CAPQuaM Perinatal Construct

Literature Review

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Submitted by:
The Joint Commission
One Renaissance Boulevard
Oakbrook Terrace, IL 60181

Executive Summary

Neonatal hypothermia after birth is a world-wide issue that has been associated with infant morbidity and mortality. There is demonstrated variation with respect to defining routine care around hypothermia, and the debate continues in terms of the methods and accuracy of temperature measurement. Despite the variations in methods it has been demonstrated that interventions to warm infants do improve outcomes.

This literature search was focused on the following key concepts:

- Variability in Processes of Perinatal Care
- Temperature Control/Hypothermia
- Mechanisms to Maintain Body Temperature
- Barriers to Thermal Regulation
- Accuracy of Temperature Measurement
- Equity & Disparities

Care processes were determined based upon the variable physiological risk factors of the premature infant. These risk factors put infants at risk for hypothermia and are associated with adverse outcomes. Variability in care is due to the fact that individual infant characteristics determine the necessary interventions to attain normothermic temperature upon admission to the NICU.

Hypothermia upon admission to NICU is directly correlated with poor outcomes, intraventricular hemorrhage and death. This literature search demonstrated support for known interventions to protect extremely low birth weight (ELBW), very low birth weight (VLBW), low birth weight (LBW), small for gestational age (SGA), preterm, and premature babies from hypothermia upon admission to the neonatal intensive care unit (NICU). The aim of these interventions is to ensure neonatal survival.

Mechanisms to decrease hypothermia were examined. Interventions used during labor and delivery were evaluated for outcome effects. Key interventions identified were: control of the delivery room environment, use of warming and humidifying systems, and procedures tested to prevent heat loss. It was noted that heat loss is significant during transport of the neonate from the delivery room to the NICU. Skin to skin contact demonstrated to prevent heat loss during the transition phase from womb to birth, is also beneficial during transport.

The acuity of the neonate, specifically the need to resuscitate, creates a challenge to thermal management. Barriers identified were specific to the physiological state of the newborn and its ability to self-regulate temperature. Although some sources consider skin to skin contact a barrier to the management of temperature, others determined that it does not interfere with temperature regulation when done correctly.

Accurate temperature measurement in the neonate is a critical intervention. There are a number of factors that impact accuracy:

- Room temperature
- Incubator types
- Timing and frequency of temperature assessment
- Exposure of the baby
  Position of the baby

- Type of thermometer
- Site of temperature measurement

Conflicting information was found on temperature site recommendations. Most studies recommend the axillary site for temperature assessment. However, some studies discouraged the use of axillary sites due to low correlation with core temperature. Indwelling rectal temperatures were most accurate for core temperature assessment. Skin temperature readings were found to be more indicative of hypothermia. Accurate measurement of temperature helps to manage hypothermia; however it is not correlated with improvement in neonatal outcomes.

The literature review process yielded few sources that provided direct information on systematic variations of thermal management in relation to diverse populations. The findings touched on the potential for diversity based upon prenatal care, mode of delivery (i.e., cesarean section), and the location of birth.

Neonatal hypothermia is directly correlated with poor outcomes. There are a number of variables that impact neonatal temperature control, mechanisms to maintain heat or prevent heat loss. Despite the variations, it has been demonstrated that interventions to warm infants do improve outcomes.

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I. Methodology

The work began with a review of the Perinatal Construct Table. The search process was guided by six concepts within the construct:

1. Variability in Processes of Perinatal Care
2. Temperature Control/Hypothermia
3. Mechanisms to Maintain Body Temperature
4. Barriers to Thermal Management
5. Accuracy of Temperature Measurement
6. Equity and Disparities

The search was conducted from December 2011 – March 2012. 742 citations retrieved, 63 sources used.

PubMed Search

The following strategies were used:

Search 1

Search terms:

"body temperature regulation" [Mesh] AND "Infant, Newborn" [Mesh], "body temperature" [Mesh] AND "Infant, Newborn" [Mesh], "hyperthermia [majr] AND "Infant, Newborn" [Mesh], heating [Mesh] AND "infant," newborn" limited to English language, but not limited by year of publication.

(Mothers [majr] OR pregnancy [majr]) AND ("healthcare disparities" [Mesh} OR "health disparities" [Mesh] OR "minority health" [Mesh OR "cultural diversity" [Mesh]) Limits English, published in last 10 years.

Search 2

Search terms – "newborn normothermia" or "newborn hypothermia" (no limits), for non-indexed citations.

Web Search

- An internet search was performed using keywords similar to the ones used for the PubMed search.
- Additionally the following terms were searched: "African American," "Native American," "Hispanic American" AND "temperature regulation." "Rural vs. Urban care of the neonate," AND "hypothermia."
- The National Quality Forum (NQF) website was searched for NQF endorsed performance measures.
- The Agency for Healthcare Research and Quality (AHRQ) National Guideline Clearinghouse site was searched.

Search Considerations

- Some resources were not used because it was deemed that the studies were too focused on limited topics, and small patient volumes i.e., babies with malformations, and studies on intrapartum medications and subsequent impact on neonate presentation.
- Resources used included those related to the care of the neonate.
- Studies used included normal newborns, premature and very premature infants, and babies of SGA, LBW, VLBW and ELBW.
- Resources citing long term outcomes were limited. There was one study that considered infants through 18 months of age.

