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Review

Importance of maintaining the newly born temperature in the normal range from delivery to admission

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SUMMARY

Over the last 50 years an increasing amount of evidence on neonatal resuscitation and stabilisation practices has led to written recommendations on all aspects of newborn care in the first few minutes of life. Much evidence for thermoregulatory management of both term and preterm infants has existed for decades and more recently research has identified new techniques to maintain normothermia in newly born infants. The use of increased environmental temperatures, skin-to-skin care, radiant warmers, plastic coverings and hats, exothermic mattresses and heated humidified gases have or are undergoing evaluation. However, despite the apparent acceptance of these techniques, a substantial number of infants continue to become hypothermic soon after delivery, leading to an increased risk of comorbidities and of death. Gaps in our knowledge remain and further research opportunities are available. However, we must also ensure that established thermoregulatory methods for which the evidence already exists are given as much emphasis as other aspects of newborn care and are implemented meticulously in all healthcare settings.

1. Introduction

The last 50 years have seen a significant increase in the published evidence regarding neonatal resuscitation and stabilisation practices. Since 2000 the International Liaison Committee on Resuscitation (ILCOR) has reviewed available evidence regularly which has led to an increase in animal and human research upon which to base recommendations [1]. The World Health Organization has also produced written recommendations for use in healthcare settings with varying levels of resources [2]. Recent ILCOR recommendations have referred to use of oxygen, airway management and ventilation, cord-clamping, circulatory stabilisation, and neuroprotective measures such as therapeutic hypothermia for term infants [1]. However, despite advances in these areas of neonatal resuscitation, maintaining a newborn infant's temperature within the desired range remains a challenge. Guidance on thermoregulatory techniques, such as skin-to-skin contact, and drying and wrapping, has been an initial and integral part of newborn life support algorithms [1,3–5] even before guidance on airway management. However, infants continue to suffer cold stress in all health care systems [6–11].

This review summarises both past and current evidence, which emphasises the vital importance for maintaining normothermia at birth in all but the most specialised of situations. Failure to do so increases mortality and morbidity at all gestations. The best approach to achieving normothermia is also summarised as well as gaps in knowledge.

2. Why is it important?

Pierre Budin may have been one of the first neonatologists with an appreciation of thermal control in the newborn. In *The nursling* (1907) he emphasised its importance after noting a markedly increased survival rate when infants' rectal temperature was maintained [12]. Sadly his observations were never fully understood or applied during the first half of the 20th century and there was confusion about the relative effects of temperature and humidity.

In the 1950s Silverman et al. [13] reconfirmed Budin's work, finding that 83.5% of infants nursed in incubators with higher ambient temperatures (31.7 °C) survived compared with 68.1% of those nursed in incubators with lower ambient temperatures (28.9 °C). When categorised by birth weight (>1500 g, 1001–1500 g and <1001 g) this difference in survival persisted and was particularly marked in the infants weighing <1001 g (50% of those infants nursed in the warmer incubators survived compared with 14.3% of infants in the cooler incubators). The group also confirmed that it

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was temperature maintenance rather than humidity that improved survival [14,15]. In 1964 Buetow and Klein [16] reported their comparison 'study' infants cared for in incubators that maintained a skin temperature of 36 °C ± 0.2 °C for the first 96 h of life with 'control' infants cared for in standard incubators with ambient temperatures of 31.1–32.2 °C. In infants weighing 1251–1500 g survival was significantly higher in the 'study' group than in the 'control' group (79% vs 54%, $P = 0.01$), although no difference between the two groups was seen in infants weighing 1000–1250 g. Unlike the work of Silverman this study was not randomised and might have been open to substantial bias. Also it covered the first hours and days of life, rather than the first few minutes of life that are the remit of this paper. However, the key message from these studies is crucial and was highlighted more than 50 years ago – hypothermia after birth increases mortality.

Subsequent work demonstrated that hypothermia is associated with an increased metabolic rate [17] and a variety of clinical sequelae such as respiratory distress [18–23], peripheral oedema [24], poor feeding and weight gain [25], an increased tendency to bleeding (particularly pulmonary haemorrhage [24] and intraventricular haemorrhage [26]) and abnormal clotting [27], infection [8], hypoglycaemia [24], necrotising enterocolitis [28], and acid–base balance disturbance [17]. Many of these findings were not replicated in a recent study by Laptook et al. [8] but this may reflect the limitations in methodology of all reported studies.

As thermal care at birth has been included in guidelines for the past 50 years, and more recently in international consensus documents [1] and WHO guidelines [2], it may be thought that hypothermia was a problem of the past. However, two large studies in the USA [8] and the UK and Republic of Ireland [6,7] have demonstrated that hypothermia on admission to neonatal intensive care units (NICUs) remains an issue in preterm infants, and studies from resource-poor settings show that hypothermia in term babies remains a significant issue worldwide [9–11,29].

