

ORIGINAL RESEARCH & CONTRIBUTIONS

Elimination of Admission Hypothermia in Preterm Very Low-Birth-Weight Infants by Standardization of Delivery Room Management

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Abstract

Context: Temperature instability is a serious but potentially preventable morbidity in preterm infants. Admission temperatures below 36°C are associated with increased mortality and late onset sepsis.

Objective: The goal of our quality-improvement effort was to increase preterm infants' admission temperatures to above 36°C by preventing heat loss in the immediate postnatal period.

Design: This quality-improvement initiative used the rapid-cycle Plan-Do-Study-Act approach. Preterm infants born at less than 33 weeks' gestation with very low birth weight less than 1500 g who were born at a Regional Level III Neonatal Intensive Care Unit (NICU) in San Jose, CA, were enrolled. Our intervention involved standardizing the management of thermoregulation from predelivery through admission to the NICU. Data on admission temperature were collected prospectively.

Main Outcome Measures: The primary outcome measure was hypothermia, defined as temperature below 36°C on admission to the NICU.

Results: The hypothermia rate was reduced from 44% in early 2006 to 0% by 2009. There was a slight increase to 6% in 2010. Subsequently, with further real-time feedback, we were able to sustain 0% hypothermia through 2011. Our hypothermia rate remained substantially lower than state and national hypothermia benchmarks that have shown moderate improvement over the same period.

Conclusion: We reduced hypothermia in very low-birth-weight infants using a standardized protocol, multidisciplinary team approach, and continuous feedback. Sustaining improvement is a challenge that requires real-time progress evaluation of outcomes and ongoing staff education.

Introduction

Hypothermia is a serious but potentially preventable morbidity in preterm infants. Studies have shown that for each 1°C decrease in admission temperature below 36°C, there is an increase in mortality by 28% and in late-onset sepsis by 11%.¹ Hypothermia also is associated with hypoglycemia, respiratory distress, and metabolic acidosis. The incidence of hypothermia is between 31% and 78% for those with birth weight less than 1500 g.² Infants

at less than 28 weeks' gestation have the highest incidence of hypothermia. The skin temperature of an exposed preterm infant will drop at a rate of approximately 0.5°C to 1.0°C per minute.³ Both physical characteristics and environmental factors predispose the preterm infant to hypothermia.

The physical characteristics include a large surface area-to-volume ratio, immature skin with minimal stratum corneum, a thin layer of insulating fat, poor vasomotor control, and lack of nonshivering thermogenesis. The environmental factors include low ambient air temperature in delivery rooms and neonatal intensive care unit (NICU) admission rooms, and low surface temperature of beds used at admittance and during resuscitation. Delivery rooms are usually kept cool for the comfort of the mothers and the staff, but the cool air causes the preterm infants to lose heat through conduction and convection. Because of these factors, preterm newborns are unable to maintain equilibrium between heat gain and loss and are dependent on their caregivers to provide that balance.

In 1997, the World Health Organization (WHO)⁴ provided the following definition of hypothermia of newborns:

- Potential cold stress: 36.0°C to 36.5°C; cause for concern
- Moderate hypothermia: 32.0°C to 36.0°C; danger, immediate warming of the baby needed
- Severe hypothermia: less than 32.0°C; outlook grave, skilled care urgently needed.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers⁵ and WHO recommend that the temperature in all standard single-patient rooms (labor and delivery, recovery, and postpartum) be 24°C to 25°C and that the nursery be 24°C to 25.6°C. The recommendations further state that delivery room temperatures should never be below 20°C.

In 2006, after identification of a high rate of hypothermia in infants with very low birth weight (VLBW), we initiated a quality-improvement (QI) effort to prevent hypothermia in preterm infants admitted to our NICU. Our primary goal was to prevent hypothermia in newborn VLBW infants by preventing excessive heat loss in the delivery room. Our target admission temperature was an axillary skin temperature between 36°C and 37°C. We achieved this goal by standardizing delivery room management and NICU admission processes for all VLBW infants.

