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# A quality improvement project to reduce hypothermia in preterm infants on admission to the neonatal intensive care unit

**WAI YAN YIP[1], BIN HUEY QUEK[1], MARY CHOI WAN FONG[2], THILAGAMANGAI[2], SALLY SIEW GIM ONG[2], BEE LEONG LIM[2], BO CHU LO[2], and PRATIBHA AGARWAL[1,3]**

[1]Department of Neonatology, KK Women's and Children's Hospital, 100 Bukit Timah Road, Singapore 229899, Singapore, [2]Division of Nursing, KK Women's and Children's Hospital, 100 Bukit Timah Road, Singapore 229899, Singapore, and [3]Department of Child Development, KK Women's and Children's Hospital, 100 Bukit Timah Road, Singapore 229899, Singapore

Address reprint requests to: Wai Yan Yip, Department of Neonatology, KK Women's and Children's Hospital, 100 Bukit Timah Road, Singapore 229899, Singapore. Fax: +65-62-91-9079; E-mail: yip.wai.yan@singhealth.com.sg

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## Abstract

**Objective:** To study effectiveness of quality improvement interventions in reducing hypothermia in preterm infants on admission to neonatal intensive care unit.
**Design:** Quality improvement methodologies including multidisciplinary planning and implementation of evidence-based interventions. Data during and post-implementation were collected.
**Setting and participants:** In total, 84 preterm infants with birth weights ≤ 1500 g delivered during implementation period (October 2008–April 2009) were compared with 168 historical controls and 947 infants in the subsequent 4 years.
**Intervention(s):** In addition to routine interventions, delivery room temperatures were increased, and use of full-body polyethylene wraps and woollen caps were implemented during initial stabilization. Education and training were provided to reinforce the new interventions.
**Main Outcome Measure(s):** Primary outcome was incidence of hypothermia and mean admission temperature. Secondary outcomes were rates of intraventricular haemorrhage and mortality.
**Results:** Incidence of admission hypothermia decreased from 79.4 to 40.5% ($P < 0.001$), constituting a 49% improvement (OR = 0.177, 95% CI: 0.099–0.316). Mean admission temperature increased from 35.8 ± 0.8°C to 36.5 ± 0.7°C ($P < 0.001$). Hyperthermia incidence was higher at 6% compared to baseline of 1.3% ($P = 0.049$). The incidence of admission hypothermia remained stable at 47.4% in the 4 years post-implementation. Rates of intraventricular haemorrhage and mortality remained unchanged. Small for gestation, low 5-min Apgar score and singleton delivery were factors found to be associated with admission hypothermia.
**Conclusion:** The implementation of evidence-based best practices resulted in significant reduction in admission hypothermia in preterm infants, which persisted for 4 years post-implementation. The practices have since become standard of care in our institution.

**Key words:** hypothermia, preterm, very low birth weight infants, quality improvement

## Introduction

Hypothermia in newborns is a universal problem and is associated with increased morbidity and mortality. Delayed adjustment to newborn circulation, hypoglycaemia, metabolic acidosis, coagulopathy, oxygen dependency, intraventricular haemorrhage, late-onset sepsis, neurodevelopmental disturbances and death have been reported [1–4].

The World Health Organization (WHO) has recommended that the temperatures of newborns be maintained between 36.5 and 37.5°C. Mild hypothermia is defined as body temperatures between 36 and 36.4°C, moderate hypothermia between 32 and 35.9°C, and severe as <32°C [5]. The rates of severe morbidity in preterm infants including neurological injury (severe intraventricular haemorrhage or periventricular leukomalacia), severe retinopathy of prematurity, necrotizing enterocolitis, bronchopulmonary dysplasia and nosocomial infection have been reported to be lowest at admission temperatures between 36.5 and 37.2°C [6].

Due to greater evaporative, convective and conductive heat losses, as well as the diminished physiologic responses to cold stress, preterm infants, especially the very low birth weight (VLBW) infants (1500 g and below), are particularly at risk of hypothermia. Despite the conventional approach of drying and wrapping these neonates in pre-warmed towels and caring for them under radiant heaters during the initial stabilization, hypothermia is still a significant problem. The incidence of hypothermia in VLBW infants on admission to neonatal intensive care units (NICU) ranges between 31 and 78% [7].