II. Variability in Processes of Perinatal Care

Summary

This review of literature indicates that variation in interventions may be associated with poor outcomes. Infant characteristics such as age, Apgar score and weight contribute to the variation in interventions to prevent hypothermia upon admission to the NICU. Hypothermia upon admission to the NICU is associated with intraventricular hemorrhage and death.

Variations in the management of neonates during transition from intrauterine to extrauterine life may be associated with poor outcomes. Heat loss is significant during transport of the neonate from the delivery room to the NICU.

As noted above, infant characteristics determine the variation of the care that is employed. Management of heat loss as well as temperature regulation is varied among healthcare organizations. Interventions that have been found to affect this are noted below:

- Positioning of infants has lead to variation in temperature control.
- Skin to skin contact prevents heat loss and has been found beneficial during transport.
- The use of double walled incubators in the NICU is found to control heat loss.
- Massage therapy was found to increase infant temperature.

Bibliography

Antonucci, R., Porcella, A., & Fanos, V. (2009). The infant incubator in the neonatal intensive care unit: unresolved issues and future developments. *Journal of Perinatal Medicine*, 597-598.

During transport, thermo control is lost. Most transport incubators operate off less battery power, and cannot modify humidity. In infants of VLBW, high evaporative losses are due to the inadequate keratinization of the skin, which becomes functionally mature at 32-34 weeks gestation. This high transepidermal water loss (TEWL) may result in hypothermia.

For healthy skin development, VLBW infants should be kept at 80-90% humidity until their skin functions. Newborns' physical structure puts them at risk for heat loss, large head, body surface area in relation to weight, and little subcutaneous fat.

Amari, A., Schulze, K., Ohira-Kist, K., Kashyap, S., Fifer, W., Myers, M., & Sahni, R. (2009). Effects of body position on thermal, cardiorespiratory and metabolic activity in low birth weight infants. *Journal of Early Human Development, 85*, 497-501.

Six hour continuous recording of absolute surface temperature profiles, cardio respiratory activity and oxygen and carbon dioxides exchange, along with minute to minute assessment of behavior sleep states were performed on in 32 healthy growing LBW infants. Despite thermoregulatory adjustments in cardio respiratory function, infants sleeping prone have relatively higher body temperature. The cardio respiratory responses to this modest increase in temperature indicate that thermal and metabolic control of cardiac and respiratory pumps seem

to work in opposition. Prone position has been found to increase peripheral perfusion. Circulatory efforts in prone position are weighed more favorably in terms of thermal stability. Infants sleeping in prone position have relatively higher body temperature.

Bissinger, R., & Annibale, D. (2010). Thermoregulation in very low birth weight infants during the golden hour, results and implications. *Advances in Neonatal Care, 10*(5), 230-238.

- Warm the delivery room to 78-80^0 with 50% humidity
- Polyethylene wrap the baby before drying - reduces insensible water loss by 70%, when the wrap is left in place, decrease insensible water loss by 30%.
- Transwarmer mattress
- Woolen hats
- Drying the baby - patting technique and avoid rubbing the baby to destroy fragile growth of epidermis.
- Preheated radiant warmer

Bystrova, K., Matthiesen, A., Vorontsove, L., Widstrom, A., Ransjo-Arvidson, A., & Uvnas-Mobert, K. (2007). Maternal axillar and breast temperature after giving birth: effects of delivery ward practices and relation to infant temperature. *BIRTH, 34*(4), 291-300.

Axillary and breast temperature rises in all mothers after birth. Breast temperature increased in skin to skin contact mothers. A positive correlation is found in skin to skin mothers, maternal axillary temperature, and infant foot temperature within 90 minutes. Infant foot temperature rose 2 times higher than mother axillary temperature. Skin to skin contact as well as early suckling increased temperature variation. There was a correlation between mother temperature increase and baby foot temperature increase.

Diego, M., Field, T., & Hernandez-Reif. (2008). Temperature increases in preterm infants during massage therapy. *Infant Behavior and Development, 31*, 149-152.

Study of 72 pre-term infants indicates that massage therapy is safe to use in pre-term infants in isolettes. Additionally the findings highlight the contribution of human touch. Massage therapy: 15 minute sessions 3 times/day, massage head, back, arms and legs and flexion and extension of the extremities resulted in temperature increase.

Fransson, A., Karlsson, H., & Nilsson, K. (2005). Temperature variation in newborn babies: importance of physical contact with the mother. *Ach Dis Child Fetal Neonatla ed, 90*, F500-F504.

Abdominal and foot skin temperature were continuously recorded in 27 healthy full term babies during the first two days of life and related to the care situation - that is, whether the baby was with the mother or in its cot.

Mean rectal and abdominal and foot skin temperature were lower on day 1 than day 2.

The foot skin temperature was directly related to the care situation, being significantly higher when the baby was with the mother. The abdominal skin temperature was much less influenced by external factors. When the neonates were with their mothers, the mean difference between rectal temperature and abdominal skin temperature was 0.2˚C compared with a mean difference between rectal temperature and foot skin temperature of 1.5˚C, indicating a positive heat balance. In the cot the corresponding temperature differences were 0.7˚C and 7.5˚C. A temperature difference between rectal and foot skin temperature of 7 - 8˚C indicates a heat loss close to the maximum for which a neonate can compensate.

Conclusion: This study emphasizes the importance of close physical contact with the mothers for temperature regulation during the first few postnatal days.

