

Quality-Improvement Effort to Reduce Hypothermia Among High-Risk Infants on a Mother-Infant Unit

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BACKGROUND AND OBJECTIVE: Neonatal hypothermia is common in low birth weight (LBW) (<2500 g) and late-preterm infants (LPIs) (34 0/7–36 6/7 weeks' gestation). It can be a contributory factor for newborn admission to a NICU, resulting in maternal-infant separation and increased resource use. Our objective was to study the efficacy of a quality-improvement bundle of hypothermia preventive measures for LPIs and/or LBW infants in a mother-infant unit.

METHODS: We conducted plan-do-study-act (PDSA) cycles aimed at decreasing environmental hypothermia for LPIs and/or LBW infants in a mother-infant unit with no other indications for NICU-level care. Interventions included using warm towels after delivery, a risk identification card, an occlusive hat, delayed timing of first bath, submersion instead of sponge-bathing, and conducting all assessments under a radiant warmer during the initial hours of life. We implemented these interventions in 3 PDSA cycles and followed hypothermia rates by using statistical process control methods.

RESULTS: The baseline mean monthly hypothermia rate among mother-infant unit LPIs and/or LBW infants was 29.8%. Postintervention, the rate fell to 13.3% (−16.5%; $P = .002$). This decrease occurred in a stepwise fashion in conjunction with the PDSA cycles. In the final, full-intervention period, the rate was 10.0% (−19.8%; $P = .0003$). A special-cause signal shift was observed in this final period.

CONCLUSIONS: Targeted interventions can significantly reduce hypothermia in otherwise healthy LPIs and/or LBW newborns and allow them to safely remain in a mother-infant unit. If applied broadly, such preventive practices could decrease preventable hypothermia in high-risk populations.

Newborn hypothermia is associated with an increased risk of neonatal hypoglycemia, respiratory distress, sepsis, metabolic acidosis, and death.^{1–9} The prevalence of neonatal hypothermia, defined as a rectal temperature <36.0°C,¹⁰ is increased in low birth weight (LBW) (<2500 g) and late-preterm infants (LPIs) (34–36 6/7 weeks' gestation) because of decreased intrinsic thermoregulation and higher

surface area-to-body mass ratios.¹¹ Interventions that reduce neonatal hypothermia include immediate drying, head caps, early skin-to-skin placement, occlusive plastic wraps, and immersion tub-bathing.^{2,10–13} Combining these thermoregulation strategies is most effective because together they target all the mechanisms of heat loss: radiation, evaporation, conduction, and convection.^{9,11,14,15}

abstract

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To date, studies of newborn hypothermia have been restricted to the NICU population, omitting the much larger population of LPIs and higher weight categories of LBW newborns, many of whom are cared for in mother-infant units rather than NICUs. At our institution, mother-infant unit LPIs include infants between 35 and 36 6/7 weeks' gestation, whereas mother-infant unit LBW infants include those between 1750 and 2500 g. Because mother-infant units have more variable environments than NICUs and generally do not use extrinsic heat sources, such as radiant warmers and isolettes, interventions that enhance newborn thermoregulation may be even more effective in these settings. Additionally, neonatal hypothermia in a mother-infant unit requires active management, including the use of equipment, testing, and staffing needs that can result in transfers to the NICU. Precluding hypothermia in this higher-risk population in a mother-infant unit could ease provider workload and prevent unnecessary and costly escalation of care.

We noted a hypothermia rate of 29.1% for mother-infant unit LPIs and/or LBW newborns and 9.5% for all newborns in our mother-infant unit at an academic, tertiary-care hospital with an adjacent level 3 regional NICU. Hypothermia correction was consuming significant nursing and physician time and effort leading to laboratory testing and potential NICU transfers. Our hypothesis was that most newborn hypothermia was due to improvable environmental factors and was therefore preventable. The aim of this quality-improvement (QI) project was to reduce the incidence of neonatal hypothermia in a mother-infant unit by implementing multiple thermoregulation strategies with a particular project focus on mother-infant unit LPIs and/or LBW infants.