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Methods

Problem Identification

Santa Clara Valley Medical Center is a county hospital in San Jose, CA, with a 40-bed Regional Level III NICU that admits 50 to 75 VLBW infants annually, 80% of whom are inborn.

In December 2005, a preterm infant born at 24 weeks' gestation with a birth weight of 715 g was admitted to our NICU with a temperature of 33.2°C. Despite maximal interventions to correct the hypothermia, the temperature did not increase to above 36°C until after 16 hours of life. At that time, all VLBW infant deliveries were attended by a multidisciplinary team composed of a physician, a registered nurse, and a respiratory therapist. Immediate postdelivery thermal management included placing the infant on a prewarmed resuscitation bed, drying skin surfaces, placing a hat, and wrapping the infant in a warm blanket. Frequently the infant was left exposed for assessment during the initial resuscitation.

We gathered baseline data for the next 6 months (January 2006 to June 2006) and recognized that the rate of hypothermia was 68% in VLBW (1000 to 1500 g) infants and was even higher—at 84%—in extremely low-birth-weight (< 1000 g) infants. Root cause analysis of the cases of hypothermia identified multiple issues, including the following:

- A lack of close monitoring of the infant's temperature after the initial assessment
- A thermoregulation policy that did not address the special considerations for preterm infants
- A knowledge gap regarding the neonatal neutral thermal environment among staff
- No standard for the effective use of thermal equipment (eg, combination incubator-warmer [Giraffe OmniBed, Ohmeda Medical, now GE Healthcare, Chalfont St Giles, UK], chemical warming mattress, isolette, resuscitation bed)
- Limited staff training in the use of special thermal equipment (only 6 selected registered nurses, called "Super Users," were trained in the use of the Giraffe OmniBed)
- Ambient air temperatures in the delivery room and admission room were adjusted for staff comfort and were frequently less than 20°C.

Study Participants

All preterm neonates who were born at our Medical Center between January 2006 and December 2011 at less than 33 weeks of gestation with a birth weight under 1500 g were the target population for this QI effort and received standardized delivery room and NICU admission management. We obtained institutional review board approval for data collection and publication of the results of our QI effort.

Planning

We formed a multidisciplinary Thermoregulation Committee consisting of nurses, physicians, and nurse practitioners to research, develop, and implement new guidelines for the management of thermoregulation. Our thermoregulation guidelines were based on a review of the medical literature,⁶ best practice recommendations from the California Perinatal Quality Care Collaborative (CPQCC),⁷ evidence-based principles from the

Neonatal Resuscitation Program,⁸ and recommendations from WHO for ambient air temperatures in the delivery room.⁴ We implemented a QI initiative using the rapid-cycle Plan-Do-Study-Act approach (PDSA) improvement model.

After the guidelines were developed, Thermoregulation Committee team members were responsible for staff education regarding thermoregulation and the new treatment guidelines, and for ensuring multidisciplinary team compliance with the guidelines. The timeline of the planning and implementation is shown in Figure 1.

Intervention

The thermoregulation guidelines involved the use of multiple modalities divided into three phases: predelivery preparation, resuscitation, and NICU admission. Key equipment and supplies used throughout included a prewarmed resuscitation bed (a servo-controlled radiant warmer), polyethylene occlusive wrap, chemically activated warming mattress (Figure 2), warming lights (used in the initial phase of implementation), newborn hat, warm blankets, and an axillary thermometer.