Gabriel, M., Matrin, I., Escobar, A., Villalba, E., Blanco, I., & Pol, P. (2009). Randomized controlled trial of early skin-to-skin contact: effects on the mother and the newborn. *Acta Paediatrica, 99*, 1630-1634.

RCT- Greater thermal stability in the skin to skin group as evidenced by average skin temperature rise of 0.07^0 C was observed. This study did not support temperature correlation and breastfeeding success, however, skin to skin contact has been associated with greater breastfeeding success.

Heimann, K., VaeBen, P., Peschgens, T., Stanzel, S., Wenzle, T., & Orlikowsky, T. (2010). Impact of skin to skin care, prone and supine positioning on cardiorespiratory parameters and thermoregulation in premature infants. *Neonatology, 97*, 311-317.

This article found no increase in apnea attacks and bradycardic episodes and no difference in respiratory rate, breathing pattern, oxygen saturation, episodes and duration of desaturation comparing infant positions. Temperature was not higher during skin to skin and prone position compared to supine position, except a rise between start and end of the measuring cycle. Higher rectal temperatures at beginning and end of a 6 hour monitoring cycle, in Skin to Skin Contact (SSC) , and Prone Position, when compared to SSC in Supine Position.

Knobel, R., & Holditch-Davis, D. (2007). Thermoregulation and heat loss prevention after birth and during neonatal intensive-care unit stabilization of extremely low-birth weight infants. *Journal of Obstertic, Gynecolgic, and Neonatal Nursing, 36*, 280-287.

It was found that these interventions were all effective ways to stabilize thermoregulation and to prevent heat loss in ELBW infants:

- *Pre warming the delivery room.*
- *Use of plastic bag (polyethylene, polyurethane) wrap in delivery room*
- *Hat wrap*
- *Warm blanket*
- *Warmer table*
- *Radiant heat on the infant during transport*
- *When non-warmed supplies were put next to the infant, recorded body temperature dropped*.

Laroia, N., Phelps, D., & Roy, J. (2010). Double wall versus single wall incubator for reducing heat loss in very low birth weight infants in incubators (Review). *The Cochrane Collaborations*(2), 1-21.

Intent: to test the double wall vs. single wall incubator for insensible water loss, rate of oxygen consumptions, episodes of hypothermia, time to regain births weight, duration of hospitalization and infant mortality in premature infants.

Review of RCT, or quasi RCT- results: Double walled incubators have the advantage of decreasing heat loss, decreasing heat production efforts and decreasing radiant heat loss when compared to single wall incubator. Infants were found to have reduced oxygen consumption needs, heat loss was minimal. All of these affects do not support the statement that double wall incubators have any benefit on long term outcomes including infant mortality or duration of hospital stay.

Miller, S., Lee, H., & Gould, J. (2011). Hypothermia in very low birth weight infants: Distribution, risk factors and outcomes. *Journal of Perinatolgy, 31*, S49-S53.

This was a study conducted to evaluate the epidemiology of neonatal hypothermia in preterm infants using World Health Organization (WHO) temperature criteria. Results demonstrated low birth weight, cesarean delivery and a low Apgar score were associated with hypothermia. Spontaneous labor, prolonged rupture of membranes and antenatal steroid administration were associated with decreased risk of hypothermia.

Moderate hypothermia was associated with higher risk of intraventricular hemorrhage (IVH). Moderate and severe hypothermic conditions were associated with risk of death. It was concluded that hypothermia by WHO criteria is prevalent in VLBW infants and is associated with IVH and mortality. Use of WHO criteria could guide the need for quality improvement projects targeted toward the most vulnerable infants.

Strohm, B., & Azzopardi, D. (2010). Temperature control during therapeutic moderate whole-body hyperthermia for neonatal encephalopathy. *Achives of Disease in Childhood. Fetal and Neonatal Edition, 95*, F373-F375.

There is less temperature variability in the Servo control group of letting the infant cool for 72 hours, and greater control in warming them after 72 hours.

West, C., Williams, M., & Weston, P. (2005). Feasibility and safety of early transfer of premature infants from incubators to cots: A pilot study. *Journal of Paediatrics and Child Health, 41*, 659-662.

Study with a primary focus on documenting whether medically stable infants can transfer safely from incubators to unheated, open cots when their weight reaches 1500 grams. The secondary focus was to determine temperature stability, growth, medical complications and time to

discharge for these infants. Results indicated the potential to transfer very low birthweight infants to an open unheated cot at a bodyweight of 1500 grams. Additional studies are recommended before this intervention is put into routine clinical practice.

III. Temperature Control/Hypothermia

Summary

The physiological presentation of the premature (less than 28 weeks gestation), VLBW, LBW, SGA (less than 1500 grams) infant puts it at risk for hypothermia and is associated with adverse outcomes.

Physiological risk factors include:
- Large surface area to body mass
- Decreased sub-cutaneous fat
- Decreased brown fat
- Greater body water content
- Immature skin
    - Increasing evaporative water and heat loss
    - Delayed development of skin blood flow control
    - Inadequate keratinization
- Poor metabolic mechanism responding to thermal stress
- Reduced ability for peripheral vasoconstriction
- Poor metabolic mechanism responding to thermal stress

The acceptable range of body temperature for the neonate is 36.5^0 C to 37.5^0 C. Noting that the metabolic process of thermogenesis begins at 35^0 C-36^0 C, mild hypothermia is defined as 32 ^{0} C to 35.9^0 C and moderate hypothermia is found to be less than 32^0 C. This would suggest that the threshold for neonatal temperature is 36.5^0 C.