The incidence of hypothermia on admission, defined as core temperature of <36.5°C, among VLBW infants born at our hospital, which is the largest perinatal referral centre in Singapore, was 79.4% in 2007 and 86.4% in 2006. A quality improvement (QI) initiative was planned to reduce our incidence of hypothermia. The effectiveness of the new interventions were studied during the implementation period, as well as following implementation to evaluate for sustained effectiveness.

## Methods

A multidisciplinary QI team comprising of neonatologists, midwives, and nurses was formed to evaluate factors contributing to hypothermia, and to plan and implement strategies to reduce the incidence of hypothermia on admission to the NICU by 50% in VLBW infants of 32 weeks' gestation or less. The reduction target was chosen based on prior studies using similar interventions reporting 50–60% reduction in hypothermia incidence [8]. QI methodologies, including the fishbone diagram and Pareto chart, were used to identify and prioritize the contributing factors (Fig. 1). Evidence-based measures were then introduced to address the most important causes of hypothermia at our centre.

In addition to our usual routine in preparing for preterm deliveries, including switching on the radiant warmer to maximal heat output, preparing pre-warmed towels and pre-warmed caps (stockinette or woollen), the following new processes were implemented using the plan, do, study and act (PDSA) framework:

(i) Change in drying practice and use of polyethylene occlusive wrap and woollen caps:
Instead of the prior practice of drying infants immediately after birth, removal of wet towels, and wrapping them in pre-warmed towels, they were now placed in pre-warmed polyethylene bags, which were wrapped over them from the neck down immediately after delivery without drying. This was followed by drying of the head and covering with woollen caps (Figure 2). All examinations and interventions were done with the infants in the wrap, including auscultation, endotracheal intubation, cardiopulmonary resuscitation and insertion of umbilical catheters, if required. The wraps were kept on during transport of the infants to the NICU either by radiant warmers without portable battery or by transport incubators. The wraps were removed in the NICU only when the core temperature was more than 36.5°C in a stable thermal environment.

(ii) Increasing ambient temperatures of the delivery rooms:
In the operating rooms, heating units to raise ambient temperature to 25°C were placed adjacent to the infant resuscitaires, which were separated from the operating area by an automated door. For preterm deliveries in the labour ward, air-conditioners were switched off during the second stage of labour.

(iii) Education of medical and nursing staff:
Lectures and demonstrations were held to educate doctors, nurses and midwives involved in the care of preterm neonates in the labour ward, operating rooms and NICU, on the importance of hypothermia prevention and the new strategies being introduced. Regular reinforcements were provided to ensure compliance with the new interventions.

All VLBW infants delivered at our hospital during the project implementation period were included. The new measures were implemented in August 2008 and prospective data collection occurred between October 2008 and April 2009. Data on infant demographics and clinical characteristics, including birth weight, gestational age, small for gestational age (SGA), gender, multiple births, mode of delivery, Apgar scores, prolonged rupture of membranes (PROM) (≥ 18 h), maternal pyrexia (≥ 37.5°C), chorioamnionitis (clinical and/or bacteriological and/or histological), antenatal steroids and major congenital malformations were collected. The outcome data collected included temperature (axillary or rectal) on arrival at the NICU, blood gas, blood pressure, persistent pulmonary hypertension of newborn (diagnosed clinically in the presence of increased lability requiring increased ventilatory support with suggestive echocardiography findings), intraventricular haemorrhage, chronic lung disease, and in-hospital mortality (excluding delivery room deaths). Comparisons were made with historical controls delivered in 2007 from the existing hospital VLBW database.

The primary outcome measures were the incidence of hypothermia (defined as axillary or rectal temperature < 36.5°C) on NICU admission and the mean admission temperature for the two periods. The secondary outcomes were to compare the rates of severe intraventricular haemorrhage (grades III and IV, according to Papile classification) and in-hospital mortality.

Upon completion of the QI project, the new interventions became the standard practice for hypothermia prevention at our hospital. Data on admission temperatures, morbidities and mortality from our existing VLBW database continued to be analysed until 2013 to evaluate for persistence of improvement, to compare outcomes and to identify potential risk factors for admission hypothermia.