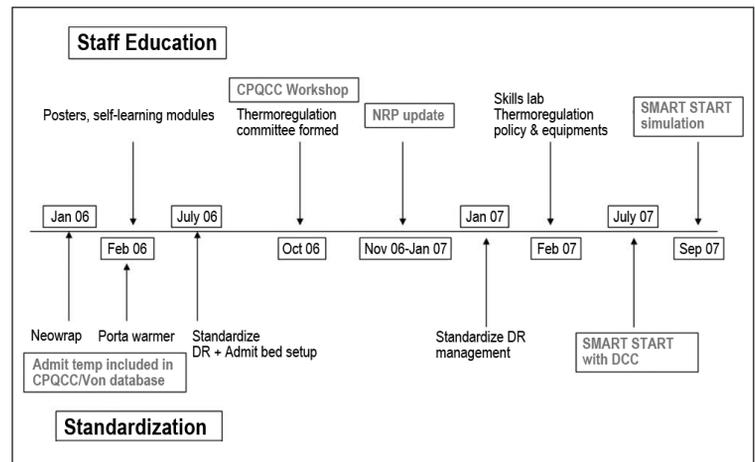


Figure 1. Implementation timeline.

Admit = admission; CPQCC = California Perinatal Quality Care Collaborative; DCC = delayed umbilical cord clamping; DR = delivery room; Neowrap = polyethylene occlusive wrap (NeoWrap, Fisher & Paykel Healthcare, Irvine, CA); NRP = Neonatal Resuscitation Program; Porta warmer = chemical warming mattress (Cardinal Health, McGaw Park, IL); Von = Vermont Oxford Network.

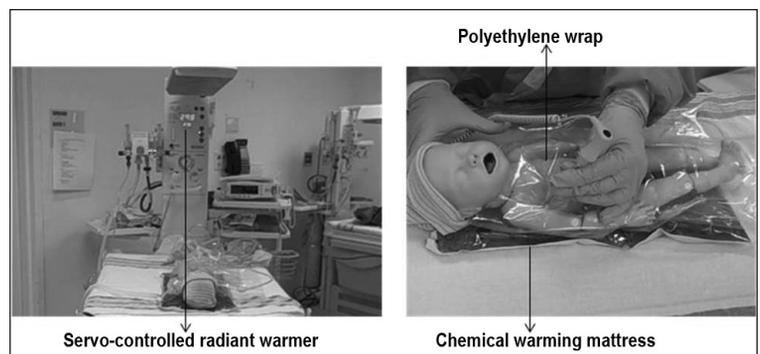


Figure 2. Thermal equipment used for resuscitation.

The predelivery preparation included the following:

- Set the resuscitation bed on manual control set at maximum heat output
- Increase ambient temperature in the delivery room to 25°C or higher
- Turn on the warming lights
- Activate the chemical warming mattress according to the manufacturer's instructions
- Place polyethylene occlusive wrap over the warming mattress.

A scripted, standardized, multidisciplinary approach to resuscitation, called the Smart Start protocol, was implemented for delivery room management in 2007 (Table 1 available online at www.thepermanentejournal.org/files/Summer2013/hypothermia.pdf). This included delayed umbilical cord clamping as an intervention to prevent intraventricular hemorrhage.⁹ After delivery, the infant was handed to the pediatric clinician who held the baby in a sterile warm blanket with the chemical warming mattress underneath to prevent hypothermia. The infant was held approximately 25 to 40 cm (10 to 15 in) below the level of introitus for vaginal deliveries and below the level of the incision for cesarean delivery. The pediatric staff counted the time after delivery out loud, and the obstetrician clamped and cut the cord after 30 to 60 seconds.

Smart Start included specific, predefined tasks and responsibilities for all staff members. One registered nurse was assigned to temperature management, which involved the following tasks at each time point.

Birth:

- Without drying, immediately wrap the infant with polyethylene wrap
- Place the infant on the chemical warmer mattress
- Dry the infant's head and place a hat on the head
- Assess the infant through the polyethylene wrap
- Take and record the infant's axillary temperature every 5 minutes during resuscitation
- Attach the servo-control temperature probe with insulating cover.

Before and at NICU admission:

- Increase the ambient air temperature in the admission room to 23°C to 25°C before admission
- Prewarm the admission bed (Giraffe OmniBed) to 36.5°C and water-circulating heating pad to 40°C
- Prewarm all surfaces with which the infant will come into contact
- Take the infant's axillary temperature with the polyethylene wrap on and before moving the infant to the admission bed
- Leave the polyethylene wrap on until the temperature is 36.5°C or higher
- Dry the infant with a warm blanket after the polyethylene wrap is removed.