Bibliography

Antonucci, R., Porcella, A., & Fanos, V. (2009). The infant incubator in the neonatal intensive care unit: unresolved issues and future developments. *Journal of Perinatal Medicine*, 597-598.

In infants of VLBW, high evaporative losses are due to the inadequate keratinization of the skin, which becomes functionally mature at 32-34 weeks gestation. This high transepidermal water loss (TEWL) may result in hypothermia.

For healthy skin development, VLBW infants should be kept at 80-90% humidity until their skin functions. Newborns' physical structure puts them at risk for heat loss, large head, body surface area in relation to weight, and little subcutaneous fat.

Aylott, M. (2006). The neonatal triangle. Part 2: Thermal regulatory and respiratory adaptation. *Paediatric Nursing, 18*(6), 38-42.

Infant physiology that affects their ability to regulate temperature:
- Fetal cold stress response is not active in utero as the mother constitutes a massive heat reservoir.

- In utero core temperature of the neonate is 5^0 C above that of the mother, and extremities are same as the mother.
- There is no thermoregulation prior to birth.
- Cold stress response after birth consists of increased involuntary muscular activity, vasoconstriction and non-shivering thermogenesis.
- Shiver is not active in the human newborn. Healthy term babies can maintain this by increasing the metabolic rate of the heat production from minutes to a few hours depending on their environmental conditions. After that energy stores become depleted and hyperthermia rapidly ensues.
- Factors associated with preterm baby (less than 35 weeks) and hypothermia include:
    - Large surface area to body mass
    - Decreased sub-cutaneous fat
    - Decreased brown fat
    - Greater body water content
    - Immature skin increasing evaporative water and heat loss
    - Ineffective positioning ability
    - Poor metabolic mechanism responding to thermal stress
    - Delayed development of skin blood flow control, reduced ability for peripheral vasoconstriction.

This chain of events contributes to peripheral vasoconstriction, pulmonary vasoconstriction deterioration of oxygenation and perfusion. Tissue hypoxia and accumulation of lactic acidosis all result from anaerobic metabolism. This process precipitates respiratory demise and hypothermia switches off surfactant syntheses. Basal metabolic rate decreases with tissue hypoxia and blunt thermal responses accelerate the development of acute hypothermia.

The study concluded that hypothermia is associated with adverse outcomes.

Bissinger, R., & Annibale, D. (2010). Thermoregulation in very low birth weight infants during the golden hour, results and implications. *Advances in Neonatal Care, 10*(5), 230-238.

Exposure to risk factors in the environment leaves premature VLBW infants vulnerable to cold stress in the first hours of life. Delivery room management that focuses on the adaptation of the infant and early interventions improves outcomes.

Borse, N., Deodhar, J., & Pandit, A. (1996). Effects of thermal environment on neonatal thermoregulation. *Indian Pediatrics*, 718-720.

The following factors were shown to impact neonatal thermoregulation:

- Full term Average Gestational Age babies had significantly lower mean body temperature during the first 12 hours ($p=0.003$).
- LBW and SGA also had lower temperature during the first 12 hours ($p= 0.007$).
- Babies with encephalopathy (HIE) also had significantly lower mean temperatures during first 12 hours.
- Preterm babies with LBW and SGA had temperatures below 36^0 C, during first 12 hours of life.

- Univariate analysis identified gestational age < 34 weeks BW < 1500 G, SGA and HIE as high risk factors for hypothermia.

Chardon, K., Cardot, V., Leke, A., Delanaud, S., Bach, V., Dewasmes, G., & Telliez, F. (2006). Thermoregulatory control of feeding and sleep in premature infants. *Obesity, 14*(9), 1535-1542.

In premature infant physiology, research conducted in the area of energy supply from food intake has been found to be crucial for organ operation, body homeothermia and optimal growth.

The Himms-Hagen model was tested with rats and can also be put forward for the human neonate, which also uses BAT (Brown Adipose Tissue) to produce metabolic heat.

Feeding episodes occur during a transient increase in body temperature. Feeding is initiated by a dip in blood glucose concentration after sugar uptake by activated BAT.

14 neonates (bottle fed-on demand) food intake always took place during an increase in skin temperature (0.19-0.21 C). Awakening occurred 17-18 minutes after the minimum skin temperature level had been reached.

When feeding time was imposed, feeding was not necessarily situated during an increase in skin temperature; however sleep duration after food intake increased significantly.

The discussion supports that on demand feeding fulfills the thermal needs of the neonate. In the on demand group, initiation of a feeding episode is clearly associated with an increase in body temperature. This occurs due to the sympathetic stimulation of BAT.

Failure of this cycle (thermoregulatory feeding) by which arousal is mediated, due to depletion of the caloricgenic fat stores in BAT tissue, as observed in newborns with cold injury or hypothermia, or during hypoxia could lead to malnourishment, and fatal events.

Flenady, V., & Woodgate, P. (2005). Radiant warmers versus incubators for regulating body temperature in newborn infants. *Cochrane Neonatal Group*, 4 (CD000435), 1-44.