TABLE 1 Outline of the PDSA Bundles Implemented in the Mother-Infant Unit

PDSA 1	PDSA 2	PDSA 3
July 2015	August 2015	December 2015
Population: All Newborns	Population: LPIs and LBW Newborns	Population: All Newborns
Immediately towel dry after birth	High-risk crib card ID Occlusive hat Delay bath >12 h Assessments under radiant warmer	All baths delayed >12 h Submersion baths

ID, identification.

METHODS

Context

This QI project was implemented in the mother-infant unit at the Children's Hospital at Dartmouth-Hitchcock (CHaD), a 63-bed, Children's Hospital Association-accredited children's hospital within a 396-bed, tertiary-care center (Dartmouth-Hitchcock Medical Center) in Lebanon, New Hampshire. CHaD's mother-infant unit has ~1200 inborn deliveries annually and is composed of 22 Labor, Delivery, Recovery, and Postpartum (LDRP) beds and 19 bassinets with mother and infant residing in the same room. Otherwise-healthy infants remain in the mother-infant unit if they are ≥ 35 weeks' gestation and weigh ≥ 1750 g at birth. Per CHaD policy, infants who have a confirmed rectal temperature $< 36^{\circ}\text{C}$ should be transferred to the NICU.

Interventions

A small team of health care providers met bimonthly to identify areas of care improvement to prevent newborn hypothermia. The team consisted of a pediatric hospitalist, a nurse manager, the unit clinical nurse specialist, several mother-infant unit nurses (including charge nurses), and a medical student. These meetings resulted in the development of care practice standards that were implemented across 3 plan-do-study-act (PDSA) bundles and rolled out to physician and nursing staff by using the usual methods of communication (e-mails, posters, and staff meetings; Table 1). For each

of the PDSA bundles, an e-mail was sent out to all the providers working in the mother-infant unit, and the charge nurse played an active role in disseminating the new policies. Biweekly audits were done by a medical student and reported back to the hypothermia team to ensure that all the interventions were being implemented.

The first PDSA bundle occurred in July 2015 and involved thoroughly drying all infants immediately after birth with towels before mother-infant skin-to-skin contact. Before this, drying at birth was implemented with nonabsorbing, soft blankets.

The second PDSA bundle occurred in August 2015 and specifically targeted known mother-infant unit LPIs and LBW infants and consisted of the following:

- Use of a plastic-lined, knit hat;
- Delaying baths until at least 12 hours after birth;
- Conducting all provider assessments in the first 12 hours of life under a radiant warmer; and
- Identifying LPIs and/or LBW infants with a crib card containing a reminder to implement these practices.

Before this bundle, there were no specific thermoregulation protocols in place for mother-infant unit LPIs and/or LBW births. There was no standardization of hat use, the timing of baths, or the location of newborn physical assessments. Bathing occurred between 2 and 3 hours of life, and physical assessments often occurred in a standard bassinet. Of

note, bundle implementation differed slightly between mother-infant unit LPIs and LBW infants, with LPIs receiving crib cards and hats at birth and LBW infants only getting them after weighing (to establish their LBW status) at ~2 hours of life. The plastic-lined, thermal knit hats were provided by DandleLION Medical and consisted of a polyethylene occlusive liner encased by 2 layers of yarn.

The third PDSA bundle occurred in December 2015 and delayed baths for all newborns until at least 12 hours of life and standardized submersive bathing. Previously, baths were variably provided but mostly consisted of sponge-bathing under a radiant heat source that still predisposed infants to greater evaporative heat losses and hypothermia compared with submersion baths.¹²

Study of the Intervention

We analyzed all infants born at Dartmouth-Hitchcock Medical Center in Lebanon, New Hampshire, from July 2014 to August 2016 who remained within the mother-infant unit at the time of delivery. Infants who were excluded from the study were deceased infants, stillbirths, and infants who were transferred to the NICU within the first 24 hours of life for a reason other than hypothermia. All infants who were transferred with hypothermia concurrent with any other reason, such as hypoglycemia, sepsis, or hyperbilirubinemia, were not excluded. Birth data, including sex, gestational age, birth weight, birth date and/or time, and length of stay (LOS), were collected from the electronic medical record by automated report. Manual chart review was done to determine the reason for immediate NICU transfer (if applicable), each newborn's minimum and maximum recorded temperature in the first 24 hours of life, the time since birth of the minimum recorded temperature,

and the temperature measurement method (axillary or rectal).