Independent samples *t*-test was used to analyse continuous variables and chi square analysis was used for categorical variables, using SPSS version 19. Multiple comparisons were performed with one-way ANOVA with Bonferroni adjustments. All tests were conducted at the 0.05 significance level. The mean with standard deviation were reported when normality assumptions were satisfied, otherwise median values were reported. Logistic regression analysis was performed to identify risk factors associated with hypothermia. Potential

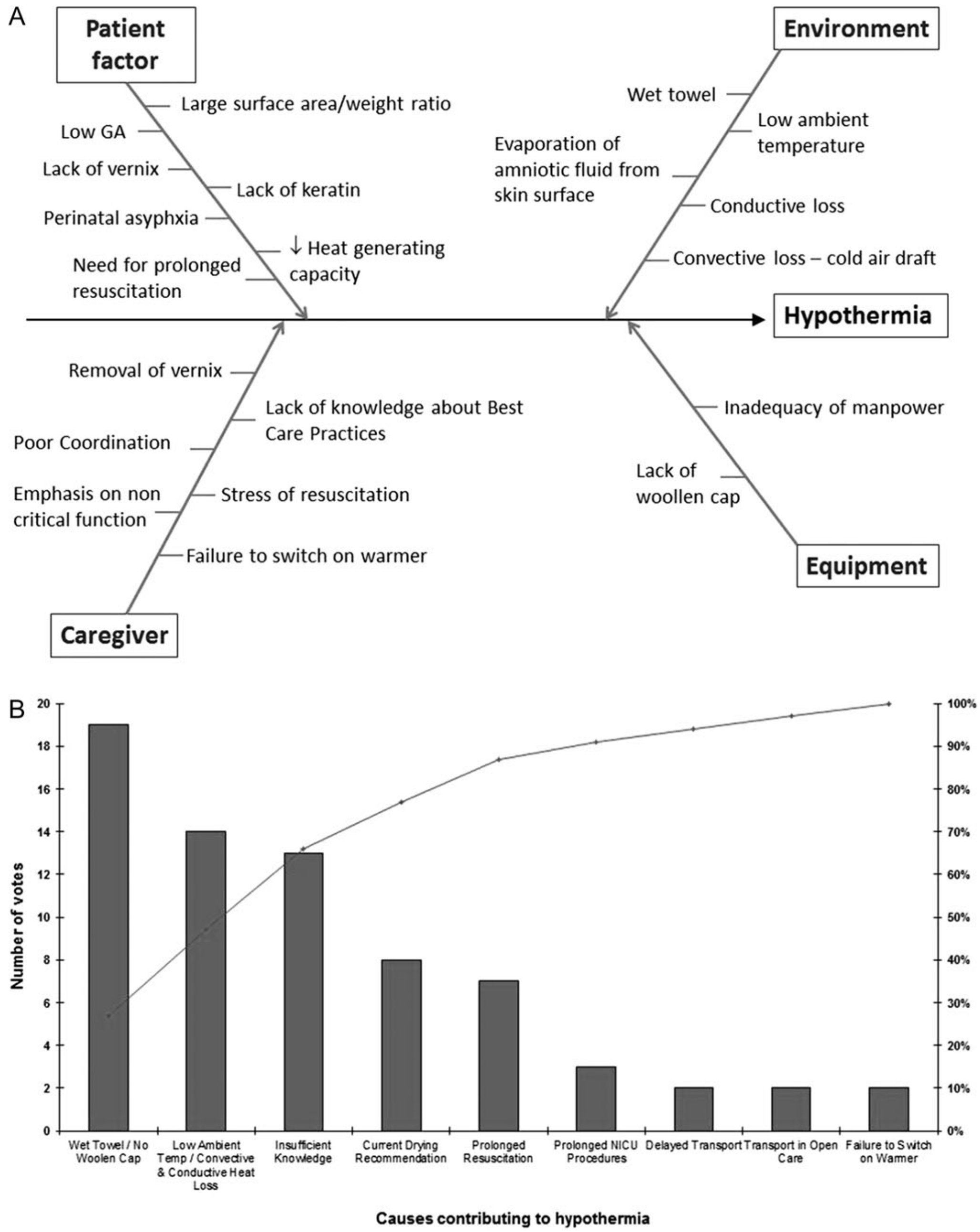


**Figure 1** Possible causes contributing to admission hypothermia in preterm infants were identified by brain-storming, and illustrated in a fishbone diagram (A), after which the most important causes were prioritized, by participants ($n = 70$) voting for one factor each, and illustrated in a Pareto chart (B).

variables identified from univariate analyses were included in the regression model, and potentially interacting variables were excluded.

The study was registered with and approved by the hospital QI committee and ethics committee (Singapore Health Services Centralised Institutional Review Board).

## Results

Between October 2008 and April 2009, there were 84 VLBW infants born at or below 32 weeks of gestation. The baseline characteristics of infants in the intervention group were similar to the historical controls in 2007, with the exception of more multiple births within the intervention cohort (Table 1).