This review found inconclusive evidence to show the effects of radiant warmers versus incubators for regulating body temperature in newborn babies. It was determined that LBW babies have higher chance of survival if they are kept warm and traditionally this has been done using incubators to maintain body temperature. Babies who require more hands-on care are nursed in open cots with radiant warmers. This review also found that radiant warmers increased water loss in LBW babies in the newborn period when compared to incubators. This needs to be accounted for in daily fluid intake. It is still unclear which method of maintaining body temperature is best for newborn babies.

Fletcher, A. (2008). Health loss prevention in neonates. *Journal of Perinatology, 28*, 857-859.
The response to a cold body temperature does not include peripheral vascular constriction, inhibition of sweating, voluntary muscle movement and involuntary muscle movements.

The main mechanism of heat production in neonates is non-shivering thermogenesis. Non-shivering thermogenesis results in an increase in norepinephrine and thyroid stimulating hormone (TSH). This leads to an increase in T4 and T3, causing fat oxidation and heat production.

This is a large caloric demand. Newborn energy loss in an unattended cool room is about 150kcal per minute.

This results in physiologic stress, increased oxygen consumption, metabolic acidosis, hypoglycemia, decreased cardiac output, increased peripheral vascular resistance.

Gray, P. H., & Flenady, V. (2011). Cot-nursing verses incubator care for preterm infants. *Cochrane Neonatal Group*, 8(CD 003062), 1-35.

Cot nursing using a heated water filled mattress has similar effects to incubator care with regard to temperature control and weight gain. Outcomes need to be investigated further using RCT. Space heated rooms were used.

When compared to incubator care, cot nursed infants had no difference in mean body temperature. No difference in weight gain. In the cot nursing group, fewer infants were breast fed on discharge, and fewer infants died. Cot nursing with warming of the nursery resulted in statistically significant smaller weight gain during week one compared to the incubator group in one trial. No difference between week two and three.

Mothers of the cot nursed infants felt they had more access, however, additional warmth is needed to maintain their body temperature such as clothing, bedding and heated room.
Cot nursing with warming of the nursery during week one compared to incubator care revealed poorer weight gain.

Episodes of hyperthermia in the cot nursing group were reported more frequently in one trial. There was a strong trend towards less death prior to hospital discharge.

Jaffe, C. A. (2009). Routine assessment of temperature in healthy newborns: Lack of evidence for its clinical utility. *Archives of Pediatrics & Adolescent Medicine, 160*(3), 283.

This study found no benefit to measuring temperature as a guide for indication of illness or problem with infant. No consistent patterns of abnormality. Polyurethane occlusive wrapping was applied upon delivery. Giraffe Radiant Warmer (GE Tech) warmer was computer controlled, and humidity was added at 60-80%.

Knobel, R., Holditch-Davis, D., Schwartz, T., & Wimmer, J. (2009). Extremely low birth weight preterm infants lack vasomotor response in relationship to cold body temperatures at birth. *Journal of Perinatology, 29*(12), 814-821.

Measured abdomen and foot temperature differences in first 12 hours of life in preterm and Differences in temperature (> 2^0 C) have been used to indicate vasoconstriction.

Only one baby showed effort in ability to achieve vasoconstriction. This was demonstrated by extremity temperature being less than abdominal temperature by 2 degrees.

Most had higher peripheral than abdominal temperatures and that is where they were losing heat. This evened out over time of hours after birth.

7 out of 10 infants studied.

Laptook, A., Salhab, W., & Bhaskar, B. (2007). Admission temperature of LBW infants: Predictors and associated morbidities. *Pediatrics, 119*(3), e643-e649.

Study of infants without major congenital anomalies and birth weights ranging 401 – 1499 grams. Associations between antepartum/birth variables and admission temperature and selected morbidities/mortality and admission temperature were examined.

Admission temperature was inversely related to mortality. Temperature up/mortality down. Temperature up/sepsis and morbidity down

Fall in body temperature impairs circulatory pathways, and pulmonary vasomotor tone, and acid-base homeostasis.

Efforts to limit heat loss are important initial steps in the stabilization of newborns immediately after birth.

McCall, E., Alderdice, F., Halliday, H., Jenkins, J., & Vohra, S. (2008). Interventions to prevent hypothermia at birth in preterm and/or low birthweight infants. *Cochrane Databse Syst Rev*(1). doi:10.1002/14651858.CD004210.pub3.

Cochrane Review: To assess efficacy and safety of interventions designed for prevention of hypothermia in preterm and/or low birthweight infants applied within 10 minutes after birth in the delivery suite compared with routine thermal care. Seven studies involving 391 infants used additional preventative actions in the first 10 minutes of life to prevent problems with hypothermia.

Conclusion: Plastic wraps or bags, plastic caps, skin-to-skin care (SSC) and transwarmer mattresses all keep preterm infants warmer, leading to higher temperatures on admission to neonatal units and less hypothermia. However, firm recommendations for clinical practice cannot be given.

McCall, E., Alderdice, F., Halliday, H., Jenkins, J., & Vohra, S. (2010). Interventions to prevent hypothermia at birth in preterm and/or low birthweight infants. *Cochrane Database of Systematic Reviews*(3). doi:10.1002/14651858.CD004210.pub4.

Skin-to-skin care (SSC) was shown to be effective in reducing the risk of hypothermia when compared to conventional incubator care for infants (1 study, n = 31; RR 0.09; 95% CI 0.01, 0.64). The transwarmer mattress reduced the incidence of hypothermia on admission to NICU in VLBW infants (1 study, n = 24; RR 0.30; 95% CI 0.11, 0.83).

