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Thermal Stability of the Premature Infant in Neonatal Intensive Care

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ABSTRACT

Hypothermia continues to be a problem for premature infants being cared for in neonatal intensive care because care and procedures expose infants to cold environmental temperatures and infants have immature thermoregulation. Researchers continue to study this problem in order to optimize care with evidence based thermal practices. This paper reviews current research and recommendations to give nurses evidence to formulate thermal stability guidelines for premature infants as well as areas where more research is needed.

Even though more than sixty years have lapsed since Silverman[1] and colleagues first showed neonatal hypothermia is associated with increased mortality, thermal stability for premature infants in the neonatal unit continues to be a problem requiring constant attention. Researchers continue to search for optimal thermal practices to prevent cold stress, ensure thermal stability, and minimize energy expenditures in the premature infant. However, there are very few evidenced based standards to use as guidelines for nurses caring for infants in the NICU. This review will present current research related to thermal stability of the neonate and offer guidelines for optimal thermal care for the premature infant in intensive care.

Normal Body Temperature

The main goal of achieving thermal stability in a premature infant is to maintain a normal body temperature. Before we can discuss ways in which this goal can be accomplished, we first need to agree on the definition of normal body temperature. Temperature will vary with the site that is measured and the device with which temperature is measured. Neonatal textbooks give general temperature ranges for premature infants by site with rectal being 36.5 °C to 37.5 °C, skin as 36.2 °C–37.2 °C, and 36.5 °C to 37.3 °C for axillary sites.[2] The 2012 American Academy of Pediatrics/American Congress of Obstetricians and Gynecologists prescribe an axillary temperature standard of 36.5 °C in the delivery room and an axillary temperature range of 36.5 °C to 37.4 °C prior to discharge for an infant in an open crib in clothing.[3] Therefore, it should be a minimal safe standard to require all infants in the NICU maintain an axillary temperature of at least 36.5 °C. Because extremely low birth weight (ELBW) infants are more like poikilotherms (similar to a cold blooded animal or reptile) and have unstable body temperature which tends to follow environmental temperature, these infants should be kept warmer to minimize the chance of cold stress.[4] We previously found that ELBW infants have more stable heart rate values when kept at a central skin temperature of 36.8 °C to 36.9 °C during their first day of life.[5] Our research and that of others have also underscored the importance of monitoring two temperature sites on premature infants while cared for in the NICU.[6–8] ELBW infants have immature thermoregulation and have periods of time where they keep their peripheral temperature warmer than their central temperature.[6,7] This state is undesirable and may increase the chances of morbidity. It is imperative to monitor for this condition and minimize procedures, feedings and stimulation to the infant if the central temperature is low. Good temperature monitoring and adherence to a minimum axillary temperature level such as 36.5 °C are the first important steps to thermal stability.

The Thermal Environment

Infants less than about 32 weeks gestational age have immature thermoregulation and cannot maintain a normal body temperature without auxiliary heat to their environment.[9] Standard of care dictates a premature infant should be housed inside an incubator, under a radiant warmer or with additional heat to their body through a heat mattress or by skin to skin care from a parent. This additional heat will help prevent heat loss and prevent cold stress. To prevent heat loss during transfers from these environments or during care, the air temperature inside a NICU or a delivery room should be kept warm.

Incubators

These devices were developed in the 19th century and the first incubator was a double walled zinc tub developed at a Russian hospital in 1835.[10] Tarnier invented the first enclosed, heated air incubator which was used in a Paris hospital and has evolved into the modern day incubator. Standard incubators provide heated air with a fan device to circulate the air, high visibility walls, a servo-control device to monitor the infant's body temperature and provide a feedback control to regulate the heated air environment as well as

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provisions to add humidity to the environment. Some disadvantages to this device are that it is costly to maintain and run, it forms a barrier between the infant and the family, and it is potentially hazardous to the infant from the warm moist environment, heating elements and the use of electricity. The benefits far outweigh the disadvantages and researchers have established the benefits to the premature infant of thermal stability, less energy expenditure, better growth, and improved survival over the last sixty years due to the incubator environment.[1,11–13]

A Cochrane Review that was last updated in 2009 examined double versus single walled incubators through a meta-analysis of three research studies.[14] These authors found double wall incubators have advantages over single wall incubators in that they decrease heat loss, decrease the need for heat production, decrease radiant heat loss and reduce oxygen consumption in the premature infant, while having a minimal increase in conductive heat loss. The authors concluded that all these effects were small but important; however, there were no long term benefits seen in infant outcomes, mortality or length of stay. If double wall incubators are available, then their use is warranted due to short term benefits but in countries where resources are reduced, single wall incubators will provide the same long term outcomes for thermal stability.