A nursing champion initiated the QI effort to prevent hypothermia in 2006. While developing the thermoregulation guideline, she provided education to increase staff awareness of neonatal hypothermia by:

- Displaying a "thermoregulation" poster board with mechanisms of heat loss and the prevention of hypothermia in newborn infants
- Introducing, displaying, and demonstrating the effective use of the chemical warmer and polyethylene wrap for immediate postdelivery thermal management of all extremely low-birth-weight infants
- Introducing a one-hour self-study module on neonatal thermal physiology and the complications and prevention of hypothermia and hyperthermia.

Interested nursing staff on the Thermoregulation Committee were responsible for presenting a two-and-a-half-hour mandatory training on thermoregulation for all staff who attend deliveries. In addition, another two hours of thermoregulation education was provided as part of resuscitation simulation training for the delivery room.

Data Collection and Analysis

We developed a prospective data collection form for all VLBW deliveries. Data collected included the following: date and time of birth, birth weight, gestation, specific thermal equipment used (eg, chemical mattress, polyethylene wrap), axillary temperature taken in the delivery room and on admission to the NICU; ambient air temperatures in the delivery room/operating room and admission room, and surface temperatures of the resuscitation and admission beds.

We evaluated the success of implementation of the standardized care using process measures, including use of polyethylene wrap and a chemical warming mattress in the delivery room, serial temperature measurements in the delivery room, and temperature measurement on admission to the NICU. The primary outcome was prevention of hypothermia, defined as an axillary temperature below 36°C on admission to the NICU. We evaluated hyperthermia (> 37.5°C) on admission as a balancing measure to capture any inadvertent adverse effect result from our intervention. We also evaluated, as a secondary outcome during this period, survival without serious morbidity including necrotizing enterocolitis, chronic lung disease, nosocomial infection, severe intraventricular hemorrhage, and severe retinopathy of prematurity.

We monitored the percentage of preterm VLBW infants with hypothermia and hyperthermia every year from 2006 to 2011. We submitted data on preterm infants who had a birth weight

Measure	2006	2007	2008	2009	2010	2011
Number of infants	59	58	48	38	47	39
Gestational age, weeks, mean (SD)	27.7 (2.4)	28.3 (2.2)	27.4 (2.5)	27.5 (2.4)	28.2 (2.6)	28.4 (2.6)
Birth weight, g, mean (SD)	1040 (291)	1127 (235)	1040 (308)	1066 (283)	1095 (291)	1025 (277)
Percentage born by cesarean delivery	73	69	69	50	83	72
Percentage given antenatal steroid	86	95	96	97	96	100

SD = standard deviation.

ranging from 401 to 1500 g, and were at 22 0/7 to 29 6/7 weeks of gestation, to the CPQCC, which is a state collaborative that focuses on benchmarking and facilitating QI work throughout California. We compared the primary and secondary outcomes in VLBW infants less than 33 weeks of gestation born in our unit with outcomes at similar California Children’s Services-level NICUs in the CPQCC. The purpose was to benchmark our outcomes after risk adjustment for gestational age, small for gestational age, congenital anomalies, 5-minute Apgar, multiple gestations, male sex, maternal race, and no prenatal care. Figures 3 and 4 were obtained from the CPQCC report Web site with permission.¹⁰

Results

Demographics

The mean gestational age was 28 weeks (standard deviation (SD) = 2.4 weeks), and mean birth weight was 1075 g (SD = 280 g) in our overall study population. Of these, 69% were delivered by cesarean and 95% were exposed to antenatal steroids. Table 2 describes the gestational age, birth weight, and percentage of newborns who received antenatal steroids and who were delivered by cesarean in our VLBW population each year from 2006 to 2011.