Measures

Although the World Health Organization classifies hypothermia into 3 classes (mild [36.0–36.5°C], moderate [32.0–35.9°C], and severe [$<32.0^{\circ}\text{C}$]), our intervention targets newborns who became moderately or severely hypothermic.¹⁰ Our primary outcome was the monthly proportion of newborns who became hypothermic within the first 24 hours of life. We calculated this proportion by taking the monthly number of infants with a hypothermic event (as defined by a rectal temperature of $<36^{\circ}\text{C}$ in the first 24 hours of life) and dividing it by the monthly total number of infants born. The data were then analyzed in 2 subgroups: mother-infant unit LPIs and/or LBW births and all births, with mother-infant unit LPIs and/or LBW births defined as being between 35 and 36 6/7 weeks' gestation and/or having a birth weight between 1750 and 2500 g. Infants <35 weeks' gestation and those <1750 g are admitted directly to the NICU by hospital policy.

As a balancing measure, we also measured the proportion of mother-infant unit LPIs and/or LBW newborns who became hyperthermic within the first 24 hours of life. We calculated this proportion by taking the monthly number of infants with a hyperthermic event (as defined by a rectal temperature $>37.5^{\circ}\text{C}$ in the first 24 hours of life) and dividing it by the monthly total number of infants born.

Additionally, in an effort to determine if variations in the room temperature of our mother-infant unit might explain the occurrence of hypothermic events, measurements were made twice weekly in each room at the same time of day in the mother-infant unit with the same digital laser infrared thermometer. These results were subsequently

averaged and tracked over time from July 2015 to October 2015.

Analysis

We measured changes in monthly percentages of newborns with hypothermic events by both traditional and statistical process control (SPC) methods. With traditional statistics, we compared groups by using boxplots and *t* tests between the aggregated births in the pre- versus postintervention months, further subdivided into early phase (PDSA bundles 1 + 2) and full phase (after all 3 PDSA bundles were implemented) groups for both the mother-infant unit LPIs and/or LBW infants and all birth subgroups. By using SPC methods, we created p-charts to evaluate the monthly percentages of hypothermic events over time in the 27-month study period. We conducted separate evaluations for both the mother-infant unit LPIs and/or LBW infants and all births subsets. We analyzed the data, looking for special-cause signals to determine which interventions affected outcomes.

Traditional statistical measures and tests were performed by using the R programming language (R Foundation, Vienna, Austria) and included descriptive statistics, Fisher's exact tests for categorical data, *t* tests for continuous data, and the F test for analysis of variance. SPC (p-chart) analyses were conducted by using the QI Macros package implemented in Microsoft Excel 2011 software (KnowWare International Inc, Denver, CO). P-chart centerlines and control limits were recalculated at the start of our first PDSA bundle and when ≥ 7 subsequent data points were below the 1 side of the centerline average, representing a special-cause signal shift.¹⁶

