Temperature monitoring and control in the newborn baby

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Abstract

The importance of keeping the newborn baby warm has been known for centuries but worldwide in the 21st century hypothermia remains a major contributor to neonatal mortality. Although less of a problem in high income countries there is evidence that low temperatures have an impact on outcome at vulnerable times, particularly in the baby born preterm. It is clear that if we are to see further improvements in mortality and morbidity in the most immature babies there must be careful attention given to all aspects of basic neonatal care, including thermoregulation. Continuous dual temperature monitoring has advantages over intermittent measurements and is the method of choice in the immature and sick newborn. There is no evidence of any differences in outcome between radiant heaters or incubators. Whichever device is used fluid and heat loss from evaporation due to high transepidermal water loss remains a problem. This is best managed by increasing environmental humidity but the optimum level of added humidity, and the length of time that this should be applied, is still unknown.

Keywords temperature monitoring: devices and methods; temperature support: devices and techniques

Introduction

Outcome for the newborn, and in particular the preterm, baby improved dramatically in the latter half of the 20th century. There were many contributory factors with the understanding of temperature control being one of the major influences. Since the mid 1990s there has been much slower, if any, change in overall rates of mortality or morbidity. It is unlikely that the dramatic changes of the past will be seen again and further improvements in outcome will be more difficult to achieve and of a smaller scale. It is increasingly important that careful attention is given to the basics of neonatal care and that lessons from the past are not forgotten.

Thermoregulation

Heat is produced as a by-product of cell metabolism and is lost or gained with the environment through conduction, radiation, convection and evaporation. Children and adults are homeothermic, maintaining a constant deep body temperature over a wide range of ambient thermal conditions. The newborn infant, by comparison, can only achieve control of temperature over a narrower range of ambient conditions. The preterm infant has even greater difficulty and the most immature behave at times as if they are poikilothermic — their body temperature drifting up and down with the ambient temperature. The range of ambient temperature over which an infant can maintain body temperature, with minimal energy expenditure [thermoneutral range (NTR)], is very narrow in the immature infant. As environmental temperature moves outside this range, the infant adopts different strategies to maintain normothermia.

If the environment is cooler than the body, metabolic heat production increases. Catecholamine release stimulates the oxidation of brown adipose tissue distributed in the neck, between the scapulae and along the aorta (non-shivering thermogenesis). The term baby can alter body posture and skin blood flow reduces as the superficial capillaries constrict. As environmental temperature falls further outside the NTR, heat production reaches a maximum and below this point deep body temperature falls. If the environment is hotter than the body, heat is gained through conduction and radiation, as in the use of skin to skin care and radiant heaters. When above the NTR, sweating occurs in the term infant.

Heat production is delayed during adaptation to extrauterine life, especially if there is immaturity, asphyxia, hypoxia or maternal sedative administration. The preterm infant, particularly below 28 weeks' gestation, has lower heat production per unit area and a more prolonged impairment of non-shivering thermogenesis. The immature infant is further disadvantaged because of increased evaporative heat losses — a consequence of high transepidermal water loss (TEWL) due to passive diffusion of water through a thin, poorly keratinized epidermis. The ability to alter skin blood flow and change posture are also impaired in the preterm infant as well as in the presence of illness. Sweating is delayed in the most immature newborns by 2—3 weeks, a result of neurological rather than glandular immaturity.

Thermoregulation and outcome

William Silverman and others showed, in a series of randomized controlled trials, that keeping small babies warm could result in an absolute reduction in mortality of at least 25% of that seen in the 1950s.This improvement was seen over all gestation and birthweight groups. The importance of humidity was recognized and, in the 1970s, Hammarlund and Sedin published data on the heat fluxes due to transepidermal water losses in the preterm baby. Recommendations for optimum environmental temperature settings, based on the concept of the neutral thermal environment, were developed and technological advances have improved the devices used to keep small babies warm.

By the 1990s the impression was that thermoregulation of the newborn was understood and well managed but, worldwide today, hypothermia is still a major cause of death after birth. The extent of this problem is such that the World Health Organization (WHO) has published guidelines on the management of the newborn aimed at reducing the deaths from hypothermia (http://whqlibdoc.who.int/hq/1997/WHO_RHT_MSM_97.2.pdf).

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Recent evidence has shown that poor management of temperature in the baby at vulnerable times can impact on outcome. Whether as a cause or consequence, low body temperature in newborns lead to increased metabolism and hypoglycaemia, reduced tissue perfusion, ischaemia and metabolic acidosis and has been shown to be inversely related to mortality.

