypothermia rate after implementing our thermoregulation bundle. Among the 454,617 VLBW infants admitted to 1112 Vermont Oxford Network centers from 2009 to 2016 who survived at least 12 hours after admission, rates of admission temperatures<36.5°C decreased from 52.6% to 38.2%. Rates of moderate to severe hypothermia (<36°C) decreased from 26.2% in 2009 to 14.8% in 2016 (E

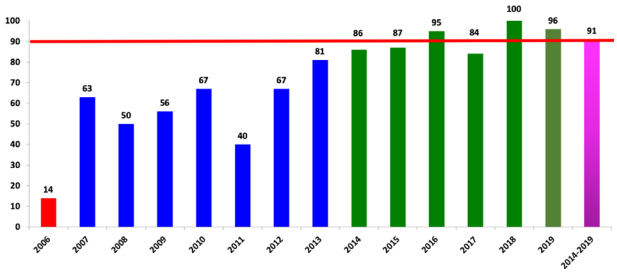

Figure 1 Per cent normothermia (36.5°C–37.5°C) in extremely low birthweight infants by year.

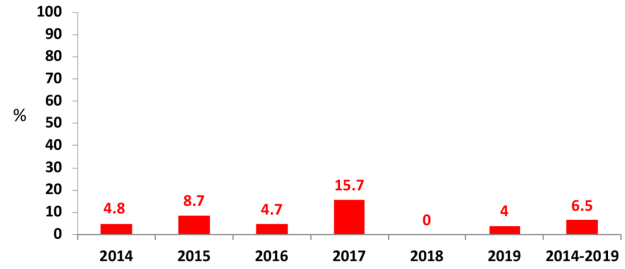

Figure 2 Per cent hyperthermia (>37.5°C) in extremely low birthweight infants by year.

Edwards, personal communication 2020). These rates are unacceptably high. Adverse outcomes are directly related to the degree of hypothermia. In a retrospective study of 9833 inborn infants <33 weeks' gestational age at birth, the lowest rate of the composite adverse outcome defined as mortality or any of the following: severe neurological injury, severe retinopathy of prematurity, necrotizing enterocolitis, bronchopulmonary dysplasia, or nosocomial infection from 29 NICUs in the Canadian Neonatal Network was associated with admission temperatures between 36.5°C and 37.2°C.[11] There is no consistent definition for normothermia, hypothermia or hyperthermia in the immediate neonatal period. WHO in 1997 recommended maintaining temperature between 36.5°C and 37.5°C for thermal protection of newborn.[7] However, different temperature ranges have been used to define normothermia, hypothermia and hyperthermia (table 2).[7–9 11–30] Authors from 16 studies used temperature of ≤36.5°C to define hypothermia; five reports used ≤36°C and 7 reports did not include any temperature criteria to define hypothermia (table 2). For hyperthermia, 10 studies used >37.5°C; 3 studies used >38°C; 2 studies from Canada used >37.2°C; and 18 reports had no criteria to define hyperthermia. In a prospective cohort study including 1764 inborn preterm neonates born between 22 and 33 weeks admitted to nine university-based level III NICUs in Brazil, they reported an extremely high rate of hypothermia (44% in the DR and 51% on admission to NICU).[31] After adjusting for confounding variables, practices associated with hypothermia in the DR were DR temperature of <25°C (OR 2.13, 95% CI 1.67 to 2.28) and maternal temperature at delivery of <36°C (OR 1.93, 95% CI 1.49 to 2.51), and hypothermia in the DR or in the NICU was associated with increased neonatal mortality (OR 1.64, 95% CI 1.03 to 2.61).[31] Interestingly, in this study,[31] exothermic mattress was not used. In our study, we were able to decrease hypothermia rates significantly with the use of exothermic mattress and having DR/OR temperature set at 23°C.

In spite of standardized guidelines for neonatal resuscitation, 40%–65% of preterm infants are hypothermic at delivery, and hypothermia remains an independent risk factor for mortality in this population.[32] Use of warm, humidified gases during resuscitation is also associated with lower hypothermia rates.[27 33] We did not use warm, humidified gas in our DR/OR. We also did not record maternal temperature during delivery. Since maternal temperature will impact newborns' temperature, it is important to document maternal temperature to minimize the risk of hypothermia and hyperthermia in newborns. In a QI report

Table 2 Published guidelines for hypothermia, normothermia and hyperthermia, target temperatures and DR/OR temperature