Ethical Considerations

The Dartmouth College Committee for the Protection of Human Subjects

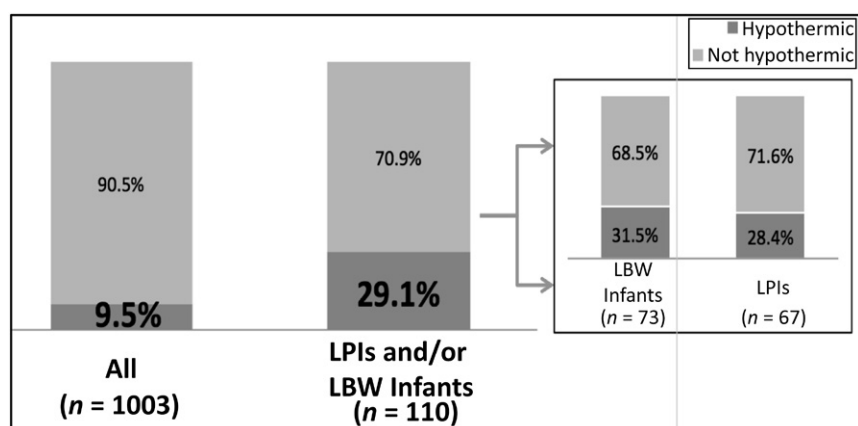


FIGURE 1

Proportion of births with a hypothermic event (rectal temperature $<36^{\circ}\text{C}$) for all births, LPIs, and/or LBW infants at baseline (9.5% vs 29.1%; $P < .001$; Fisher's exact test). The baseline proportion of hypothermia did not significantly differ between LBW infants and LPIs (31.5% vs 28.4%; $P = .684$; Fisher's exact test).

TABLE 2 Demographics Between Preintervention and Postintervention Cohorts

	Preintervention Births (n = 110)	Postintervention Births (n = 114)	P
Girls, %	42.2	53.3	.22
GA, d	257	256	.36
Birth wt, g	2493	2612	.06
LOS	3.2	3.3	.84

GA, gestational age.

determined the project to be exempt from review as QI.

RESULTS

From July 2014 to September 2016, there were 2570 eligible births of newborns admitted to the mother-infant unit. Of these, 2161 (84%) met inclusion criteria, including 1005 births in the preintervention period (before the first PDSA cycle) and 1156 in the postintervention period. Mother-infant unit LPIs and/or LBW infants numbered 215 (or 10% of the total cohort), including 110 births in the preintervention period and 105 births in the postintervention period.

In the preintervention months, the hypothermia rate was 3 times higher in mother-infant unit LPIs and/or LBW infants compared with all mother-infant unit births (Fig 1; 29.1% vs 9.5%; $P < .001$). No significant difference in the rate of hypothermia was found when

comparing mother-infant unit LPIs versus LBW births (Fig 1; 31.5% vs 28.4%; $P = .684$). Of the LPIs and/or LBW infants who had a hypothermic event at baseline, 12.5% were transferred to the NICU from the mother-infant unit. Within the cohort of LPIs and/or LBW infants, there were no demographic differences between the preintervention and postintervention cohorts for sex ($P = .22$), gestational age ($P = .36$), birth weight ($P = .06$), or LOS ($P = .84$; Table 2).

Postintervention, the average monthly hypothermia rate for the mother-infant unit cohort of LPIs and/or LBW infants was reduced from the preintervention rate of 29.8% to 13.3% ($P = .002$). Examining the decrease by dividing the postintervention period into an early phase (PDSA bundles 1 and 2) and a full phase (after all 3 PDSA bundles were implemented) reveals a stepwise decrease in the

average monthly hypothermia rates from 29.8% to 19.2% to 10.0%, respectively (Fig 2A), which is a significant variation ($P = .0006$; analysis of variance F test). Pairwise comparisons between each of the 3 phases find only the full-intervention rate, not the early-intervention PDSA cycles alone, to be significantly different from the preintervention rate (29.8% vs 10.0%; $P = .0003$; Fig 2A), suggesting that the reduction in hypothermia rates occurred on concurrent implementation of all 3 PDSA bundles. Notably, the start of the full-intervention period corresponded to a p-chart special-cause signal shift, which is represented by the 9 consecutive data points below the baseline centerline from December 2015 to August 2016 (Fig 2B; last 9 months). The mean maximum temperature for mother-infant unit LPIs and/or LBW infants did not significantly change before and after the intervention (37.29°C vs 37.32°C ; $P = .17$).

To a lesser degree, the postintervention average monthly hypothermia rate among all mother-infant unit births was also significantly reduced from a preintervention rate of 9.4% to 7.1% (Fig 3A; $P = .019$), with a corresponding p-chart demonstrating this reduction (Fig 3B). The mean maximum temperature and hyperthermia incidence for all mother-infant unit infants remained unchanged before and after the intervention (37.29°C vs 37.30°C ; $P = .69$).