Overall, 34 of the 84 infants (40.5%) within the intervention group had hypothermia on admission, constituting a 49% improvement from 2007 (OR = 0.177, 95% CI: 0.099–0.316). The mean temperature on admission to the NICU had also significantly increased to 36.5 ± 0.7°C (95% CI: 36.3–36.7°C) (range: 34–38.5°C) from 35.8 ± 0.8°C (95% CI: 35.7–36°C) (range: 32.6–37.7°C) ($P < 0.001$). The improvement was evident from the start of the QI project and was sustained throughout the implementation period, with monthly mean admission temperatures ranging between 36.2 and 36.8°C. The severity of hypothermia also

**Figure 2** Occlusive wrapping method using a pre-warmed polyethylene bag with a slit made down the midline was demonstrated on a manikin during training.



**Table 1** Characteristics of infants in the QI intervention group compared with historical controls

| Baseline characteristics | QI project period, October 2008–April 2009 ($n$ = 84) | Historical controls 2007 ($n$ = 168) | $P$-value |
|---|---|---|---|
| Birth weight (g), mean | 1025 ± 271 (Range 430–1500) | 1066 ± 290 (Range 390–1500) | 0.28 |
| Gestation (weeks), mean | 28.1 ± 2.2 (Range 23–31.7) | 28.4 ± 2.4 (Range 22.7–36) | 0.32 |
| SGA, $n$ (%) | 22 (26.2) | 31 (18.5)[a] | 0.30 |
| Female sex, $n$ (%) | 33 (39.3) | 79 (47.0) | 0.24 |
| Multiple births, $n$ (%) | 31 (36.9) | 41 (24.4) | 0.038 |
| Delivery by caesarean section, $n$ (%) | 59 (70.2) | 99 (58.9) | 0.08 |
| Apgar score <6 at 1 min, $n$ (%) | 34 (40.5) | 56 (33.7)[b] | 0.29 |
| Apgar score <6 at 5 min, $n$ (%) | 4 (4.8) | 12 (7.2)[b] | 0.45 |
| PROM, $n$ (%) | 24 (28.6) | 52 (31.0) | 0.67 |
| Maternal pyrexia, $n$ (%) | 5 (6.0) | 18 (10.7) | 0.22 |
| Chorioamnionitis, $n$ (%) | 32 (38.1) | 84 (50.3)[a] | 0.067 |
| Complete antenatal steroids, $n$ (%) | 61 (72.6) | 123 (73.7) | 0.30 |
| Major congenital malformation, $n$ (%) | 6 (7.1)[a] | 4 (2.4)[a] | 0.22 |

[a]Data missing in 1 infant.
[b]Data missing in 2 infants.

decreased, with the majority of hypothermia occurring in the mild range in the intervention group. No significant difference in intraventricular haemorrhage or mortality was seen between the intervention and historical cohorts (Table 2). Logistic regression was not performed as there was considerable missing data points.

Although the numbers were small, more infants within the intervention group had admission hyperthermia (> 37.5°C) (Table 2). The five hyperthermic infants within the intervention group had birth weights ranging between 925 and 1370 g, and gestational ages between 25 and 30 weeks. The admission temperature ranged from 37.6 to 38.5°C. There was history of maternal pyrexia in two of the infants. Excluding all hyperthermic infants, the mean admission temperatures of the two cohorts still differed significantly (36.4 ± 0.7°C versus 35.8 ± 0.7°C).

Within the intervention group, there was no significant difference in the antenatal, perinatal or postnatal characteristics, as well as intraventricular haemorrhage or mortality, between the hypothermic and non-hypothermic infants. Five of the non-hypothermic infants developed hypothermia after admission into the NICU, at a median age of 113 min (range of 80–199 min) with the lowest temperatures ranging from 34.5 to 36.1°C.

The new measures have been standard practice for hypothermia prevention at our hospital since the completion of the QI project. Of the 1017 VLBW infants born after implementation, between 2009 and 2013, 994 were delivered at our institution, of which 947 (95.3%) had data for analysis. The incidence of hypothermia was 47.4%. The mean admission temperature was 36.4 ± 0.3°C (95% CI: 36.3–36.4°C) (range: 31.8–38.5°C). Of the 449 hypothermic infants, 255 (56.8%) had mild hypothermia, 193 (43%) had moderate hypothermia and 1 (0.2%) had severe hypothermia. Hyperthermia occurred in 24 (2.5%) infants.