The effects of hyperthermia are less well understood but in infants with moderate-to-severe hypoxic ischaemic encephalopathy, hyperthermia is associated with an increased risk of death or moderate-to-severe disability. There is little data on the effects of hyperthermia and the human preterm infant but in the preterm animal model, hyperthermia is associated with severe lung injury and increased inflammatory cytokine expression.

It is clear, more than 50 years after the work of Silverman, that thermal control, particularly of the immature infant, is still an important issue in need of further thought and study. Given the importance of thermoregulation two questions are paramount: how best to measure temperature and how best to maintain thermal balance.

Temperature measurement

The normal temperature

In day-to-day care the only means of assessing the thermal state of a baby is by measuring body temperature. Defining a 'normal' body temperature is difficult as this will depend on where, how, and the time of day/night when measured. The temperature within the tissues of the body varies with metabolic rate and there is no such thing as a single central body temperature. Normal temperature ranges for newborns have not been clearly established but published ranges for both term and preterm infants are:

- rectal at 36.5–37.5 °C
- axillary at 35.6–37 °C.

It has been suggested that conditions for thermoneutrality are met in very low birthweight infants when core temperature is between 36.7 and 37.3 °C and the central-skin temperature difference fluctuates less than0.2–0.3 °C/hour.

An infant may expend a large amount of energy to maintain a 'normal' central temperature. The preterm baby is at higher risk as a consequence of the very narrow NTR when compared with those born at term. Despite an apparent normal temperature the infant may well be thermally stressed and at increased risk of adverse outcome.

How, where and frequency of temperature measurement

The primary purpose of measuring the newborn's temperature is to detect cold stress as fever is an unusual symptom of illness and most often influenced by environmental factors. Treatment is often initiated on relatively small changes in temperature so devices used for measurement must be accurate, reliable and easy to use. In the newborn sites of measurement are: rectum, axilla or skin, although these all offer only an estimate of body core temperature.

Devices

Mercury in-glass thermometers were used for many years however with concerns about accuracy, the length of time to reach a stable point and risk of harm posed by mercury they are no longer used in most high income countries, except as a research tool for comparing new devices. More automated thermometers have become available that utilize electronic, infrared, chemical and liquid crystal technologies.

Electronic thermometers have temperature sensors inside the tip and are covered with a sheath. They are used in monitoring or predictive mode. In the monitor mode the temperature is displayed once a steady state has been achieved, usually about 3–5 min. With predictive mode the temperature is 'predicted' by a calculation based on the rate of rise in the few seconds of use. Tympanic thermometers have an infrared sensor that records heat radiated from the tympanic membrane. Temporal artery thermometers work by detecting changes in heat emitted from the superficial temporal artery (STA). The thermometer is moved across the forehead and as it passes over the STA there is a peak in the emitted temperature which is captured by the sensor. Chemical/liquid crystal thermometers work by placing a plastic strip, impregnated with temperature sensitive chemicals/crystals, against the skin. These change colour in response to variations in temperature.

Site and frequency

Intermittent rectal thermometry is used infrequently (the exception is during monitoring of therapeutic hypothermia where a continuous readout is given). As well as concerns about rectal trauma the reproducibility under clinical conditions is uncertain. This is affected by differences in the depth of insertion, dwell time, whether the baby has just passed stool and on the flow and temperature of the blood returning from the lower limbs. Axillary temperature is usually measured intermittently. There is little associated risk but error in measurement is observed depending on placement of the probe, adequate closure of the axillary pit, blood flow to the axillary region and possibly activation of non-shivering thermogenesis. Electronic probes and chemical/crystal strips attached to the skin have little associated risk and are used for both intermittent and continuous temperature monitoring. Accuracy of these techniques may be affected by environmental temperature, approximation of probe to skin and peripheral perfusion.

Continuous monitoring using electronic probes, if placed correctly, offer a close approximation to deep body temperature, particularly when using the 'zero heat flux' principle. With this technique a probe is placed over an area of skin from which no heat can be lost. The skin under the probe equilibrates with the deep body temperature as heat moves down the temperature gradient from core to skin. In practice this can be achieved when the baby is lying on its back on a non-conducting mattress with a probe placed between the scapulae. Measuring temperature intermittently gives a 'snapshot' of the baby's temperature; it tells nothing about the energy the baby may be expending to maintain that temperature. The continuous measurement and display of central (abdominal, axilla or zero heat flux) and peripheral (sole of the foot) temperatures gives an early indication of thermal stress by showing a change in the central–peripheral difference which occurs before any alteration in central temperature.