Whether the incubator in use is single wall or double wall, it is important to monitor body temperature while the infant is inside the incubator, as well as the inside incubator air temperature. Early research has confirmed that controlling the air temperature for an infant can be just as effective on reducing heat loss as controlling infant temperature using servo-control.[15] The most important aspect of controlling an infant's temperature inside an incubator is deciding at what value the infant's temperature should be maintained – or the normal body temperature desired – and monitoring temperature frequently enough so that the desired normal body temperature is achieved. If a body temperature of 36.5 °C is desired, then the servo should be set at 36.5 °C and the abdominal skin temperature should be monitored to make sure it stays at approximately 36.5 °C. Changing servo-control temperature frequently, due to variations in infant temperature, results in broad swings in the infant's body temperature. It is better to trouble shoot fluctuations in body temperature and aim towards resolving the cause of the fluctuation, along with using axillary heat if necessary.

Radiant Warmers

Another Cochrane review was conducted by Flenady & Woodgate in 2003 with no additional updates on the use of radiant warmers versus incubators in the thermal care of premature infants.[16] All studies on this comparison were done in the 70s and 80s. From the eight studies reviewed, the authors concluded that radiant warmers cause a statistically significant increase in insensible water loss (IWL) and a trend towards increased oxygen consumption which was not statistically significant. Radiant warmers are often used to stabilize infants following delivery room resuscitation, for procedures not conducive to the confined space of an incubator, and for transportation of the infant for surgical interventions. There are no recent research studies related to radiant warmers; however, there is one report of neonatal hyperthermia under a radiant warmer.[17] In this report, a 38 week, 3.6 kg infant admitted to the NICU for Ebstein's anomaly was under a standard radiant warmer (Giraffe Warmer, GE Healthcare) set to servo-control mode at 36.5 °C, measured on the abdominal skin. The infant was in an observational research study, thus having temperatures measured and recorded frequently. The clinicians observed a peak value of 38.8 °C when the warmer malfunctioned and delivered 100% heat output due to the servo reading a lower temperature than what the infant actually measured. Fortunately, the nurse turned off the warmer because of the infant's measured temperature. This care report underscores the importance of measuring an infant's temperature periodically even though temperature readouts are available from monitoring devices.

Humidity

Thermal care of the premature infant has included added humidity to the incubator environment for at least 50 years. Blackfan (1933) was the first researcher to show the importance of using added humidity with neonatal care.[18] Evaporative heat loss is the largest source of heat loss in that heat leaves the infant's body through the skin.[19,20] Transepidermal water loss has also been found to be inversely related to gestational age.[21] Therefore, standards dictate infants of the lowest gestational ages receive increased amounts of humidity. Researchers have continued to show the benefits of humidity in improving thermal stability, fluid and electrolyte balance, and skin integrity by reducing evaporative heat and water losses.[22–25] But still today, there are no standards as to how much humidity should be in an incubator and for how long should it be used.

Practice Variations

Current survey research has showed there are varied practices world-wide concerning use of humidity with no definite standard of care. A study of 26 NICUs in New Zealand and Australia showed all centers surveyed used humidity but only 77% had protocols to guide its use.[26] More than 80% of centers surveyed started humidity at a higher level greater than or equal to 80% RH. There was a wide variation in practice in respect to which infants received humidity and as to how long humidity was used. Infants were placed in humidity up to 37 weeks gestational age and for anywhere between 3 and 77 days. Initiation of humidity into the incubator environment was anywhere from admission to 72 h of age and it was used up to 28 days. Six of the centers provided humidity greater than or equal to 70% beyond 14 days of life. Another 2012 survey of French NICUs confirmed the wide variation in practice.[27] All of these units used humidity between 45% and 100% RH, but amount and duration varied according to gestational and postnatal age. Mean values from these 186 NICUs were 80% $\pm$ 15% for infants less than 28 weeks gestational age and 68% $\pm$ 21% for infants above that gestation. Infants in these units are cared for at 75% $\pm$ 20% if less than 7 days of age or 69% $\pm$ 20% if older.

Humidity Studies

One study conducted a retrospective review of 87 infants cared for in incubators without humidity compared to 95 infants nursed in high humidity between 2002 and 2005.[28] Infants in the humid environments received humidity at 70%–80% for the first week which was decreased to 50%–60% the second week until each infant was 30–32 weeks post menstrual age. Body temperature was servo-controlled between 36.5 °C and 37.5 °C in both groups. Although body temperature was comparable in both groups, there was less fluid intake, urine output, and insensible water loss, as well as less maximum weight loss and lower incidence of hypernatremia during the first week of life in the high humidity group. The high humidity group also had an increased incidence of hyponatremia on the first day of life compared to the group with no humidity. These researchers did not find a significant increase in incidence of infection in the high humidity group as previous studies have found.[22]

Risks to Using Humidity

Although there are many benefits of using humidity for the care of ELBW infants, one risk to using humidity is a delay in the maturation of the skin barrier. Agren et al. (2006) showed that transepidermal water losses were higher and the gradual decrease in those losses delayed in infants cared for at 75% as opposed to 50% relative humidity