Average temperature measurements were taken twice weekly in the mother-infant unit in 3 distinct thermostat zones from July 2015 to October 2015 and did not significantly vary over time (mean = 22.1°C ; range = 21.3 – 22.6°C).

DISCUSSION

This newborn hypothermia prevention QI initiative with the implementation of multiple

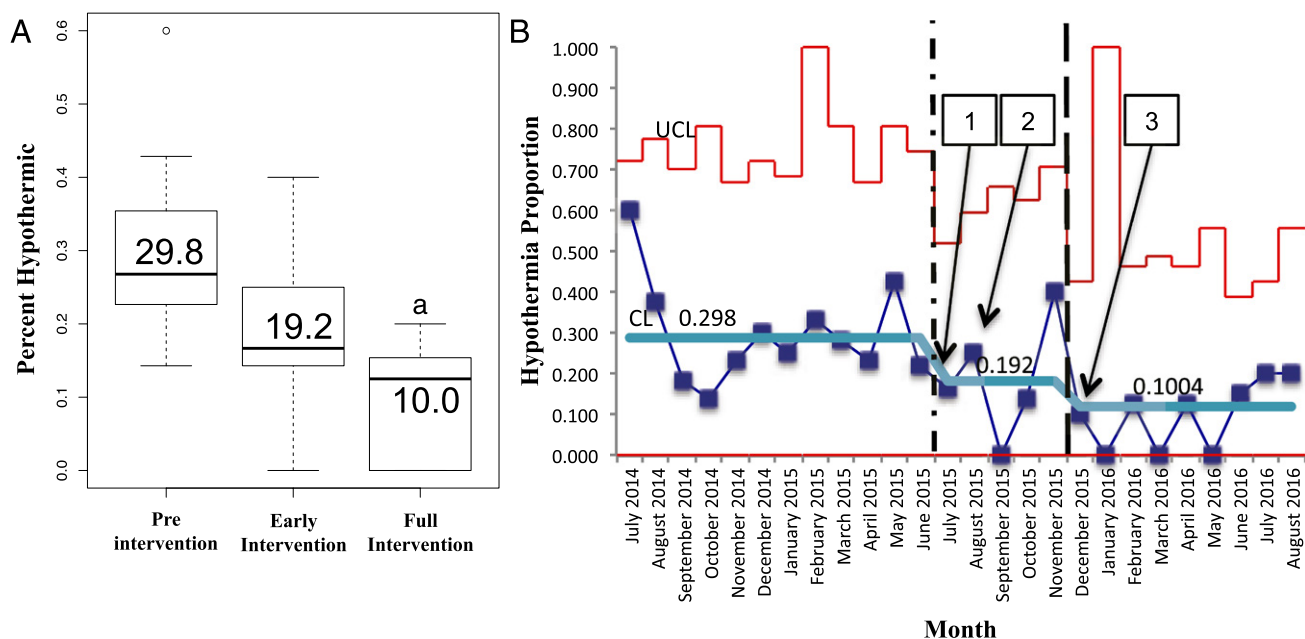


FIGURE 2

A, Average monthly hypothermia rates in the pre-, early-, and full-intervention study periods among LPIs and/or LBW births. ^a Denotes a significant difference. B, P-chart of the hypothermic birth rate with control limits. The short, dashed line represents the start of early intervention; the long, dashed line represents the full intervention; and the numbers represent PDSA bundles. CL, control limit; UCL, upper control limit.

