

# Reducing Hypothermia in Preterm Infants Following Delivery

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## KEY WORDS

hypothermia, temperature, newborn, quality improvement

## ABBREVIATIONS

BW—birth weight  
CPAP—continuous positive airway pressure  
DR—delivery room  
GA—gestational age  
L&D—labor and delivery  
OR—operating room  
QI—quality improvement  
RDS—respiratory distress syndrome  
VLBW—very low birth weight

Dr Russo helped develop the practice plan and the algorithms, helped collect and oversee the data, and was involved in writing the manuscript; Ms McCready and Ms Venturini helped develop the practice plan and the algorithms and were involved in writing the manuscript; Ms Torres helped develop the practice plan and the algorithms, facilitated temperature regulation of the operating room and implementation of the practice plan in labor and delivery, and was involved in writing the manuscript; Ms Theuriere helped develop the practice plan and the algorithms and in review of the data and was involved in writing the manuscript; Dr Spaight helped in the data collection and was involved in writing the manuscript; Ms Hemway helped develop the practice plan and collect data and was involved in writing the manuscript; Ms Handrinos helped develop the practice plan; Ms Perlmutter and Drs Huynh and Grunebaum helped develop the practice plan and were involved in writing the manuscript; Dr Perlman was involved in developing and implementing the practice plan, conceptualized and designed the study, contributed to design of the analyses and interpretation of the results, and took the lead in drafting the initial and subsequent versions of the manuscript; and all authors approved the final version of the manuscript.

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## abstract

**BACKGROUND:** Moderate hypothermia (temperature  $<36^{\circ}\text{C}$ ) at birth is common in premature infants and is associated with increased mortality and morbidity.

**METHODS:** A multidisciplinary practice plan was implemented to determine in premature infants  $<35$  weeks old whether a multifaceted approach would reduce the number of inborn infants with an admitting axillary temperature  $<36^{\circ}\text{C}$  by 20% without increasing exposure to a temperature  $>37.5^{\circ}\text{C}$ . The plan included use of occlusive wrap a transwarmer mattress and cap for all infants and maintaining an operating room temperature between  $21^{\circ}\text{C}$  and  $23^{\circ}\text{C}$ . Data were obtained at baseline ( $n = 66$ ), during phasing in ( $n = 102$ ), and at full implementation ( $n = 193$ ).

**RESULTS:** Infant axillary temperature in the delivery room (DR) increased from  $36.1^{\circ}\text{C} \pm 0.6^{\circ}\text{C}$  to  $36.2^{\circ}\text{C} \pm 0.6^{\circ}\text{C}$  to  $36.6^{\circ}\text{C} \pm 0.6^{\circ}\text{C}$  ( $P < .001$ ), and admitting temperature increased from  $36.0^{\circ}\text{C} \pm 0.8^{\circ}\text{C}$  to  $36.3^{\circ}\text{C} \pm 0.6^{\circ}\text{C}$  to  $36.7^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$  at baseline, phasing in, and full implementation, respectively ( $P < .001$ ). The number of infants with temperature  $<36^{\circ}\text{C}$  decreased from 55% to 6.2% at baseline versus full implementation ( $P < .001$ ), and intubation at 24 hours decreased from 39% to 17.6% ( $P = .005$ ). There was no increase in the number of infants with a temperature  $>37.5^{\circ}\text{C}$  over time. The use of occlusive wrap, mattress, and cap increased from 33% to 88% at baseline versus full implementation. Control charts showed significant improvement in DR ambient temperature at baseline versus full implementation.

**CONCLUSIONS:** The practice plan was associated with a significant increase in DR and admitting axillary infant temperatures and a corresponding decrease in the number of infants with moderate hypothermia. There was an associated reduction in intubation at 24 hours. These positive findings reflect increased compliance with the practice plan. *Pediatrics* 2014;133:e1055–e1062

Moderate hypothermia (temperature  $<36^{\circ}\text{C}$ ) after delivery is common, particularly in very low birth weight (VLBW) infants, and is associated with increased mortality and morbidity, including respiratory distress syndrome (RDS), metabolic derangements, and intraventricular hemorrhage.<sup>1–10</sup> The immature infant is at high risk of net heat loss because of a high surface area to volume ratio and increased evaporative fluid losses from the skin.<sup>11</sup> Strategies introduced to minimize heat loss include occlusive wrapping, exothermic warming mattresses, warmed humidified resuscitation gases, polyethylene caps, and higher delivery room (DR) temperatures.<sup>12–26</sup> Despite these interventions, hypothermia still occurs in a substantial number (10%–35%) of infants.<sup>18,24,26</sup> Additionally, hyperthermia (temperature  $>37.5^{\circ}\text{C}$ ) is also more common and presumed to be related to the more aggressive rewarming efforts.<sup>19,20,25</sup>

