Increasing ambient operating theatre temperature and wrapping in polyethylene improves admission temperature in premature infants

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Aim: To improve admission temperatures of preterm infants ≤ 31 weeks gestation by increasing the ambient temperature in the operating theatre and wrapping in polyethylene wrap at caesarean section.

Methods: A review of admission temperature of infants with gestational age ≤ 31 weeks from January 2000 to July 2002 was performed. Between October 2002 and 2003 the ambient operating theatre temperature was increased to 26–28°C for deliveries ≤ 27 weeks gestation and to 25°C for deliveries ≥ 28 weeks gestation. From September 2004 to December 2005 the ambient theatre temperature was increased along with wrapping infants in polyethylene. A clinical audit cycle review of admission temperatures and early morbidity and mortality was undertaken.

Results: 156 premature infants were included, 42 < 28 weeks and 114 28–31 weeks gestation. The mean admission temperature in < 28 weeks infants prior to intervention was 35.3°C, after increasing ambient theatre temperature 35.9°C, and after increasing ambient temperature and using polyethylene wrap 37.0°C ($P < 0.0001$). For infants 28–31 weeks the mean admission temperatures in the three epochs were 36.3°C, 36.5°C and 36.6°C, respectively ($P = 0.002$). There was no statistically significant difference in: total days of ventilation or oxygen, definite necrotising enterocolitis, intraventricular haemorrhage grade 3 or 4 or survival.

Conclusions: Increasing the ambient temperature in the operating theatre and wrapping premature infants in polyethylene wrap improves admission temperature. Further studies are required to determine whether these interventions are associated with improved outcome in the premature neonate.

Key words: hypothermia; operating theatre; polyethylene; premature; temperature.

Much is now known regarding heat loss from the newborn infant and the effects on energy consumption. Adamsons *et al.* described the influence of temperature on oxygen consumption in term newborn infants as well as the rate of temperature loss over time if no immediate action was taken to reduce heat loss.^{1,2} In the late 1950s Silverman *et al.* provided evidence that hypothermia increased morbidity and mortality.^{3–5} Hypothermia continues to be a significant problem in the extremely premature infant.^{6,7}

Key Points

- 1 Increasing ambient operating theatre temperature and wrapping infants in polyethylene wrap improves admission temperature in premature infants.
- 2 A multidisciplinary education programme can successfully achieve an improvement in clinical practice.
- 3 Further large studies are required to determine whether improving admission temperature improves mortality and morbidity.

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The clinical implications of cold stress include: hypoglycaemia, respiratory distress, hypoxia, metabolic acidosis, coagulation defects, persistent fetal circulation, acute renal failure, necrotizing enterocolitis, weight loss and failure to increase weight, and in extreme cases death.^{8–13} The World Health Organisation (WHO) has classified mild hypothermia as a core temperature of 36–36.4°C, moderate hypothermia as 32–35.9°C and severe as less than 32°C.¹⁴ Attempts are required to minimise heat loss via the four means of heat exchange – conduction, convection, radiation and evaporation. This can be done by pre-warming resuscitation surfaces to reduce conductive losses as well as providing radiant heat. By increasing ambient theatre temperatures a reduction in heat loss via convection may occur, and drying or wrapping infants may reduce evaporative losses.

A Cochrane review of interventions to prevent hypothermia at birth in preterm and/or low-birth-weight infants has been performed.¹⁵ The review looked at plastic wraps or bags, skin-to-skin care and transwarmer mattresses, and determined that all methods led to higher admission temperatures, but there was limited data available on long-term outcome. Cramer *et al.* had similar findings in their systematic review of occlusive wraps for premature infants.¹⁶

The WHO has suggested that the delivery room temperature should be 25°C, at a minimum.¹⁴ Knobel *et al.* in their study

Table 1 Demographic data of infants born by caesarean section over the three epochs