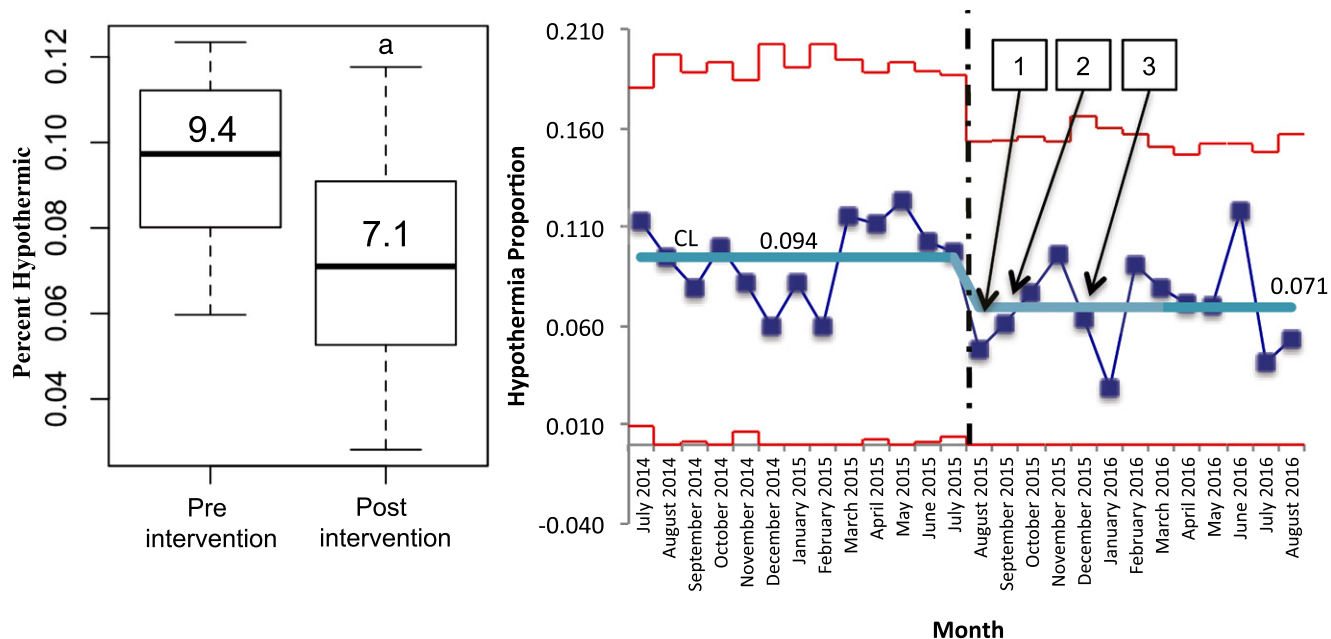


FIGURE 3

A, Average monthly hypothermia rates in the pre- and postintervention study periods among all births. ^a Denotes a significant difference. B, P-chart of the hypothermic birth rate with control limits. The short, dashed line represents the start of the intervention; numbers represent PDSA bundles. CL, control limit.

thermoregulation strategies appears successful in reducing the proportion of infants becoming hypothermic in our mother-infant unit. Perhaps unsurprisingly, the hypothermia

incidence was particularly lowered in the mother-infant unit LPI and/or LBW newborn population, the group that we targeted and that had the highest initial incidence

of hypothermia at 29.8%. With a postintervention hypothermia incidence of 10%, this represents a roughly two-thirds relative reduction in hypothermia for mother-infant

unit LPIs and/or LBW infants across the intervention period. The initiative also appears to have reduced the rate of hypothermia among all newborns in our mother-infant unit from 9.4% to 7.1%, a roughly one-quarter relative reduction. These reductions demonstrate that a significant number of newborn hypothermic events appear to be due to preventable environmental heat losses, especially in the mother-infant unit cohort of LPIs and/or LBW infants.

These reductions are likely attributable to our implemented thermoregulation strategies because a notable decrease first occurred with the first PDSA bundle, and further decreases occurred in a stepwise fashion concurrent with each PDSA bundle (Figs 2 and 3). Aside from the PDSA bundles, no other changes were made to our mother-infant unit care, such as changes to room temperatures and/or thermostat settings or how temperatures were measured or recorded by nursing staff. Similarly, there were no obvious differences between the pre- and postintervention study populations regarding sex, gestational age, birth weight, or LOS, making changing demographics an unlikely contributor.