During an audit of initial temperatures of infants admitted to our NICU, hypothermia was noted in ~55% of all infants  $<35$  weeks' gestational age (GA). More specifically, this was noted in 35% of infants  $\leq 28$  weeks' GA, 44% of infants between 29 and 32 weeks' GA, and 79% of infants between 33 and 34 weeks' GA. This surprisingly high occurrence in the larger premature infant suggested that at a minimum the practice of occlusive wrap, exothermic mattress, and double cap, which was standard for infants  $\leq 28$  weeks, should be extended to these infants. In a secondary analysis of DR factors that were associated with subsequent neonatal morbidity, an admitting temperature  $<36^{\circ}\text{C}$  was associated with more early respiratory distress.

These cumulative observations led us to embark on a quality improvement (QI) initiative with the following objectives. The first was to determine whether

a multifaceted approach, initiated before delivery and continued through admission to the NICU, would reduce the number of infants with an axillary temperature  $<36^{\circ}\text{C}$  by 50% without increasing the number of infants with a temperature  $>37.5^{\circ}\text{C}$ . The second was to determine whether maintaining temperatures in a goal range of  $36.5^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$  would be associated with less severe respiratory distress within the first 24 hours.

## METHODS

The Model for Improvement approach was used as the framework for reducing the number of preterm infants  $<35$  weeks' GA admitted with moderate hypothermia (axillary temperature  $<36^{\circ}\text{C}$ ) from the DR to the NICU at New York Presbyterian Hospital–Weill Cornell Medical College.<sup>27</sup> A multidisciplinary team involving medical and nursing staff from neonatology, obstetrics, and anesthesiology and members of the bioengineering department was assembled to devise and implement a QI practice plan. This initiative comprised 3 phases. The first was a baseline period (September through December 2011), the second was a phasing-in period (January through April 2012), and third was the implementation phase of the practice plan (May 2012 through February 2013). The Institutional Review Board of Weill Cornell Medical College approved by expedited review the QI and collection of data.

The multidisciplinary team met weekly over 4 months and developed the plan (Table 1). The goal was to maintain an infant axillary temperature at  $36.5^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$  from birth through admission to the NICU. An evidence-based literature review was undertaken that served as the basis for the plan. It was agreed that there were 2 essential components. First, a combined use of occlusive wrap without drying of the infant, a warming mattress (TransWarmer Mattress Model

# 20421; CooperSurgical, Trumbull, CT), prewarmed double caps, and a radiant warmer on 100% power, which was standard for all premature infants  $\leq 28$  weeks, was extended to all infants  $<35$  weeks' GA. The correct application of the transwarmer warming mattress was a particular focus during the in-services.<sup>28,29</sup> Second, operating room (OR) temperature was maintained between  $71^{\circ}\text{F}$  and  $74^{\circ}\text{F}$  ( $21$ – $23^{\circ}\text{C}$ ) (this range was consistent with hospital policy for the general ORs and acceptable to the obstetrical staff) but below the  $78.8^{\circ}\text{F}$  or  $26^{\circ}\text{C}$  suggested by the International Liaison Committee of Resuscitation and the World Health Organization.<sup>30,31</sup> For monitoring purposes, bioengineering sent weekly reports of all OR ( $n = 4$ ) and DR ( $n = 12$ ) temperatures to the labor and delivery (L&D) head nurse (L.T.) and NICU medical director (J.P.). Temperature control was transferred to the charge nurse in L&D at the time of full implementation to effect tighter regulation.

The following elements were considered desirable but not essential:

- Anesthesiology was asked to closely monitor maternal temperature, with a goal to maintain it at  $\sim 36.5^{\circ}\text{C}$ .
- Infant temperatures were to be obtained  $\sim 5$  to 10 minutes after birth to adjust for rapidly changing body temperatures after delivery.
- An infant was to be weighed only if the initial temperature was  $>36^{\circ}\text{C}$ .
- Transport to the NICU would be according to standard practice, that is, in a preheated infant transporter (set between  $37^{\circ}\text{C}$  and  $37.2^{\circ}\text{C}$ ) or under a transport radiant warmer (for infants  $\leq 25$  weeks old) in a servo control mode. The transport time from the DR to the NICU is  $\sim 5$  minutes.