The associated risks of hypothermia in preterm infants increase starkly with the degree of hypothermia and with prematurity [8,10]. In a retrospective observational study Laptook et al. [8] reviewed the admission temperatures of 5277 inborn infants with a birth weight of 401–1499 g born in several centres within a research network. The mean admission temperature was 35.9 ± 1 °C with 46.9% of infants being admitted with temperatures of <36 °C and only 10.8% of infants admitted with temperatures ≥37 °C. Multivariate analyses showed no association between admission temperature and morbidities such as necrotizing enterocolitis and grade III–IV intraventricular haemorrhage. However, there was a significant association between admission temperature and late-onset sepsis and mortality. For every 1 °C decrease in admission temperature below 36.5 °C there was an 11% increase in the odds of developing late-onset sepsis (odds ratio: 1.11; 95% confidence interval: 1.02–1.20) and 28% increase in the odds of dying (1.28; 1.16–1.42) (Table 1). Costeloe et al. [6,7] reported similar findings in two large epidemiological studies of infants born extremely prematurely. In the first study [6], a cohort of 811 infants born at <26 weeks of gestation were admitted to NICUs in the UK and the Republic of Ireland during a 10-month period in 1995. The median birth weight was 695 g [interquartile range (IQR): 610–786 g]. A total of 306 infants (40%) were hypothermic on admission (hypothermia defined as first recorded temperature <35 °C). Hypothermia was independently associated with death before discharge from hospital and with oxygen dependency. In 2006, a cohort of 1686 infants born at <27 weeks of gestation was admitted to neonatal units in England [7]. The median birth weight was 750 g (IQR: 639–870 g). Admission temperatures were much improved with 14% of infants having a first recorded temperature of 35 °C. However, hypothermia remained an independent risk factor for death and for oxygen dependency.

In low-resource settings the point prevalence of hypothermia has been described in hospital-based studies [9,11,29–38]. These studies are difficult to compare because of differing practices, resources, ambient environmental temperature and definitions of hypothermia. The prevalence varies with ranges of 25.6–94.9% below 36.5 °C, 85–88% below 36 °C, and 2.9–8.1% below 35 °C [9,11,29–38]. However, a large proportion of deliveries in low-resourced settings are at home or in the community, making selection bias a further impediment to interpretation of hospital studies. In a population in Nepal more than 23 000 babies had axillary temperatures measured daily for the first 4 days after birth, then every other day until mid-way through the neonatal period, and then on days 21 and 28 [10]. Mullany et al. [10] found that 21 459 of 23 240 babies (92.3%) had one or more axillary temperature measurements <36.5 °C, half of babies were moderately-to-severely hypothermic, and risk peaked in the first 24–72 h of life.

Table 1
Population-based papers since 1999.

Study	Assumed risk comparison	Relative effect on mortality (95% CI)	No. of participants (studies)	Country of study; comments
Costeloe et al. (2000) [6]	≥35.0 °C	OR: 0.58 (0.39–0.85)	4004 births 811 babies admitted	Whole UK: hospital-based, <26 weeks of gestation
Da Mota et al. (2003)[29]	<35.9 °C vs 36 °C	RR: 3.09 (2.15–4.43)	320	Brazil, hospital-based
Laptook et al. (2007) [8]	For every 1 °C reduction in temperature from 36.5 °C the risk of dying increased by 28%	OR: 1.28 (1.16–1.41)	5227	USA: multicentre, hospital
Ogunlesi et al. (2008) [9]	Hypothermia <36.5 °C	CFR, RR: 2.26 (1.14–4.48) Outborn vs inborn, RR: 0.34 (0.16–0.74)	150	Nigeria: hospital and home, death through to 6 months
Sodemann et al. (2008) [11]	<34.5 °C within first 12 h	MR: 4.81 (2.90–8.00) (<7 d) MR: 2.55 (1.29–5.04) (8–56 d)	2926	Guinea-Bissau, West Africa: hospital, home
Mullany et al. (2010) [10]	Mild hypothermia Moderate hypothermia Severe hypothermia Preterm	RR: 1.70 (1.23–2.35) RR: 4.66 (3.47–6.24) RR: 23.3 (4.31–126) RR: 12 (6.2–23)	23 248	Rural Nepal: field workers visiting homes
Miller et al. (2011) [26]	Moderate hypothermia Severe hypothermia	OR 1.50 (1.30–1.90) OR 5.60 (1.1 to 28.1)	8782	USA: multicentre, hospital
Costeloe et al. (2013) [7]	≥35 °C	OR 0.75 (0.56–1.00)	3113 births, 1686 admissions for intensive care	England, <27 weeks of gestation

CI, confidence interval; OR, odds ratio; RR, relative risk; CFR, case fatality rate; MR, mortality ratio.