Plastic wraps or bags, plastic caps, SSC and transwarmer mattresses all keep preterm infants warmer leading to higher temperatures on admission to neonatal units and less hypothermia. However, the small numbers of infants and studies and the absence of long-term follow-up mean that firm recommendations for clinical practice cannot be given.

In an attempt to maintain core body temperature within the normal range of 36.5° C to 37.5 °C (skin temperature of 0.5° C to 1.0° C lower)

When skin temperature falls to 35° C to 36° C, non-shivering thermogenesis is initiated (Bruck 1961). The World Health Organization classifies a core body temperature for newborns of 36 to 36.4 °C as mild hypothermia, 32° C to 35.9 °C as moderate and < 32° C as severe (WHO 997). Currently, there is no accepted formal definition of 'normal' temperatures for preterm infants and methods and accuracy of temperature measurement continue to be debated (Bailey 2000; Smith 2004).

Standard care includes providing a warm delivery room at a minimum of 25 °C (although rarely achieved in practice) (WHO 1997), drying the infant thoroughly, immediately after birth (especially the head) (Bloom 1994), removing any wet blankets, wrapping in a prewarmed blanket, prewarming any contact surfaces, eliminating drafts and close proximity to outside walls (Capobianco 1980). If available, radiant warmers for resuscitation and stabilization allow easy access and are effective in preventing heat losses, provided that the infant is immediately dried and placed under the prewarmed heater (Du 1969; Dahm 1972).

Interventions should either decrease total heat losses or provide external heat without compromising accessibility during resuscitation and should have minimal side effects (such as hyperthermia, burns, maceration, or infection).

Neonatal hypothermia after birth is a world-wide issue (Costeloe 2000) across all climates (Christensson 1988; Johanson 1992; Tafari 1973; Laptook 2007; Kumar 2009) and, if prolonged, can lead to harm and in severe cases death. Silverman 1958 and Day 1964 showed that reducing heat losses in preterm infants in the first few days after birth increased survival rates

Despite the variations in interventions applied, definitions of 'routine care', definitions of hypothermia and groups of infants included, across all studies there is a similar pattern emerging showing that infants in the intervention group are significantly warmer (or show a non-significant trend in that direction) when compared to infants receiving 'routine care'. There is also an indication from these studies that the effect is greater in the lightest and most immature infants. Babies of < 28 weeks or those weighing ≤ 1500 grams appeared to derive most benefit from interventions in the delivery suite to prevent hypothermia. These are also the infants most likely to suffer from the adverse effects of hypothermia and in whom further studies should be undertaken.

Miller, S., Lee, H., & Gould, J. (2011). Hypothermia in very low birth weight infants: Distribution, risk factors and outcomes. *Journal of Perinatolgy, 31*, S49-S53.

Moderate hypothermia was associated with higher risk of intra ventricular hemorrhage. Moderate and severe hypothermic conditions were associated with risk of death. (By WHO criteria)

In the population of mild hypothermia, there was no association between mild hypothermia and any of the morbidities or death.

Moderate hypothermia was associated with higher odds of IVH and death.

Severe hypothermia was associated with higher odds of death.

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te Pas, A., Lopriore, E., Dito, L., Morley, C., & Walther, F. (2010). Humidified and heated air during stabilization at birth improves temperature in preterm infants. *Pediatrics, 125*(6), e1427-e1432.

Study aimed at investigation of the effect of humidified and heated gas on admission temperature in preterm infants who require respiratory support at birth. Primary outcome: infant's rectal temperature upon admission to the NICU. The study concluded that the use of heated and humidified air during respiratory support in very preterm infants just after birth reduced the postnatal decrease in temperature and requires additional investigation.

Watkinson, M. (2006, March). Temperature control of premature infants in the delivery room. *Clinics in Perinatology, 33*(1), 43-53.

Conventional approaches to thermal care of the very preterm and low birth weight baby are outmoded. Observational studies confirmed the efficacy of plastic bags or plastic wrapping in addition to customary radiant heat in improving the admission temperature of preterm babies less than 28 weeks gestational age.

Takayama, J. I., Wang, T. B., Uvemoto, J., Newman, T., & Pantell, R. H. (2000). Body Temperature of Newborns: What is Normal? *CLINICAL PEDIATRICS, 39*, 503-510.

Study to determine normal range of axillary temperatures for newborn infants and to what degree internal and external factors influence temperature. The mean axillary temperature for newborns was 36.5^0 C. Maternal fever, birth weight, race/ethnicity were significant predictors of birth temperature. Given the frequency of "hypothermia" and absence of associated illness, the authors believe the reference range for newborn temperatures should be expanded to include lower temperatures.