An admitting axillary temperature was obtained within 15 minutes of arrival and repeat measurements every 15

**TABLE 1** Outline of the Practice Plan at Baseline, During Phasing In, and at Full Implementation

Baseline (4 mo)	Implementation Phase II (4 mo)	Implementation (10 mo)
September 2011–December 2011	January 2012–April 2012	May 2012–February 2013
All infants $\leq 28$ wk managed with occlusive wrap, exothermic mattress, and cap	Maintain OR temperature 21–23°C All infants $< 35$ wk managed with occlusive wrap, exothermic mattress, and cap Maternal temperature $\pm 36.5^\circ\text{C}$ Delayed weighing for temperature $< 36^\circ\text{C}$ Infants $\leq 25$ wk transported on radiant warmer Development of algorithms In-services of obstetrics and neonatal staff	Weekly review meetings $\times 3$ mo Monthly review meetings $\times 7$ mo  Progress report to staff $\times 3$ mo

minutes for the first hour for temperatures of  $36.5^\circ\text{C} \pm 0.5^\circ\text{C}$  and longer for temperatures  $< 36^\circ\text{C}$  or  $> 37^\circ\text{C}$ . There was no specific protocol targeting the rate of rewarming or for decreasing the axillary temperature into the desired range.

An algorithm for infants  $< 35$  weeks old was generated delineating the steps to be followed after delivery (Fig 1). This served as a guide for nursing and physician education and was posted in all DRs and ORs before implementation. Over a 3-month period the components of the plan were introduced, followed by in-services given to all staff mem-

bers including physicians and nurses on both day and night shifts. Implementation was evaluated over the next 10 months. Monthly meetings were conducted reviewing progress, and 3 monthly reports were made available to all staff. All cases of an axillary temperature  $< 36^\circ\text{C}$  were reviewed weekly and for an initial admitting temperature  $< 35.5^\circ\text{C}$  within 24 hours.

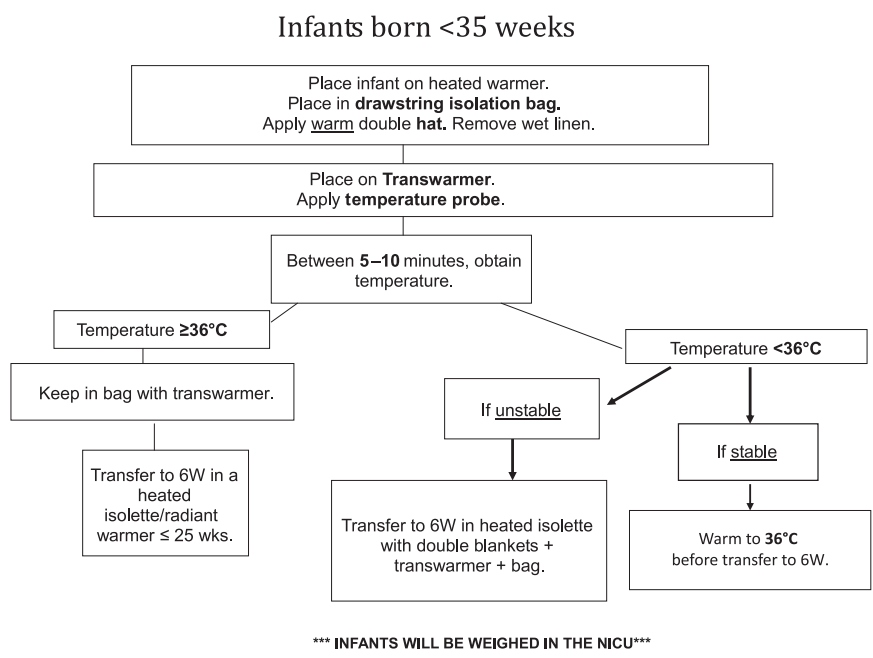
**Data Retrieval**

The following data were retrieved at baseline and through evolution of the initiative: birth weight (BW); GA; infant temperature; maternal temperature;