	Epoch one July 2000 to July 2002 <i>n</i> = 73	Epoch two November 2002 to October 2003 <i>n</i> = 35	Epoch three September 2004 to December 2005 <i>n</i> = 48	<i>P</i> -value
Mean birthweight (g)* (SD)	1235 (397)	1097 (494)	1194 (297)	0.24
Mean gestation (weeks)* (SD)	28.9 (2.4)	28.4 (2.5)	28.9 (1.8)	0.56
Male gender number (%)**	28 (38.4)	18 (51.4)	28 (58.3)	0.09
Mean Apgar 1 min* (SD)	6.1 (2.3)	5.6 (2.2)	5.3 (2.2)	0.16
Mean Apgar 5 min* (SD)	7.8 (1.6)	7.6 (1.8)	7.6 (1.8)	0.72
Antenatal steroids number** (%)	45 (61.6)	23 (65.7)	35 (72.9)	0.44

*Kruskal–Wallis test, *P* < 0.05 significant. **Chi-squared test, *P* < 0.05 significant.

found that the combination of wrapping in a polyurethane bag and increasing the ambient theatre temperature improved admission temperatures.¹⁷

The aim of this study was to improve admission temperatures of preterm infants ≤ 31 weeks gestation by increasing the ambient temperature in the operating theatre and wrapping in polyethylene wrap at caesarean section.

Methods

A retrospective review of admission temperatures of infants admitted to the Neonatal Intensive Care Unit was performed over three epochs. As this was a retrospective audit, a formal ethics application was not required as per NHMRC guidelines; however, approval for access to the medical records for the study was given by the hospital administration. Data were acquired from the neonatal intensive care unit database, any further information was obtained from the hospital electronic medical record. The database is a prospectively managed database which is completed at the time of discharge of the infant from the neonatal intensive care unit.

The first epoch was from July 2000 to July 2002 prior to any changes in clinical practice. At this time the operating theatre temperature was set at 20°C, the infant was placed under a radiant warmer, dried and wrapped with warm blankets. From November 2002 to October 2003 a clinical change was introduced increasing the ambient operating theatre temperature to 26–28°C for deliveries ≤ 27 weeks gestation and to 25°C for deliveries ≥ 28 –35 weeks gestation. The operating theatre temperature was increased and at a stable temperature prior to commencement of the caesarean section. This change in clinical practice involved an educational programme including Neonatologists, neonatal nursing staff, midwifery staff, obstetricians, operating theatre staff and anaesthetists. A further change in clinical practice was introduced in September 2004 that combined increasing the ambient operating theatre temperature with wrapping of the infant in polyethylene. Data were collected during this third epoch on whether both interventions had taken place. Admission temperatures were taken per axilla using the Terumo digital clinical thermometer C202.

Data collected included: gestation, birthweight, admission temperature, survival, total days of ventilation (including nasal

continuous positive airway pressure), days of oxygen, definite necrotising enterocolitis (NEC) (abdominal X-ray changes consistent with NEC, fresh rectal bleeding or perforation), intraventricular haemorrhage (IVH) grade III or IV and late infection.

Delivery rooms in this hospital can be warmed but not to a precise temperature. However, during this period of education on thermal protection of the neonate and the commencement of wrapping all premature infants with polyethylene wrap, a difference in admission temperatures may have occurred for vaginal deliveries.

Data were stored and analysed using SPSS 15.01 database. Figures were produced using SPSS 15.01. Differences between admission temperatures across the three epochs were assessed using the Kruskal–Wallis test. Analysis of variance was used to examine differences across the epochs for gestational age, birthweight, Apgar scores at 1 and 5 min, days of ventilation and days of oxygen. Chi-squared tests were used to examine gender, antenatal steroids, survival, NEC, IVH and late infection across the three epochs. A generalized linear model was used to examine the interaction effects of gestational age and birthweight and admission temperature with the three epochs. Correlations between birthweight and admission temperature were assessed using the Pearson product moment correlation.