The characteristics and outcomes of infants who developed hypothermia compared to those who did not are shown in Table 3. Infants who developed hypothermia had the highest gestational age but more were SGA. Hypothermic infants were more likely to have lower 5-min Apgar scores, but less likely to require delivery room interventions. They were also more likely to be born to mothers who received incomplete or no antenatal steroids. On the other hand, there were significantly more mothers with PROM, fever and chorioamnionitis among the infants who developed hyperthermia. Rates of intraventricular haemorrhage and mortality between the three groups were similar.

Factors included in our logistic regression model were maternal pyrexia, antenatal steroids, low 5-min Apgar score, gestational age and SGA, which were all found to be significant from our univariate analyses. Mode of delivery and plurality were included as they were near significant. Birth weight was also included as it is expected to impact on hypothermia incidence. PROM and chorioamnionitis, although significant in our univariate analyses, were not included as they are closely associated with maternal pyrexia. Our logistic regression analysis showed that SGA (OR = 2.106, 95% CI: 1.385–3.203), 5-min Apgar score <6 (OR = 2.766, 95%

**Table 2** Outcomes of infants in the QI intervention group compared with historical controls

| Clinical outcomes | QI project period, October 2008–April 2009 ($n$ = 84) | Historical controls 2007 ($n$ = 168) | $P$-value |
|---|---|---|---|
| Admission temperature (°C), mean | 36.5 ± 0.7 | 35.8 ± 0.8[a] | <0.001 |
| Hypothermia, $n$ (%) | 34 (40.5) | 127 (79.4)[a] | <0.001 |
| Mild hypothermia 36–36.4°C | 24 (28.6) | 45 (28.1) | |
| Mod-severe hypothermia < 36°C | 10 (11.9) | 82 (51.3) | |
| Hyperthermia, $n$ (%) | 5 (6.0) | 2 (1.3)[b] | 0.049 |
| First pH, mean | 7.28 ± 0.09[c] | 7.27 ± 0.11[b] | 0.59 |
| First base excess, mean | −5.5 ± 3.7[c] | −5.6 ± 3.7[b] | 0.85 |
| Maximum base excess in first 12 hours, mean | −6.2 ± 4.1[c] | −6.3 ± 3.4[b] | 0.80 |
| First mean arterial pressure, mean | 33 ± 9[c] | 34 ± 8[b] | 0.78 |
| Hypotension[d] in first 3 days, $n$ (%) | 36 (43.4)[c] | 49 (29.5)[b] | 0.060 |
| Pulmonary hypertension, $n$ (%) | 2 (2.4)[c] | 11 (6.7)[b] | 0.37 |
| Intraventricular haemorrhage, $n$ (%) | | | 0.66 |
| Mild (grades I–II) | 25 (30.1)[c] | 62 (37.3)[b] | |
| Severe (grades III–IV) | 4 (4.8)[c] | 10 (6.0)[b] | |
| Chronic lung disease, $n$ (%) | 17 (21.3)[c] | 28 (17.9)[b] | 0.31 |
| Mortality, $n$ (%) | 7 (8.3) | 19 (11.4)[e] | 0.46 |

[a]Admission temperature was not recorded in seven infants.
[b]Data not available in 1–12 infants due to missing data or death before assessment.
[c]Data not available in 1–4 infants due to missing data or death before assessment.
[d]Hypotension is defined as mean arterial pressure of less than gestational age with clinical evidence of reduced perfusion or metabolic acidosis, and requiring intervention with volume expansion and/or inotropes and/or steroids.
[e]Excludes one delivery room death.

**Table 3** Characteristics and outcomes of hypothermic compared to normothermic and hyperthermic infants following QI implementation (May 2009 to December 2013)