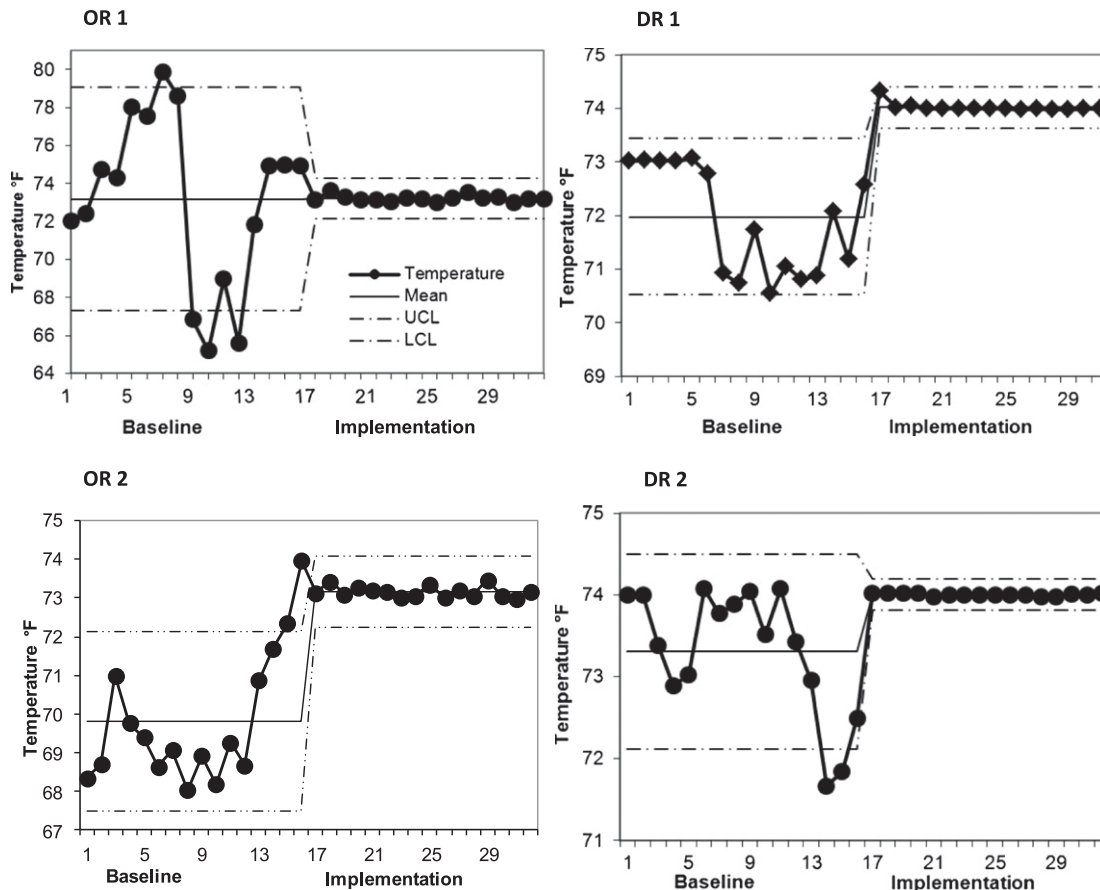
DR temperature; initial infant axillary temperature in the DR and on admission to the NICU; all temperatures for the first 2 hours; mode of delivery; interventions to stabilize or resuscitate an infant, such as use of continuous positive airway pressure (CPAP), intubation, or application of chest compressions or medications; Apgar scores at 1 and 5 minutes; and respiratory requirements on admission and at 24 hours.

**Data Analysis**

A power analysis based on preliminary observations that assumed a 50% incidence of admitting temperature  $< 36^\circ\text{C}$  indicated that 70 infants before and 150 at full implementation would be needed to show a 30% incidence or a 20% reduction in moderate hypothermia with 80% power at a significance level of 5%. Subgroup analysis was undertaken for infants  $\leq 28$  weeks old, 29 to 32 weeks old, and 33 to 34 weeks old. Temperature measurements were analyzed for 2 weeks (336 hours) from 2 ORs and 2 DRs at baseline and at full implementation, and control charts were created (Fig 2). Analysis was performed by using SPSS (IBM SPSS Statistics, IBM Corporation) and included descriptive statistics,  $\chi^2$  analysis for dichotomous data,  $t$  tests for continuous data, and analysis of variance for multiple comparisons with Bonferroni correction. Changes in OR temperature over time were evaluated with statistical process charts.<sup>32</sup> All