Process, Outcome, and Balancing Measures

The process measures were used in 100% of the preterm births, indicating that we were successful in implementing standardized delivery room care for preterm infants (Table 3). We achieved 0% hypothermia within 2 years after implementation of the Smart Start protocol in 2007. We had 2 cases of admission temperatures of 35.6°C and 35.8°C, which led to a 6% hypothermia rate in 2010. We noticed an inadvertent increase in hyperthermia as the admission temperatures improved. This balancing measure was addressed in real time, with a change in the thermoregulation guidelines to remove the polyethylene wrap once the temperature was above 36.5°C.

For primary outcome, the overall percentage of hypothermia in VLBW infants was reduced from 44% in early 2006 to 0% by 2009. There was a slight increase to 6% in 2010, but the rate returned to 0% in 2011. Figure 3 shows the yearly risk-adjusted trend of hypothermia for our unit, and Figure 4 shows the 3-year aggregate (2009 to 2011) risk-adjusted inborn hypothermia rate in our unit compared with the hypothermia rate in same-level regional NICUs that participate in the CPQCC. The 3-year aggregate percentage of hypothermia for our center was substantially lower than the average inborn hypothermia rate for regional NICUs (1.5% vs 15.6%).

Figure 5 shows the yearly risk-adjusted trend of survival without serious morbidities (secondary outcome) for our unit, and Figure 6 shows 3-year aggregate (2009 to 2011) risk-adjusted rate in all regional NICUs in CPQCC.

Discussion

We succeeded in preventing hypothermia in VLBW infants using standardized delivery room care, including a portable chemical warmer, polyethylene wrap, and a dedicated staff to

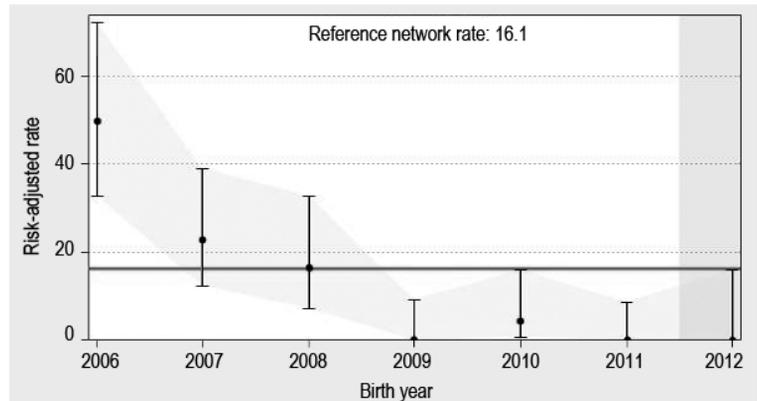


Figure 3. Risk-adjusted hypothermia rates for inborn infants at our center, trend chart, 2006 to 2012.^a

^a Dots represent our unit risk-adjusted rate of hypothermia and the lines with the error bars show the 95% confidence limits for the risk-adjusted rate. The horizontal reference line is the California Perinatal Quality Care Collaborative (CPQCC) hypothermia rate. Risk adjustment model included gestational age, small for gestational age, congenital anomalies, 5-minute Apgar score, multiple gestations, male sex, maternal race, and no prenatal care. Data for 2012 shown in gray zone are ongoing and incomplete.

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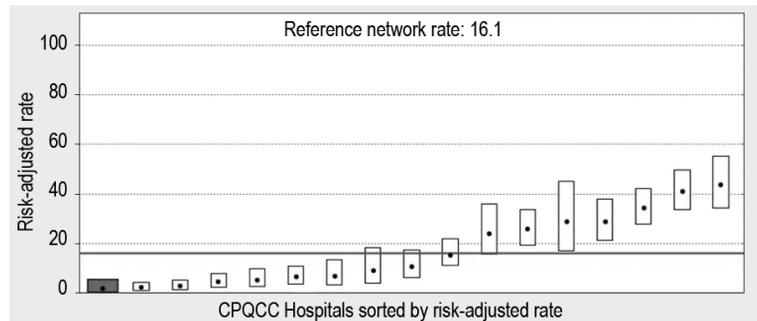