IV. Mechanisms to Maintain Body Temperature

Summary

The cited literature in addition to national and international guidelines supported the following known interventions to protect ELBW, VLBW, premature babies from hypothermia upon admission to the NICU; which aim to ensure a higher chance of survival, as well as improved short and long term outcomes:

- Pre warmed delivery room (78-80 degrees) (50% Humidity)
- Pre warmed, overhead radiant warming transport bed
- Application of humidification to the overhead warming system (60-80%)
- Patting dry with pre-warmed towels
- Wrapping the baby in polyethylene wrap immediately after birth
- Ensuring this wrap during resuscitation
- Applying a head covering
- Warmed towels over the plastic wrap
- Warmed mattress

These interventions have been found to decrease the incidence of hypothermic temperatures on admission to an NICU unit in low birth weight (1500 grams), very low birth weight (<1000 grams), Preterm (<31 weeks), premature (< 27 weeks) infants, and decreases insensible water loss by 70%. There was a lack of evidence supporting the use of warming gels on the baby skin, as well as use of warm bottles to warm this infant population. Other techniques or mechanisms to be considered include use of Heat Balance technology and slow warming with normal saline fluids in extremely hypothermic infants.

Bibliography

Agourram, B., Bach, V., Tourneux, P., Krim, G., Delanaud, S., & Libert, J. P. (2010). Why wrapping premature neonates to prevent hypothermia can predispose to overheating. *J Appl Physiol*, 108, 1674-1681.

Assessed the time required to reach warning body temperature (*t*38°C), heat stroke (*t*40°C), or extreme value (*t*43°C) in a mathematical model that involved calculating various local body heat losses. Plastic bag and bonnet may result in hyperthermia but only when metabolic heat production rises while skin temperature falls (impeding body heat losses), as can sometimes happen with fever.

Ahmed, S., Mitra, S. N., Chowdhury, A. M., Camacho, L. L., Winikoff, B., & Sloan, N. L. (2011). Community Kangaroo Mother Care: implementation and potential for neonatal survival and health in very low-income settings. *Journal of Pernatology, 31*, 361-367.

Research begins in very low income countries to promote thermal regulation, breastfeeding and maternal newborn boding.

RCT of Community based kangaroo mother care (CKMC) in Bangladesh.

Results found that newborns held at STS (skin to skin) less than 7 hours per day in the first 2 days of life do not experience better health or survival than babies without being held STS.

90% gave birth at home.

Alemida, P. G., Chandley, J., Davis, J., & Harrigan, R. C. (2009). Use of the heated gel mattress and its impact on admission temperature of very low birth-weight infants. *Advances in Neonatal Care*, 9(1), 34-9.

Investigation conducted to evaluate the ability of a transport mattress (specifically the TransWarmer Infant Transport Mattress produced by Cooper Surgical) to reduce hypothermia in a group of very low birth weight (VLBW) infants. Although there were noted limitations to this study, use of the mattress was beneficial in decreasing hypothermia in VLBW infants.

Antonucci, R., Porcella, A., & Fanos, V. (2009). The infant incubator in the neonatal intensive care unit: unresolved issues and future developments. *Journal of Perinatal Medicine*, 597-598.

This study involved recorded skin, air, and wall temperature readings in the incubator with the readings entered into a computer algorithm to control heat production.

SCS or servocontrolled skin temperature derivate heating device is best to ensure quieter infant sleep, and reduced body movements.

HeatBalance (trade) uses basic physical principles to calculate heat gains and losses, and indicated incubator temperature and humidity settings to keep babies in thermal balance, continuous monitoring is required.

Arkell, S., Blair, P., Henderson, J., & Fleming, P. (2007). Is the mattress important in helping babies keep warm? Paradoxical effects of a sleeping surface with negligible thermal resistance. *Acta Paediatrica*, 96, 199-205.

Purflo has low thermal resistance when used with an infant sleeping bag.

In thermo neutral conditions axillary temperatures in quiet sleep were lower on the conventional mattress than on the Purflo mattress. On lowering room temperature to 15-16^0 C, axillary temperatures fell, particularly in the older babies and at each age were lower on the conventional mattress than the Purflo.

Arora, S. (2008). Kangaroo Mother Care. *The nursing journal of India*, XCIX(11), 248-250.

Studies carried out in low income countries showed that a prolonged skin to skin contact between the mother and her preterm LBW infant provides effective thermal control and it is

associated with a reduced risk of hypothermia. KMC results in normal temperature during the procedure without any risk of hypothermia.

This care touches 5 senses of the infant.

LBW: 1800 grams.

If 1200-1799 grams, the babies are transferred to a special facility keeping them in continuous skin to skin contact with mother.

Association of Women's Health, O. a. (2010). Assessment and care of the late preterm infant. Evidence-based clinical practice guideline. Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN).

Respiratory Assessment is to be completed within the “immediate assessment” time frame. This is defined as the first thirty minutes of life. The AWHONN encourages practitioners to begin with assessment of respiratory status immediately after birth, provide a supplemental heat source, such as a radiant warmer, an incubator, or chemical thermal mattress, check blood serum glucose levels, if the baby is stable, and the mother desires, then implement kangaroo care (KC) (also known as skin-to-skin care).

The AWHONN acknowledges that if KC is not feasible, provide an alternate heat source, and recommends the use of a radiant warmer. In this resuscitation guideline, heat or thermoregulation is not addressed until later in the recommended steps of resuscitation of the neonate.

Baumgart, S. (1985). Partitioning of health losses and gains in premature newborns infants under radiant warmers. *Pediatrics, 75*(1), 89-99.

Partition of heat loss into convective and evaporative components and heat gain into metabolic rate of production and radiant heat needed to maintain thermal equilibrium was determined in 10 babies.

Convective heat loss comprised the major component of net heat loss.

Evaporative heat loss increased with servo control temperature.

Metabolic rate decreased with increased servo control temperature but this decrease was not significant.