**FIGURE 1** Algorithm outlining the steps to be taken after the delivery of a premature infant  $< 35$  weeks.



**FIGURE 2**

Statistical process control charts of 2 ORs and 2 DRs. Baseline represents 2 weeks of measurements, and full implementation also indicates 2 weeks of temperature measurements. Each point represents 21 individual hourly temperature measurements. Note the large swings in temperature out of the control range during the baseline period in each OR and DR. Note the increase in mean temperature and the decrease in variability at full implementation in each room. LCL, lower control limit; UCL, upper control limit.

data are presented as mean  $\pm$  SD unless otherwise stated.

## RESULTS

### General Characteristics

The initiative included 361 consecutive inborn infants <35 weeks' GA: 66 at baseline, 102 during phasing in, and 193 at full implementation. For the cohort, GA was lower at baseline than at phasing in and full implementation,  $31 \pm 2.8$ ,  $32.5 \pm 2.0$ , and  $32 \pm 2$  weeks, respectively ( $P = .001$ ), as was BW,  $1496 \pm 483$  g,  $1745 \pm 486$ , and  $1763 \pm 485$  g, respectively ( $P < .001$ ). However, by subgroup categories, for infants  $\leq 28$  weeks old and 33 to 34 weeks old, there was no difference in BW across the 3 periods; for infants 29 to 32 weeks old

there was a significant difference in BW across the 3 periods (Table 2).

### Infant Axillary DR and Admitting Temperatures

The axillary temperature of infants in the DR increased from  $36.1^\circ\text{C} \pm 0.6^\circ\text{C}$  to

$36.2^\circ\text{C} \pm 0.6^\circ\text{C}$  to  $36.6^\circ\text{C} \pm 0.6^\circ\text{C}$  ( $P < .001$ ) from baseline through full implementation (Table 3).

The admitting axillary temperature for the cohort increased from  $36.0^\circ\text{C} \pm 0.8^\circ\text{C}$  to  $36.3^\circ\text{C} \pm 0.6^\circ\text{C}$  to  $36.7^\circ\text{C} \pm 0.5^\circ\text{C}$  at baseline through full implementation

**TABLE 2** GA and BW for Infants  $\leq 28$ , 29–32, and 33–34 Weeks at Baseline, During Phasing In, and at Full Implementation

	Baseline	Partial Implementation	Full Implementation
$\leq 28$ wk	$n = 17$	$n = 9$	$n = 19$
GA, wk	$27 \pm 1.2$	$26.6 \pm 1.6$	$26.5 \pm 1.6$
BW, g	$921 \pm 212$	$878 \pm 165$	$931 \pm 253$
29–32 wk	$n = 25$	$n = 27$	$n = 81$
GA, wk	$31.3 \pm 0.8$	$31.2 \pm 1.1$	$31.5 \pm 1$
BW, g	$1465 \pm 306^*$	$1538 \pm 416^{**}$	$1676 \pm 331$
33–34 wk	$n = 24$	$n = 72$	$n = 92$
GA, wk	$33.8 \pm 0.5$	$33.9 \pm 0.5$	$33.8 \pm 0.6$
BW, g	$1936 \pm 288$	$1940 \pm 355$	$2030 \pm 402$

\* Baseline versus full implementation,  $P = .002$ .

\*\* Phasing in versus full implementation,  $P = .04$ .