The preterm baby who appears to be comfortable in its environment has a central temperature in the normal range for whichever site is being used and a central–peripheral temperature difference of 0.5–1 °C. An increasing central–peripheral temperature difference, particularly above 2 °C, is usually due to cold stress (Figure 1), and occurs before any fall in central temperature. A high central temperature, particularly if unstable, along with a wide central–peripheral gap is seen in septic babies.

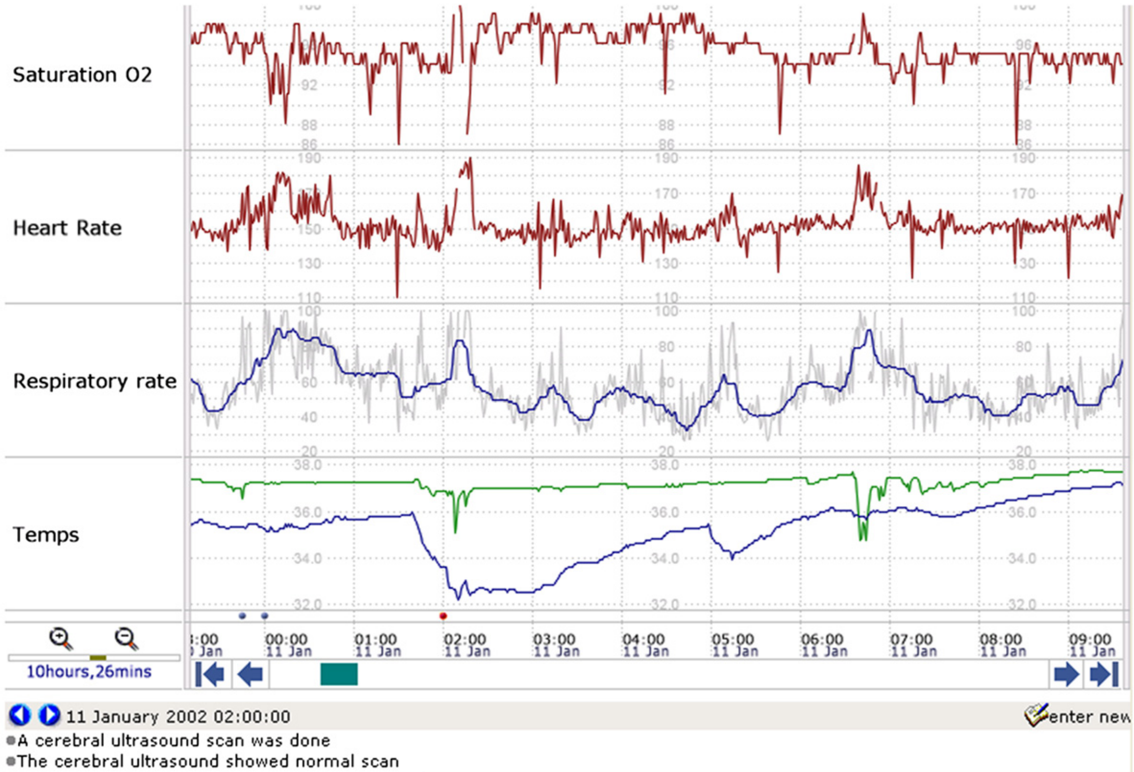

Figure 1 Central temperature shown in green; peripheral temperature shown in blue. At 01.45 h the incubator door is opened, the peripheral temperature falls dramatically with little change in the central temperature.

Variation due to device and measurement method

Accuracy of thermometers has been reviewed and according to manufacturing standards, devices should be within ±0.2 °C across a wide temperature range. However, many manufactures indicate an accuracy of ±0.6 °C when used in predictive mode. Such differences could result in some intervention if the infant's temperature is at the margins of the normal range.

Many factors may be responsible for the failure to develop a consensus recommendation for temperature monitoring in neonatal care. Studies differ in thermometer, population case mix and sample size and the external heat sources used. There are major problems with the variation in statistical methods used when comparing devices. Use of the correlation coefficient is inappropriate, when comparing any device or method of recording a physiological parameter, as this measures strength of a relationship rather than agreement. Bland and Altman propose that by comparing the individual differences between two measurements, in the context of the mean of their combined readings, will better assess the agreement of the device/technique. Recent studies have compared temperature measurements comparing electronic rectal and axillary thermometers, an infrared temporal artery thermometer and an electronic axillary thermometer against an indwelling rectal probe and an electronic and an infrared axillary skin thermometer against a glass mercury thermometer using this technique in the neonatal population. The mean difference between devices range from 0.1–0.3 °C however there are wide 95% limits of agreement giving a variability of between 0.8 and 1.7 °C.