Figure 4. Risk-adjusted hypothermia rates for inborn infants at our center compared with other regional NICUs in California, 2009 to 2011.^a

^a Each bar represents a regional center NICU participating in CPQCC. Dots represent the 3-year (2009 to 2011) aggregate risk-adjusted rate of hypothermia, and the bars extend up to the 95% confidence limits for the risk-adjusted rate for each center. Our center is the solid bar. The horizontal reference line is the average rate of hypothermia for all regional NICUs in CPQCC.

CPQCC = California Perinatal Quality Care Collaborative; NICU = neonatal intensive care unit.

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Table 3. Process, Outcome, and Balancing Measures, 2006 to 2011						
Measure	2006	2007	2008	2009	2010	2011
Process						
Utilization of thermal equipment in delivery room, %	84	95	100	100	100	100
Outcome						
Hypothermia (< 36°C), %	45	23	16	0	6	0
Balancing						
Hyperthermia (> 37.5°C), %	2	3	8	6	2	0

monitor temperature every 5 minutes in the delivery room. Even before eliminating hypothermia, we noted a major improvement in the admission temperatures, with elimination of extremes of low temperature below 35.5°C within a year of initiating this QI project. Subsequently, we were able to eliminate the use of warming lights in the delivery room because we had better servo-controlled radiant warmers for resuscitation and we began maintaining the ambient temperature above 25°C. We had an increase in the percentage of infants with axillary temperature in the hyperthermic range (> 37.5°C) as our admission temperatures were improving. This was addressed by a slight modification in the protocol of reducing the set servo-control temperature on the resuscitation bed from 37.5°C to 37°C and removing the

polyethylene wrap after the admission temperature reached 36.5°C. Because we followed the temperatures prospectively, we were able to address the hyperthermia before it became a major problem. Real-time feedback to the staff, including case reviews and monitoring the real-time hypothermia trend in monthly QI meetings, reinforced staff awareness and adherence to the thermoregulation protocol.

Prospective data collection, feedback to individual clinicians, and a review of the percentage of hypothermia cases monthly along with state and national benchmarks have been key to the overall sustainability of this QI effort. This requires strong nursing support for staff education, data collection, real-time feedback to clinicians by the “temperature police,” and both nursing and medical leadership support to provide the time for the staff.

One of the potential confounding factors of this study is the simultaneous implementation of our “Standardized Scripted Approach to Delivery Room Resuscitation of Preterm Infants—Smart Start.” This approach was implemented after two days of simulation-based training. The thermoregulation protocol was one of the aspects that were included in this training. Interventions such as delayed cord clamping and multidisciplinary team readiness for resuscitation of all high-risk deliveries, also part of the Smart Start protocol, may have had a protective effect in the thermoregulation and positively confounded the effect on admission temperatures.

We monitored survival without serious morbidities as a secondary outcome because hypothermia has been shown to be associated with late-onset sepsis, intraventricular hemorrhage, and death.^{1,11} Concomitant with the near elimination of hypothermia was a trend toward improved survival without severe morbidity. It is reassuring that not only did our intervention prevent hypothermia but it also potentially had a positive impact on the overall outcome of the premature infants. However, this impact on survival without serious morbidities could have been confounded by our multiple other QI efforts that were ongoing in our unit, such as the central line infection prevention collaborative, intraventricular hemorrhage prevention bundle, comprehensive bundled care of all VLBW infants including early parenteral nutrition immediately after birth, and a major focus on breast milk nutrition.

We were able to implement a bundled approach to prevent hypothermia in preterm infants despite varying levels of experience among those responding to deliveries (eg, pediatric house staff, hospitalists, neonatal nurse practitioners, and neonatologists). All centers with high-risk deliveries are required to have a resuscitation team ready and available at all times. After implementation of this QI effort at our center, we were able to replicate the approach at an affiliate hospital with a community-level NICU (data not presented).