	Hypothermia	Normothermia	Hyperthermia	DR/OR temperature
WHO[7]	<36.5°C	36.5°–37.5°C	>37.5°C	25°C (77°F)
ASHRAE (USA)[8]				
DR (cesarean)	NG	NG	NG	68.0°–75°F/20°–24°C
LDRP				70°–75°F/21°–24°C
NRP[12]	NG	NG	NG	NG
NRP[13]	NG	~36.5°C	NG	25°–26°C (77.0°–79.8°F)
NRP[9]	<36.5°C	36.5°–37.5°C	NG	23°–25°C (74°–77°F)
Guidelines for Perinatal Care (USA)[14]	NG	36.5°C	NG	26°C (78.8°F) All Infants
Guidelines for Perinatal Care (USA)[15]	<36.5°C	36.5°–37.4°C	NG	72°–78° (22°–26°C) Preterm <32 weeks
Bhatt *et al*[16]				
≤26 weeks GA or ≤750 g	<36.5°C	36.5°–37.5°C	NG	76°F or more, target 78°–80°F
27–28 weeks or ≤1000 g	<36.5°C	36.5°–37.5°C	NG	76°F or more, target 78°–80°F
Meyer and Bold (New Zealand)[17]	<36.5°C	36.5°–37.5°C	>37.5°C	25°C (77°F)
Harer *et al* (USA)[18]	<36.5°C	36.5–37.5°C	>37.5°C	>22.8^0 C (>73°F)
Kent and Williams (Australia)[19]	–	–	–	26°–28°C (78.8°F-82.4°F)
Pinheiro *et al* (New York)[20]	<36.5°C	36.5°–38°C	38.0°C	17°–21°C OR 21°–23°C DR
Jia *et al* (China)[21]	–	–	–	24°–26°C (75.2°–78.8°F)
Belsches *et al*[22]	<36.5°C	36.5°–38.0°C	>38.0°C	–
Lee *et al* (USA)[23]	<36.5°C	36.5°–37.5°C	>37.5°C	NG
Pinheiro *et al* (USA)[24]	<36.0°C	36.0°–38.0°C	>38.0°C	NG
Russo *et al* (USA)[25]	<36°C	36.0°–37.5°C	>37.5°C	71°–74°F (21°–23°C)
Wyckoff (USA)[26]	–	–	–	77°F (25°C)
Lyu *et al* (Canada)[11]	<36.5°C	<36.5°–37.2°C	>37.2°C	NG
Meyer *et al* (New Zealand and Netherland)[27]	<36.5°C	36.5°–37.5°C	>37.5°C	25°–26°C (77.0°–7.8°F)
Von 2018 (personal communication)				
Mild	36.0°–36.5°C	36.5°–37.5°C	>37.5°C	NG
Moderate to severe	<36.0 C			
Laptook *et al* (USA)[28]	<36.5°C	36.5°–37.5°C	>37.5°C	NG
Ting *et al* (Canada)[29]	<36.5°C	36.5°–37.2°C	≥37.2°C	NG
Bhatt *et al* (USA) (current study)	<36.5°C	36.5°–37.5°C	>37.5°C	74°F (23.3°C)
Peleg *et al* (Israel)[30]	<36.0°C	NG	NG	23°C (73.4°F) OR 25°–27°C (77.0°–80.6°F) DR

ASHRAE, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc; DR, delivery room; LDRP, labor, delivery, recovery and postpartum; NG, no guideline; NRP, Neonatal Resuscitation Program; OR, operating room.

by Russo *et al*,[25] anesthesiologists were asked to closely monitor maternal temperature with a goal to maintain it at ~36.5°C; however, compliance with this element in their bundle was not consistent. Maternal temperature was not recorded in our study. Sites for temperature measurements and the temperature range for different sites are also not evidence based. Majority of the studies used axillary site with very few centers using rectal temperature. Rates of normothermia will vary, depending on the site for measuring the temperature. Furthermore, there are no studies using temporal artery thermometers in newborns. There is a need to compare different sites for measuring temperature in the DR/OR. Strengths of our study include prospectively collected data, establishment of a PQI team, including obstetricians, nurses from obstetrics and neonatal units, use of a thermoregulation bundle; prospective, uniform methods for data collection; monthly review of the data; and reinforcement of the bundle approach based on normothermia rates achieved each month. The limitation includes lack of data on long-term outcomes. Given the association between hypothermia and adverse outcomes, maintaining normothermia in the DR/OR and in the NICU should be made a top priority.

CONCLUSIONS

We were able to achieve our goal of <10% hypothermia rate in our ELBW infants for the last two consecutive years. We had no cases of moderate hypothermia over the last 6-year study period. Minimization of hyperthermia is also critical. Perinatal multidisciplinary QI team and continued review for compliance of all the elements in the bundle are critical to achieve sustained rates of normothermia. There is also an urgent need to have a consensus on what should be considered as normothermia among ELBW infants around the time of birth.

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Contributors DRB and NR conceptualized and designed the study, drafted the initial manuscript, reviewed and revised the manuscript. RRu reviewed all of the maternal data, including the placental pathology of infants with hyperthermia; played a major role in implementing this quality improvement project as an obstetrician; and reviewed and revised the manuscript. DVB represented neonatal intensive care unit nurses, TP represented labor and delivery nurses, and SW, a key member of the resuscitation team, and were members of the quality improvement initiative for this study. They played a major role in the implementation of the plan–do–study–act cycle for this quality improvement project, and reviewed and approved the manuscript. R-AD had full access to all of the data and takes responsibility for the integrity of the data and the accuracy of the data analysis, and reviewed and revised the manuscript. DXB provided some of the demographic data and critically reviewed the manuscript for important intellectual content and approved the final version. RRa participated in the design of the study, drafted the initial manuscript, critically reviewed the manuscript for important intellectual content and revised the manuscript. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. See above marked item.

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