( $P < .001$ ) (Table 2). This was reflected in a decrease in the number of infants with a temperature  $<36^{\circ}\text{C}$  at baseline versus full implementation from 36/66 (55%) to 12/193 (6%), relative risk 0.18 (95% confidence interval, 0.10–0.34) ( $P < .001$ ) (Table 3). By subgroup analysis, for infants  $\leq 28$  weeks' GA, the initial axillary temperature increased from  $36.2^{\circ}\text{C} \pm 1.4^{\circ}\text{C}$  to  $36.7^{\circ}\text{C} \pm 0.7^{\circ}\text{C}$  at baseline versus phasing in ( $P = .23$ ) and to  $36.7^{\circ}\text{C} \pm 0.6^{\circ}\text{C}$  at full implementation ( $P = .13$ ); for infants 29 to 32 weeks old, the temperature increased from  $36^{\circ}\text{C} \pm 0.7^{\circ}\text{C}$  to  $36.4^{\circ}\text{C} \pm 0.7^{\circ}\text{C}$  to  $36.8 \pm 0.5^{\circ}\text{C}$  from baseline through full implementation ( $P < .001$ ); and for infants 33 to 34 weeks old from  $35.7^{\circ}\text{C} \pm 0.4^{\circ}\text{C}$  to  $36.2^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$  to  $36.6^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$  from baseline through full implementation ( $P < .001$ ). The number of infants  $<28$  weeks old with a temperature  $<36^{\circ}\text{C}$  decreased from 6/17 (35%) to 2/19 (10.5%) at baseline versus full implementation ( $P = .11$ ), for infants 29 to 32 weeks old from 11/25 (44%) to 1/81 (1%) ( $P < .001$ ), and for infants 33 to 34 weeks old from 19/24 (79%) to 9/92 (9.7%) ( $P < .001$ ).

The number of infants with an initial temperature  $>37^{\circ}\text{C}$  increased from 7.5% to 23% at baseline versus full implementation ( $P < .001$ ). A temperature  $>37.5^{\circ}\text{C}$  was comparable at baseline versus phasing in and full implementation, 6% versus 3.9% versus 5.6%, respectively (Table 3).

### Duration of Time of Temperature out of the Desired Range

The time for a temperature  $<36^{\circ}\text{C}$  to return to goal range decreased from

$51 \pm 44$  to  $30 \pm 20$  minutes ( $P = .03$ ) and for temperature  $>37^{\circ}\text{C}$  from  $98 \pm 86$  to  $10 \pm 12$  minutes at baseline through full implementation, respectively ( $P < .001$ ).

### DR Events

An Apgar score  $<5$  was noted in 10 infants (2.7%), and chest compressions were administered to 2 (0.5%) infants. Overall, the number of infants intubated or those administered CPAP did not differ significantly except for CPAP between phasing in and full implementation (Table 4).

### Respiratory Status at 24 Hours

The number of infants who remained intubated at 24 hours decreased at baseline versus full implementation from 26/66 (39%) to 34/193 (17.6%) (relative risk 0.53 [95% confidence interval, 0.33–0.83]) ( $P = .005$ ) (Table 4). By subgroup analysis the number of intubated infants  $\leq 28$  weeks decreased from 15/17 (88%) to 10/19 (53%) ( $P = .03$ ), for infants 29 to 32 weeks from 6/25 (24%) to 15/81 (18%) ( $P = .57$ ), and for infants 33 to 34 weeks from 5/24 (21%) to 7/92 (7.6%) ( $P = .12$ ).

The number of infants treated with CPAP increased from 13/66 (20%) to 77 (39.8%) at baseline versus full implementation ( $P < .001$ ). Overall there was no significant difference in infants needing any form of respiratory support at baseline versus full implementation, 39/66 (59%) vs 111/193 (57.4%) ( $P = .82$ ).

### Compliance With the Practice Plan

The control charts for 2 ORs and 2 DRs demonstrate excellent compliance with the temperature goals of the practice plan initiative (Fig 2). The use of occlusive wrap, exothermic mattresses, and caps for infants  $<28$  weeks old was 100% at baseline, during phasing in, and at full implementation; the corresponding numbers for infants 29 to 32 weeks were 0%, 30%, and 95% ( $P < .001$ ) and for infants 33 to 34 weeks, 0%, 20%, and 88% ( $P < .001$ ), respectively (Table 5).

The number of infants with a temperature measurement obtained in the DR increased from 42% at baseline to 55% during phasing in and 68% at full implementation ( $P < .001$ ). More specifically, for infants  $<28$  weeks old, DR measurements were obtained in 29%, 55%, and 42% at baseline, during phasing in, and at full implementation, respectively; for infants 29 to 32 weeks old, in 44%, 52%, and 79%, and for infants 33 to 34 weeks old, in 54%, 58%, and 84%, respectively (Table 5).

Maternal temperatures were obtained in 0%, 15%, and 8% at baseline, during phasing in, and at full implementation, respectively.