The addition of our thermoregulation intervention to the delivery room management of preterm births was a successful strategy at our institution and may have improved overall outcomes. We can potentially eliminate hypothermia in VLBW infants by standardizing their care with evidence-based interventions. Optimizing thermoregulation of the preterm neonate requires consistent use of multiple kinds of thermal equipment

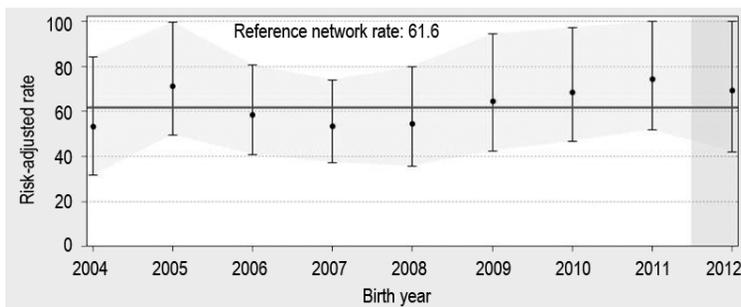


Figure 5. Risk-adjusted survival rates without serious morbidity for inborn infants at our center, trend chart, 2004 to 2012.^a

^a Dots represent our unit risk-adjusted rate of survival without serious morbidity, and the lines with the error bars show the 95% confidence limits for the risk-adjusted rate. The horizontal reference line is the average rate of survival without serious morbidity in the California Perinatal Quality Care Collaborative (CPQCC). Risk adjustment model included gestational age, small for gestational age, congenital anomalies, 5-minute Apgar score, multiple gestations, male sex, maternal race, and no prenatal care. Data for 2012 shown in gray zone are ongoing and incomplete.

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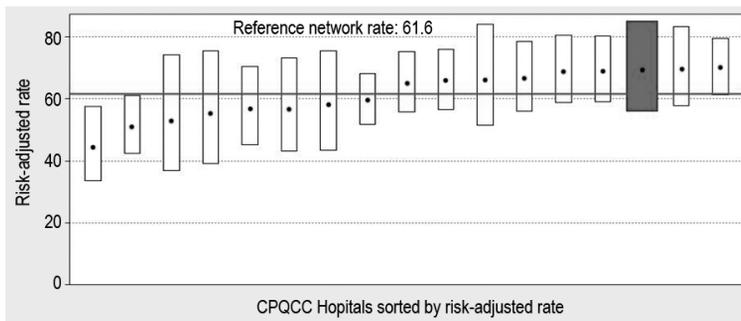


Figure 6. Risk-adjusted survival rates without serious morbidity for inborn infants at our center compared with other regional NICUs in California, 2009 to 2011.^a

^a Each bar represents a regional center NICU participating in CPQCC. Dots represent the 3-year (2009 to 2011) aggregate risk-adjusted rate of survival without severe intraventricular hemorrhage, severe retinopathy of prematurity, chronic lung disease, necrotizing enterocolitis, or nosocomial infection, and the bars extend up to the 95% confidence limits for the risk-adjusted rate for each center. Our center is the solid bar. The horizontal reference line is the average rate of survival without serious morbidity for all regional NICUs in CPQCC.

CPQCC = California Perinatal Quality Care Collaborative; NICU = neonatal intensive care unit.

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and close monitoring of temperature. This requires extensive staff education and real-time feedback to individual caregivers to enforce adherence to the thermoregulation guidelines. Finally, the rapid-cycle PDSA model for improvement was critical to implementing this QI effort. ❖

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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Inalienable Right

That each newborn has the right to be born wanted, loved, and protected; and while growing to maturity within and without the womb that every measure possible, as is known, be undertaken to afford the very best environment, nutrition, and opportunity for growth and development.

— *The Children's Bill of Rights*, Billy F Andrews, MD