Because the risk of overheating is a potential concern and has been shown in the literature with the use of exothermic mattresses,^{17,18} it is reassuring that the maximum recorded temperatures did not significantly differ from sampled pre- to postintervention study populations. This finding is consistent with other studies that show that thermoregulation strategies similar to ours can be safely conducted without increasing infant hyperthermia.^{11,15,19}

Strengths of this study include data integrity because hypothermic

events were verified by individual chart review. This also allowed us to determine the anatomic site of temperature measurement so as to only include hypothermic events that were confirmed by rectal measurement, which has been shown in the literature to be more precise than axillary measurement in newborns.^{20,21} An additional strength includes the 27-month study window, which ensured sufficient data to analyze for verifiable changes by SPC methods. In addition, our highly engaged, veteran QI team held regular meetings and conducted rigorous, ongoing study review that buttressed the work and allowed the PDSA bundles to be properly implemented and sustained over time.

Our study corroborates the findings of previous work demonstrating a reduction in hypothermic events with thermoregulation strategies.^{11–15,19} However, all previous studies have been restricted to the NICU environment. In contrast, our study focused on the more limited array of available interventions in the mother-infant unit, extending previous findings.

Moreover, the results of this QI initiative further support that some LPIs and LBW infants may safely remain in the mother-infant unit. Whereas some institutions may have more conservative gestational age or weight defaults for NICU admission, our results further corroborate that otherwise-healthy infants weighing >1750 g and born at >35 weeks' gestation can safely room-in and thermoregulate in the mother-infant unit. Families benefit from rooming-in when it is safe and available to them; rooming-in has numerous benefits and is considered more family centered.²² In addition, limiting NICU admissions to those newborns who require intensive care provides service delivery of higher value for regional health

systems.²³ Recent studies indicate that NICUs have been potentially overused in the past decade, with a recent shift in admissions to higher-weight newborns of older gestational ages.²⁴ At our institution, extensive efforts are made to maintain rooming-in, and thus may explain our low rate of transfer to the NICU even when a hypothermic event does occur; but potentially in other hospital settings, a higher NICU transfer rate may be attributable to low measured temperatures.

Limitations of this study include that this QI initiative took place in a small children's hospital in a unit staffed by a small number of pediatric hospitalists and mother-infant nurses. As a result, PDSA bundles were relatively easy to communicate and enact and could prove to be more difficult to implement at larger institutions. Furthermore, generalizability may be limited to institutions that provide rooming-in services in their mother-infant units, although this has generally become the standard of care. Another limitation is that we did not control for any potential secular trends between pre- and postintervention months. Although we did not identify any demographic shifts between the pre- and postintervention periods, there may have been unmeasured differences, such as seasonal room temperature changes, that may have confounded the results. Lastly, although most cited articles discuss the impact of hypothermia on very-preterm infants, the relevance of reducing neonatal hypothermia among healthy LPIs and higher weight categories of LBW newborns is uncertain. However, the potential value in promoting rooming-in and possibly preventing unnecessary NICU transfers will likely greatly outweigh the low cost and ease of implementing simple thermoregulation strategies.

CONCLUSIONS

We describe a successful QI effort to reduce neonatal hypothermia in our mother-infant unit, particularly among LPIs and/or LBW infants. The results of this QI initiative indicate that relatively simple environmental changes can reduce preventable hypothermia events and potentially reduce the number of unnecessary NICU transfers, further workup, and diverted staff resources. If adopted at other institutions, a subset of LPIs and/or LBW infants who are otherwise healthy and currently

residing in the NICU can safely room-in in a mother-infant unit and remain normothermic. This has the potential to reduce unnecessary NICU use and provide newborn care that is more family centered and of higher value.

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ABBREVIATIONS

CHaD: Children's Hospital at Dartmouth-Hitchcock
LBW: low birth weight
LOS: length of stay
LPI: late-preterm infant
PDSA: plan-do-study-act
QI: quality improvement
SPC: statistical process control

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Quality-Improvement Effort to Reduce Hypothermia Among High-Risk Infants on a Mother-Infant Unit

Christine Andrews, Colleen Whatley, Meaghan Smith, Emily Caron Brayton, Suzanne
Simone and Alison Volpe Holmes

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