### DISCUSSION

This multidisciplinary QI initiative with implementation of a practice plan targeted at avoiding moderate hypothermia after delivery was associated with a significant increase in the DR and admitting axillary temperatures of inborn

**TABLE 3** DR and Initial Temperature, Number of Infants of BW  $<35$  Weeks' GA With Initial Temperature  $<36^{\circ}\text{C}$  or  $37.5^{\circ}\text{C}$  at Baseline, During Phasing In, and at Full Implementation

Temperature	Initial Temperature, $^{\circ}\text{C}$		
	$<35$ wk Baseline, $n = 66$	Partial Implementation, $n = 102$	Implementation, $n = 193$
DR temperature, $^{\circ}\text{C}$	$36.1 \pm 0.6$	$36.2 \pm 0.6$	$36.6 \pm 0.6^*$
NICU temperature, $^{\circ}\text{C}$	$36.0 \pm 0.8$	$36.3 \pm 0.6$	$36.7 \pm 0.5^*$
No. of infants with temperature $<36^{\circ}\text{C}$	36/66 (55%)	24/102 (23%)	12/193 (6%)*
No. of infants with temperature $>37.5^{\circ}\text{C}$	4/66 (6.0%)	4/102 (3.9%)	11/193 (5.6%)

\*  $P < .001$  (differences between the 3 phases of implementation).



**TABLE 4** Need for Intubation or CPAP in the DR and Intubation at 24 h in the NICU at Baseline, During Phasing In, and at Full Implementation

Characteristic	Baseline, n = 66	Partial Implementation, n = 102	Full Implementation, n = 193
DR			
Intubation	15 (23%)	13 (13%)	31 (16%)
CPAP	19 (29%)	26 (25%)	71 (37%)*
NICU			
Intubated at 24 h	26 (39%)	12 (11.7%)**	34 (17.6%***)

\* Partial versus full implementation,  $P = .03$ .\*\* Baseline versus phasing in,  $P = .002$ .\*\*\* Baseline versus full implementation,  $P = .005$ .**TABLE 5** Compliance With the Practice Plan at Baseline, During Phasing In, and at Full Implementation

		Baseline, %	Phasing In, %	Implementation, %
Occlusive wrap, exothermic mattress, cap	≤28 wk	100	100	100
	29–32 wk	0	30	95
	33–34 wk	0	20	88
	Overall	33	50	94*
DR temperature measurement of the infant	≤28 wk	29	55	42
	29–32 wk	44	52	79
	33–34 wk	54	58	84
	Overall	42	55	68*

\*  $P < .001$  (difference between baseline, phasing in, and full implementation).

infants admitted to the NICU. The greatest impact of the initiative was in the larger premature infants, between 29 to 35 weeks old, which probably reflects the introduction of occlusive wrap and exothermic wrap in this subpopulation. Accordingly, there was a concomitant significant reduction in the number of infants admitted with moderate hypothermia, with the most striking decrease again observed in the larger premature infant. Importantly, the initiative was not associated with an increase in the number of infants with a temperature  $>37.5^{\circ}\text{C}$ . In addition, the time spent out of the desired range decreased by a mean of 20 minutes for infants with moderate hypothermia and by  $>60$  minutes for infants with an elevated temperature, a novel observation. There was a shift in respiratory support needed at 24 hours at full implementation, with a lesser requirement for intubation and a corresponding increase in the number on CPAP, a finding that was significant only for infants  $\leq 28$  weeks.

Overall there was excellent compliance with the essential components of the practice plan (occlusive wrap, exothermic mattress, and OR temperature control), with reasonable adherence of the desired elements. A particular success of the plan was the ability to increase the OR temperature with a significant decrease in variability, as indicated in the control charts (Fig 2). Although the range of OR temperature ( $71\text{--}74^{\circ}\text{F}$ ) was lower than that recommended by the International Liaison Committee of Resuscitation and the World Health Organization,<sup>30,31</sup> it reflected a compromise with the obstetric staff, who were initially resistant to this change. Getting buy-in from bioengineering and transferring temperature control to the L&D staff were essential to achieving this goal.