| Characteristics and outcomes | Normothermic infants ($n$ = 474) | Hypothermic infants ($n$ = 449) | Hyperthermic infants ($n$ = 24) | $P$-value |
|---|---|---|---|---|
| Antenatal | | | | |
| PROM, $n$ (%) | 153 (32.3) | 91 (20.3) | 10 (41.7) | <0.001 |
| Maternal pyrexia, $n$ (%) | 58 (12.3) | 29 (6.5) | 8 (33.3) | <0.001 |
| Chorioamnionitis, $n$ (%) | 209 (44.2) | 125 (27.8) | 14 (58.3) | <0.001 |
| Complete antenatal steroids, $n$ (%) | 368 (77.6) | 315 (70.2) | 19 (79.2) | 0.03 |
| Perinatal | | | | |
| Multiple births, $n$ (%) | 160 (33.8) | 122 (27.2) | 9 (37.5) | 0.07 |
| Delivery by caesarean section, $n$ (%) | 304 (64.1) | 326 (72.6) | 13 (54.2) | 0.08 |
| Delivery room interventions (bag and mask, intubation, external cardiac massage, adrenaline), $n$ (%) | 393 (83.1) | 345 (76.8) | 21 (87.5) | 0.04 |
| Apgar score <6 at 5 min, $n$ (%) | 20 (4.2) | 43 (9.6) | 1 (4.2) | 0.004 |
| Neonatal | | | | |
| Birth weight (g), mean | 1090 ± 270 | 1087 ± 299 | 1096 ± 229 | 0.98 |
| Gestation (weeks), mean | 28.5 ± 2.6 | 29.3 ± 3.2 | 27.4 ± 1.7 | <0.001 |
| SGA, $n$ (%) | 125 (26.4) | 226 (50.3) | 0 (0) | <0.001 |
| Female sex, $n$ (%) | 237 (50) | 226 (50.3) | 11 (45.8) | 0.28 |
| Admission temperature (°C), mean | 36.9 ± 0.3 | 35.8 ± 0.6 | 37.9 ± 0.3 | <0.001 |
| Intraventricular haemorrhage, $n$ (%) | | | | |
| Mild (grades I–II) | 136 (28.9) | 130 (29.3) | 8 (33.3) | 0.82 |
| Severe (grades III–IV) | 23 (4.9) | 21 (4.7) | 2 (8.3) | |
| Mortality, $n$ (%) | 31 (6.5) | 45 (10) | 2 (8.3) | 0.15 |

CI: 1.554–4.923) and singleton delivery (OR = 1.383, 95% CI: 1.019–1.876) were independent factors associated with admission hypothermia, whereas maternal pyrexia reduced the risk of hypothermia (OR = 0.6, 95% CI: 0.367–0.982). Gestational age, antenatal steroids, birth weight and mode of delivery were not significant factors.

## Discussion

The implementation of a series of evidence-based measures into everyday clinical practice, specifically, the use of polyethylene bags [8–11] and woollen caps [9, 11] during initial stabilization, warmer delivery rooms as recommended by the WHO, and ongoing education and training, resulted in significant reduction in our incidence of admission hypothermia among VLBW infants, with mean admission temperatures increasing significantly to the normothermic range, as recommended by the WHO. This improvement was sustained over the 4 years following implementation. Studies on the effectiveness and safety of skin-to-skin care and heated mattresses during initial stabilization in VLBW preterm infants were limited at the time of our implementation, therefore, these measures were not adopted.

The reported incidence of hypothermia varies worldwide. One of the reasons may be the different definitions of hypothermia being used, with some studies reporting <36°C and others reporting <36.5°C as hypothermia. We chose to use 36.5°C as our cut-off considering the increasing evidence of association between admission hypothermia and severe morbidity in preterm infants [6]. In addition, the latest International Liaison Committee on Resuscitation (ILCOR) guidelines in 2015 recommended that newborn admission temperature be maintained between 36.5 and 37.5°C and be recorded as a predictor of outcomes and a quality indicator [12].

Our reduction in hypothermia incidence of 49% is similar to those reported in prior studies [8]. Although we did not perform a priori sample size calculation, the number of infants in our study would have provided a 90% power in showing reduced hypothermia incidence from 70 to 50% using a two-sided significance level of 0.05.

There were significantly more multiple births in our intervention cohort compared to historical controls. This is likely due to increased pregnancy rates from artificial reproductive technology. Interestingly, in our post-implementation cohort, the delivery of multiples was independently associated with a lower risk of hypothermia. One possible reason is that there are usually more personnel present at the delivery of multiples, therefore more attention to thermoregulation. In addition, multiples are usually delivered by caesarean section at the operating room, where the resuscitation area is separated by a door, leading to easier ambient temperature control.

Within our post-implementation cohort, SGA was an independent risk factor for hypothermia and this can be explained by the reduced subcutaneous fat tissue and relatively large body surface area in these infants. Hypothermic infants also had lower 5-min Apgar scores, implying that sicker infants are at higher risk of developing hypothermia. However, our analysis also showed that hypothermic infants required less delivery room intervention, likely because they were more mature in gestation compared to the non-hypothermic infants. The lower risk of hypothermia in infants born to febrile mothers is an expected observation.