Results

Two hundred and ninety-nine babies less than 32 weeks gestation were admitted during these three epochs, 156 (52%) of which were delivered by caesarean section. The demographics of the infants across the three epochs are provided in Table 1. There were no significant differences in the infants between the three epochs. A subanalysis of groups was performed with infants between 24 and 27 weeks gestation and between 28 and 31 weeks gestation.

Caesarean section deliveries

The mean admission temperature in infants between 24 and 27 weeks gestation during the first epoch prior to any changes in clinical practice was 35.3°C. During the second epoch the mean admission temperature increased to 35.9°C and during

Table 2 Mean admission temperatures of infants in the three epochs in gestational age groups 24–27 weeks and 28–31 weeks gestation

	Epoch one July 2000 to July 2002	Epoch two November 2002 to October 2003	Epoch three September 2004 to December 2005	P-value
Mean admission temperature	<i>n</i> = 17	<i>n</i> = 15	<i>n</i> = 10	
24–27 weeks gestation (°C)* (SD)	35.3 (0.98)	35.9 (1.0)	37.0 (0.65)	<0.0001
Mean admission temperature	<i>n</i> = 56	<i>n</i> = 20	<i>n</i> = 38	
28–31 weeks gestation (°C)* (SD)	36.3 (0.57)	36.5 (0.44)	36.6 (0.5)	0.005

*Kruskal–Wallis test, $P < 0.05$ significant.

Table 3 Morbidity and mortality across the three epochs

	Epoch one July 2000 to July 2002 <i>n</i> = 73	Epoch two November 2002 to October 2003 <i>n</i> = 35	Epoch three September 2004 to December 2005 <i>n</i> = 48	P-value
Survive (%)*	63 (86)	29 (83)	43 (90)	0.67
Mean total days ventilation (SD)**	18 (30)	25 (30)	23 (26)	0.4
Mean days oxygen (SD)**	33 (41)	56 (69)	34 (36)	0.07
Definite NEC (%)*	4 (5.5)	4 (11.0)	2 (4.2)	0.35
IVH III/IV (%)*	6 (8.2)	1 (3)	1 (2.1)	0.42
Late infection (%)*	17 (23)	15 (43)	13 (27)	0.1

*Chi-square test, $P < 0.05$ significant. **Kruskal–Wallis test, $P < 0.05$ significant. IVH, intraventricular haemorrhage; NEC, necrotising enterocolitis.

the third epoch increased to 37.0°C (Kruskal–Wallis $P < 0.0001$). The range of temperatures in the first epoch was 32.8–36.4°C with only 18% (3/17) having an admission temperature of 36.4°C. In the second epoch the range of temperatures was 34.5–38.4°C with 27% (4/15) having an admission temperature of 36.4° or above. Only one infant had a temperature above 37.5°C. During the third epoch the range of temperature on admission was 36.0–37.8°C with 80% (8/10) having an admission temperature of 36.4°C or above. Two infants had an admission temperature above 37.5°C.

In infants between 28 and 31 weeks gestation the mean admission temperature in the first epoch was 36.3°C and increased significantly over the three epochs (Kruskal–Wallis $P = 0.005$) (Table 2). The range of admission temperature in the first epoch was 34.7–38.0°C with 46% (26/56) having an admission temperature 36.4°C or above. Only one infant had a temperature above 37.5°C. During the second epoch the range of temperatures was 35.8–37.2°C with 60% (12/20) having an admission temperature above 36.4°C. In the third epoch the temperature on admission ranged from 35.0°C to 37.8°C with 79% (30/38) having an admission temperature above 36.4°C. Only one infant had an admission temperature above 37.5°C.

There were no significant differences in survival, total days of ventilation, days of oxygen, definite NEC, IVH grade III or IV and late infection (Table 3).