Regarding the desired elements, compliance with the practice plan was not consistent. Notably, there was an inability to consistently obtain maternal temperatures. We attribute this shortcoming

to frequent resident rotations coupled with infrequent attendance at in-services by the anesthesiology staff. An unanticipated finding was poor compliance in obtaining an infant temperature in the DR in the smallest infants. We attribute this finding to multiple immediate interventions needed in these infants after delivery to facilitate a smooth postnatal transition, including temperature management control and intense focus on limiting excessive oxygen exposure.<sup>33</sup>

Investigators have evaluated different interventions, predominantly in VLBW infants  $<1500$  g or a GA  $<30$  weeks, to prevent heat loss, including using occlusive wrap, exothermic mattresses, warm caps, polyethylene caps, or heated humidified air or raising the OR temperature either singularly or in combination, with varied success.<sup>10–26</sup> Because of baseline data demonstrating frequent hypothermia in the larger premature infant, the combination approach of wrap, exothermic mattress, and cap was extended to all infants  $<35$  weeks old. Indeed, the greatest impact of the QI was noted in these infants. Importantly, the overall incidence of moderate hypothermia was reduced from 55% at baseline to  $\sim 6\%$  at full implementation. More specifically, in infants 29 to 32 weeks old, the incidence of moderate hypothermia decreased from 44% to 1%, and for infants 33 to 34 weeks old it decreased from 79% to 9.7%.

In several previous studies, an untoward consequence of a combination approach was a significant number of infants admitted with an elevated temperature  $>37.5^{\circ}\text{C}$ .<sup>17,24</sup> This is a concern because an elevated temperature has been associated with greater neonatal mortality and morbidity.<sup>34</sup> Moreover, experimental observations point to an association of elevated temperature and subsequent pneumothorax and interstitial air in ventilated preterm newborn lambs.<sup>35</sup> In this report, a small

number of the infants had an elevated temperature  $>37.5^{\circ}\text{C}$  at full implementation, which was not different from baseline. We attribute this positive finding in part to targeting a lower OR temperature.

An important and unanticipated success of the practice plan was a reduction in the duration of time spent outside the goal temperature range of  $36.5^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ . This was particularly striking for infants with a temperature  $>37^{\circ}\text{C}$ , where this time was reduced by  $>60$  minutes, but was also significant for those with moderate hypothermia.

The major reason for avoiding moderate hypothermia stems from long-standing cohort studies indicating an association between a low temperature at birth and increased mortality and morbidity.<sup>1–10</sup> Specifically, Lupton et al<sup>3</sup> showed that for every degree decrease in temperature below  $36.5^{\circ}\text{C}$ , mortality increased by 28%. Regarding morbidity, observational studies have reported an association between hypothermia at birth and surfactant unresponsiveness in infants with RDS, subsequent intraventricular hemorrhage, and late-onset sepsis.<sup>3,5,7,9,10</sup> This raises the distinct possibility that hypothermia, depending on the degree or the duration,

may have negative effects on pulmonary function. Indeed, one observational study showed hypothermia as a precursor to failure to respond to surfactant in infants with RDS.<sup>5</sup> Consistent with this hypothesis, after implementation of the practice plan, there was a shift in the intensity of respiratory support at 24 hours, with a reduction in the number of infants intubated coupled with a corresponding increase in those on CPAP. Importantly, the respiratory management of VLBW infants in the DR and in the NICU has remained unchanged for several years. A recent workshop report sponsored by the National Institute of Child Health and Development reported temperature instability including hypothermia in 10% of infants at 35 to 36 weeks and suggested a link between temperature instability and subsequent respiratory distress.<sup>36</sup> This association parallels the findings in this report.

This study has several limitations. First, a before-and-after design consistent with a practice plan approach precludes making any direct inference between improved temperatures and the positive respiratory outcomes in this report. Second, we used a temperature range of  $36^{\circ}\text{C}$  to  $37^{\circ}\text{C}$  as our target goal, a range that includes the category of mild hypothermia as

defined by the World Health Organization. We consider this range more physiologic and consistent with that applied to the daily temperature management range of neonates in the NICU.

## CONCLUSIONS

We have demonstrated that moderate hypothermia after delivery can be minimized without a concomitant increase in an elevated temperature with a multifaceted team approach. The essential elements for success of this QI initiative included use of the occlusive wrap, exothermic mattresses, and warmed caps for all infants  $<35$  weeks old and maintaining the OR temperature around  $72^{\circ}\text{F}$ . Maintaining infant temperature in the desired range of  $36^{\circ}\text{C}$  to  $37^{\circ}\text{C}$  was associated with less intensive respiratory support at 24 hours.

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## Reducing Hypothermia in Preterm Infants Following Delivery

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