There is a potential risk of hyperthermia in most heat loss prevention strategies. Hyperthermia has metabolic consequences and has been associated with poorer neurodevelopmental outcomes in the setting of perinatal hypoxia-ischaemia and therefore should be avoided. Hyperthermia incidences of between 4.2 and 17% have been reported with the use of polyethylene wraps [13–15]. Although our sample size was small, our baseline rate of hyperthermia of rose significantly during the QI initiative. Therefore, close monitoring and control of infant temperature during initial stabilization and transfer is essential.

Despite the significant reduction in our incidence of hypothermia, we found no significant difference in morbidity and mortality between the hypothermic and non-hypothermic infants. Other retrospective and randomized controlled studies addressing hypothermia prevention have similar findings [16–21]. This is contrary to what has been reported in large population studies and is likely due to our small sample size [6, 22, 23].

The importance of maintaining delivery room temperature around 25°C was evident in a recent study which reported almost two times more hypothermia in infants delivered in rooms with mean temperature of 22.5°C compared to 25.1°C [24]. In our study, we were unable to record the actual ambient temperatures achieved or staff compliance with these measures. There is a possibility that draughts from doors, air-conditioners and staff movement may have caused the delivery room temperatures to be lower than 25°C at the time of delivery.

Even though our QI initiative has achieved the target outcome, 40–47% of our infants remained hypothermic, albeit mostly mild. In addition to admission temperature, infant temperature in the delivery rooms should be routinely monitored so that efforts for hypothermia prevention can be better targeted. Additional interventions may also need to be considered. The use of heated mattresses is promising but concerns with hyperthermia remains [13–15, 18, 25]. Our method of polyethylene occlusive wrapping may warrant modification, perhaps to include head wrapping. Polyethylene caps and total body polyethylene wrap have been found to be as effective as wrapping the torso only [20, 21, 26]. The use of heated humidified gas during stabilization and transfer to NICU, and using a mode of transport with continuous heat source powered by portable battery have been evaluated [19, 27–29]. There is, however, limited evidence for their efficacy currently.

Future studies should explore care provider and environmental factors affecting thermoregulation in VLBW infants. Measurement of staff awareness and compliance is important, as thermoregulation is often perceived to be of secondary importance in the initial stabilization of ill infants. Assignment of specific roles for thermoregulation and providing personalized feedback of infant temperatures to the delivery team should be evaluated for their impact on hypothermia incidence [30]. Additionally, the impact of reduced hypothermia incidence on longer-term outcomes, such as 2-year neurodevelopmental outcomes, deserves further evaluation and is currently being done in our centre.

## Conclusion

The implementation of a series of evidence-based best practices resulted in significant reduction in the incidence of hypothermia on admission to the NICU among VLBW infants. The practices have since become the standard of care for hypothermia prevention in our institution. The reduction in hypothermia incidence and improvement in admission temperature continued in the subsequent 4 years following the implementation of our QI initiative. Additional interventions need to be evaluated in infants who remained hypothermic.

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## References

1. Costeloe K, Hennessy E, Gibson AT *et al.* The EPICure study: outcomes to discharge from hospital for infants born at the threshold of viability. *Pediatrics* 2000;**106**:659–71.
2. Culic S. Cold injury syndrome and neurodevelopmental changes in survivors. *Arch Med Res* 2005;**36**:532–8.