There was a significant interaction between birthweight and gestational age with the three epochs in admission temperature

($P = 0.04$, $P = 0.004$). In the first and second epoch there was a correlation between birthweight and admission temperature ($P < 0.0001$ and $P < 0.009$, respectively). However, in the third epoch combining increased ambient operating theatre temperature and wrapping with polyethylene, this correlation no longer existed ($P = 0.26$). This was also seen for gestational age and admission temperature across the three epochs ($P < 0.0001$, $P = 0.03$, $P = 0.5$, respectively). Scatter plots of birthweight and gestational age with admission temperature are provided in Figures 1 and 2.

Vaginal deliveries

During the study period the gestation and birthweight were significantly higher than in the third epoch than the first two epochs ($P = 0.012$ and $P = 0.005$, respectively). In infants with a gestation between 24 and 27 weeks gestation the mean admission temperature did increase over the three epochs (35.6°C, 35.8°C, 35.9°C), but was not statistically significant ($P = 0.6$). This was also true for infants between 28 and 31 weeks gestation (36.5°C, 36.6°C, 36.7°C; $P = 0.17$). However, there was an increase in the proportion of infants with an admission temperature of 36.4°C or above between the first and second epoch (16.7% to 47%), but this was not seen in the third epoch, in which there were only four infants less than 28 weeks gestation. The proportion of infants with an admission temperature equal

Fig. 1 Scatterplot of birth weight and admission temperature for the three epochs.

Fig. 2 Scatterplot of gestational age and admission temperature for the three epochs.

to or above 36.4°C increased over the three epochs for infants 28–31 weeks gestation (60.8%, 68.7% and 74.2%, respectively).

Discussion

This clinical audit cycle confirms the findings of other studies that increasing the ambient operating theatre temperature and wrapping infants in polyethylene can increase admission temperatures. Involvement of all disciplines in the education process most likely resulted in the success of this change in clinical practice. This study is limited by its retrospective nature; however, the database from which the information is collected is managed prospectively.

Vohra *et al.* have performed two randomised trials using polyethylene occlusive skin wrapping to prevent heat loss in premature infants, both showing an improvement in admission temperatures.^{18,19} They found a positive correlation between birthweight and admission temperature even with polyethylene wrapping. Our study found that this correlation was lost when increasing the ambient operating theatre temperature was combined with polyethylene wrapping, indicating that it is the extremely low birthweight baby who will benefit most from this combination of practices.

It is important to not overheat neonates, especially those at risk of hypoxic ischaemic encephalopathy. In our study during the first epoch only one case had an admission temperature above 37.5°C, one patient (2%) had a temperature above 37.5°C during the second epoch and during the third epoch three cases (6%). It is reassuring that these numbers remained low; however, care must be taken to ensure that hyperthermia does not persist following admission to the neonatal intensive care unit.

Involvement of all disciplines was required for this change in clinical practice to be successful. One of the concerns frequently raised by operating theatre staff and surgeons was the concern regarding risk of increased wound infection with increasing the ambient room temperature. There is now a growing body of evidence suggesting that there are a number of benefits of perioperative normothermia including reduced wound infection, reduced hospitalisation, earlier extubation and reduced blood loss, in comparison to allowing mild hypothermia which usually occurs with surgery performed without any warming of the patient or ambient room temperature.^{20–24}

Shivering in women about to undergo caesarean section is common, and neuraxial anaesthesia may increase this due to lower body sympathectomy producing core-to-peripheral redistribution of heat. Horn *et al.* found that with pre-warming prior to epidural insertion and throughout caesarean section that there was decreased maternal shivering and that the neonate had a higher core temperature and umbilical vein pH.²⁵ Given these findings, and improved surgical outcomes with perioperative warming, increasing the ambient operating theatre temperature appears to be of low risk with significant benefit to both the mother and the neonate.

Conclusions

Increasing the ambient operating theatre temperature and wrapping in polyethylene improves the admission temperature

of premature infants, particularly those less than 28 weeks gestation. Larger studies are required to determine whether this results in long-term benefit in respect to mortality and morbidity.

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