These few small studies suggest that there is a large variation between methods and this is of concern in clinical practice. Although the mean difference is small, and of no consequence to clinical decision-making, the degree of variability suggests that interventions may be carried out unnecessarily in some infants and not at all in others when they would be appropriate. These concerns further strengthen the argument in favour of using continuous monitoring of dual temperatures as a means of following trends rather than concentrating on absolute values of intermittent measurements.

How best to maintain temperature

Simple methods for preventing heat loss are well known – a warm delivery room, drying, wrapping and applying a hat, skin to skin care or lying baby on a non-conducting mattress, breastfeeding, warm resuscitation and transportation. Despite this knowledge there are still reports of 'cold' babies in both high and low income countries. Most trials on temperature maintenance have focused primarily on how best to keep immature infants warm. Although the lowest acceptable admission temperature is not known, it is suggested that temperatures should be above 36 °C in this group. Trials have generally looked at two approaches, barriers to heat loss or supplemental heat application.

At birth the baby will lose heat rapidly, particularly due to evaporation. Heat losses can be minimized, as described above, but many preterm babies are cold on arrival in the neonatal unit. Heat from radiant heaters is often insufficient to compensate for the large losses due to evaporation. To overcome this, babies are wrapped in polyethylene occlusive skin wraps or placed into plastic bags to reduce TEWL. One systematic review of five studies utilizing plastic wraps/bags and stockinet hats showed that infants less than 28 weeks gestation who were wrapped were warmer on admission to the NICU (WMD 0.76 °C; 95% CI 0.49, 1.03) but no such effect was seen in the stockinet trial. However, two of the trials included in the systematic review showed that, although admission temperature had increased with the use of plastic wraps, over a third of babies were still admitted with a temperature less than 36.5 °C. Another technique, the use of gel warming mattresses, has also been trialled. In each of these trials the warming mattress contributed to an increase in the admission temperature of the baby. While this is seen as an improvement, between 3 and 55% babies were admitted to the NICU with hypothermia (temperature less than 36.5 °C) and 1–28% of babies had an admission temperature of more than 37.5 °C. Despite the recognized association between low temperature and poor outcome no trial to date has shown that measures to improve admission temperature has resulted in lower morbidity or death before discharge.

The optimum management of the thermal environment during ongoing neonatal care has been discussed in the literature. No study has shown any significant difference in outcome for babies nursed using either radiant heater or incubator. It is important that units consider seriously the management of the thermal environment of the preterm baby but the choice of device used is a matter of individual preference. However, whichever method is adopted, evaporative fluid losses remain a major challenge in the management of the preterm baby.

The skin barrier of the preterm baby is immature and there is a high water concentration gradient between the body and the external environment. This results in TEWL with the gradient being very steep if the ambient water vapour pressure is low. The more immature the baby the steeper the gradient and higher the losses, and this is exacerbated if the skin is further damaged during neonatal care procedures. The skin matures rapidly after birth and, in practical terms, TEWL falls to around that of the term baby within 10–14 days of age. The most effective method of reducing TEWL is by an increase in environmental humidity around the baby. In the baby under 28 weeks' gestation this should be maintained for at least the first 10 days of life and is most easily achieved by the use of humidified incubators. A plastic cover can be used with radiant heaters but it must be remembered that there will be rapid fluid losses whenever this is removed for any procedure. Covering the skin with a semi-permeable/impermeable membrane, or the use of emollients, creates a barrier reducing TEWL. Whilst these have been shown to reduce TEWL, in some studies they have been associated with an increased incidence of bacterial and fungal infection.

Movement of water through the skin is important in the maturation process however the optimum level of environmental humidity is as yet unknown as prolonged exposure to relatively high ambient humidity delays the establishment of an effective skin barrier structure and function.

Conclusions

The importance of keeping babies warm has been recognized for centuries. However, even in the 21st century, our understanding of what is a normal temperature and how best to measure it still remains a challenge. In clinical practice decisions must be made on which method of measurement to use, whether intermittent or continuous monitoring is appropriate and how the data are interpreted and acted upon. There are, as yet, no good data to guide us in deciding on the optimum management of the baby's external environment. What is clear is that this important area of care can no longer be considered to be a 'problem solved'. A practical approach is to try and understand what it is that you are trying to achieve, knowing the advantages, disadvantages and limitations of the instruments and techniques that are available to you and not assume approaches for assessing a temperature are interchangeable. ◆

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Practice points

- Methods of measuring temperature are not interchangeable and it is vital that staff understand the limitations of the devices they use if unnecessary treatment changes are to be avoided.