3. Laptook AR, Salhab W, Bhaskar B. Admission temperature of low birth weight infants: predictors and associated morbidities. *Pediatrics* 2007; **119**:e643–9.
4. Gleissner M, Jorch G, Avenarius S. Risk factors for intraventricular haemorrhage in a birth cohort of 3721 premature infants. *J Perinat Med* 2000; **28**:104–10.
5. World Health Organization. Thermal protection of the newborn: a practical guide. In: *Maternal and Newborn Health/Safe Motherhood Unit (WHO/RHT/MSM/97.2)*. Geneva: World Health Organization, 1997.
6. Lyu Y, Shah PS, Ye XY *et al*. Association between admission temperature and mortality and major morbidity in preterm infants born at fewer than 33 weeks' gestation. *JAMA Pediatr* 2015;**169**:e150277. doi:10.1001/jamapediatrics.2015.0277.
7. Bhatt DR, White R, Martin G *et al*. Transitional hypothermia in preterm newborns. *J Perinatol* 2007;**27**:S45–7.
8. Cramer K, Wiebe N, Hartling L *et al*. Heat loss prevention: a systematic review of occlusive skin wrap for premature neonates. *J Perinatol* 2005; **25**:763–9.
9. McCall EM, Alderdice FA, Halliday HL *et al*. Interventions to prevent hypothermia at birth in preterm and/or low birthweight babies. *Cochrane Database Syst Rev* 2005: CD004210. doi:10.1002/14651858.CD004210.pub2.
10. Mathew B, Lakshminrusimha S, Cominsky K *et al*. Vinyl bags to prevent hypothermia at birth in preterm infants. *Indian J Pediatr* 2007;**74**: 249–53.
11. Watkinson M. Temperature control of premature infants in the delivery room. *Clin Perinatol* 2006;**33**:43–53.
12. Perlman JM, Wyllie J, Kattwinkel J *et al*. Neonatal Resuscitation Chapter Collaborators. Part 7: Neonatal Resuscitation. 2015 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. *Circulation* 2015;**132**:S204–41.
13. Singh A, Duckett J, Newton T *et al*. Improving neonatal unit admission temperatures in preterm babies: exothermic mattresses, polythene bags or a traditional approach? *J Perinatol* 2010;**30**:45–9.
14. McCarthy LK, O'Donnell CPF. Warming preterm infants in the delivery room: polyethylene bags, exothermic mattresses or both? *Acta Paediatr* 2011;**100**:1534–7.
15. McCarthy LK, Molloy EJ, Twomey AR *et al*. A randomized trial of exothermic mattresses for preterm newborns in polyethylene bags. *Pediatrics* 2013;**132**:e135–41.
16. Reilly MC, Vohra S, Rac VE *et al*. Randomized trial of occlusive wrap for heat loss prevention in preterm infants. *J Pediatr* 2015;**166**:262–8.
17. Lee HC, Ho QT, Rhine WD. A quality improvement project to improve admission temperatures in very low birth weight infants. *J Perinatol* 2008;**28**:754–8.
18. Chawla S, Amaram A, Gopal SP *et al*. Safety and efficacy of trans-warmer mattress for preterm neonates: results of a randomized controlled trial. *J Perinatol* 2011;**31**:780–4.
19. te Pas AB, Lopriore E, Dito I *et al*. Humidified and heated air during stabilization at birth improves temperature in preterm infants. *Pediatrics* 2010;**125**:e1427–32.
20. Trevisanuto D, Doglioni N, Cavallin F *et al*. Heat loss prevention in very preterm infants in delivery rooms: a prospective, randomized, controlled trial of polyethylene caps. *J Pediatr* 2010;**156**:914–7.
21. McCall EM, Alderdice F, Halliday HL *et al*. Interventions to prevent hypothermia at birth in preterm and/or low birthweight infants. *Cochrane Database Syst Rev* 2010: CD004210. doi:10.1002/14651858.CD004210.pub4.
22. Miller SS, Lee HC, Gould JB. Hypothermia in very low birth weight infants: distribution, risk factors and outcomes. *J Perinatol* 2011;**31**:S49–56.
23. de Almeida MFB, Guinsburg R, Sancho GA *et al*. Hypothermia and early neonatal mortality in preterm infants. *J Pediatr* 2014;**164**:271–5.
24. Jia YS, Lin ZL, Lv H *et al*. Effect of delivery room temperature on the admission temperature of premature infants: a randomized controlled trial. *J Perinatol* 2013;**33**:264–7.
25. Russo A, McCready M, Torres L *et al*. Reducing hypothermia in preterm infants following delivery. *Pediatrics* 2014;**133**:e1055–62.
26. Doglioni N, Cavallin F, Mardegan V *et al*. Total body polyethylene wraps for preventing hypothermia in preterm infants: a randomized trial. *J Pediatr* 2014;**165**:261–6.
27. Pinheiro JMB, Furdon SA, Boynton S *et al*. Decreasing hypothermia during delivery room stabilization of preterm neonates. *Pediatrics* 2014;**133**: e218–26.
28. Meyer MP, Hou D, Ishrar NN *et al*. Initial respiratory support with cold, dry gas versus heated humidified gas and admission temperature of preterm infants. *J Pediatr* 2015;**166**:245–50.
29. Meyer MP, Bold GT. Admission temperatures following radiant warmer or incubator transport for preterm infants <28 weeks: a randomised study. *Arch Dis Child Fetal Neonatal Ed* 2007;**92**:F295–7.
30. Benn J, Arnold G, Wei I *et al*. Using quality indicators in anaesthesia: feeding back data to improve care. *Br J Anaesth* 2012;**109**:80–91.