Radiant heat delivered by the warmer to infants was directly proportional to the heat need calculated from the partition.

Convection warmed incubator reduces body heath losses through convection, radiation and evaporation, but circulating warm air.

Radiant warmer positioned over an open bed platform causes increased infant heat loss through convection and evaporation when compared with the enclosed incubator.

Radiant warmers allow for the infants to receive a net radiant heat gain from the radiant warmer, whereas the incubator serves only to reduce heat loss. Purpose of the study was to measure the partition of infant heat loss and heat gain under a radiant warmer.

Abdominal skin temperature was observed.

Convection compromised the majority component of net heat loss, exceeding the heat lost through evaporation by more than 200%.

Radiant heat increased skin heat resulting in an increase in convective heat transfer to the cooler ambient air. Metabolic rate and evaporative water loss did not change with increases in temperature.

Evaporative heat loss was the same in both incubators. Radiant heat loss was greater in the single walled incubator, and convective heat loss was less. BMR did not change.

The babies under the radiant warmer had a greater convective and evaporative heat loss, and these losses greatly exceed the rate of metabolic heat production.

The linear correlation between radiant heat need calculated from the partition of heat losses and metabolic heat production described and the measure radiant heat delivered to the infant indicates a clear relationship between radiant warmer servo control function and the infant thermal physiology.

Bissinger, R., & Annibale, D. (2010). Thermoregulation in very low birth weight infants during the golden hour, results and implications. *Advances in Neonatal Care, 10*(5), 230-238.

Alterations in thermoregulation impact the survival of very low birth weight (VLBW) infants. Delivery room management focused on the adaptation of the infants improves outcomes in this vulnerable population:

- Warm the delivery room to 78-80 degrees with 50% humidity.
- Polyethylene wrap the baby before drying - reduces insensible water loss by 70% when the wrap is left in place, decrease removal by 30%.
- Transwarmer mattress.
- Woolen Hats.
- Drying the baby - patting technique and avoid rubbing the baby to destroy fragile growth of epidermis.
- Preheated radiant warmer.

Bohnhorst, B. (2010). Skin to skin care in the neonatal intensive care unit: More data regarding seriously ill infants are badly needed. *Neonataology*, 97, 318-320.

Kangaroo care came from Colombia 1970, moved throughout Europe quickly, but not so fast in the US where access to high tech equipment is not so desperate. Now accepted and called skin to skin care (SSC). Past literature focuses on psychological effects rather than physiological effects, and even less on temperature regulation. This article reviewed Heiman's

previous article about supine position in SSC and declares more evidence that in terms of thermoregulation, the neonate tolerates SSC well. There is still a need for further study with SSC and the critically ill infant.

Bredemeyer, S., Reid, S., & Wallace, M. (2005). Thermal management for premature births. *Journal of Advanced Nursing*, 52(2), 482-489.

The effect on admission temperatures when using occlusive polyethylene wraps applied immediately after the birth of extremely premature infants.

Occlusive wrap was used during resuscitation and early stabilization.

Control group was dried with pre-warmed towels and resuscitated under radiant heat. The intervention group was not dried, but immediately enclosed in an occlusive polyethylene wrap and managed under radiant heat.

Use of the wrap resulted in higher admission temperatures for infants less than 27 weeks gestation. There was no improvement on the older infants 27-29 weeks. The rate of hypothermia on admission was lower in the intervention group. But more infants recorded temperatures exceeding 37.2^0 C during the first 12 hours.

Removal of the wrap should be considered following admission to a closed care system in the NICU to decrease chance of hyperthermia.

The product was called Shrink Wrap 23 num; Southarn Cross Tapes Pty Ltd, Gosford, Australia.

Infants were received in pre-warmed towels and then transferred to a Resuscitaire in which plastic wrap had been placed. Only the head and the umbilical cord were left exposed for clinical management. The head was dried and then wrapped in undercast padding. The plastic wrap was left on during transfer, and the babies were also nested in warm towels with more plastic wrap covering the Resuscitaire to act as a barrier to convective heat loss.

Axilla temperature was measured on admission to the NICU. Infants were then weighed while still wrapped, then placed in a pre-warmed pre humidified incubator. The plastic wrap was removed once admission procedures had been completed and the baby could be left without the need to keep the incubator doors open.

This method was more accurate in reducing evaporative and convective heat loss. Care needs to consider hyperthermia once placed in the incubator and the wrap must be removed. Increased brain temperature after hypoxic event may result in exacerbated cerebral damage.

In infants less than 27 weeks, the wrap was removed and topical emollient was applied (Eucerin) and this is a new process not studied yet.

Duman, N., Utkutan, S., Kumral, A., Koroglu, T. F., & Ozkan, H. (2006). Polyethylene skin wrapping accelerates recovery from hypothermia in very low birth weight infants. *Pediatrics International*, 48, 29-32.

This study was designed to determine the effects of polyethylene occlusive skin wrapping on heat loss in VLBW infants admitted to the neonatal ICU promptly after birth. 30 newborns at less than 1500 grams were allocated to a wrap or non wrap group within an incubator after admission to the NICU. Axillary and incubator temperatures were taken on arrival and at 1 and 2 hours. Infants in the wrap group reached a normal axillary temperature faster than non wrap infants and required lower incubator temperatures.

Polyethylene film wrapping effectively helps to correct hypothermia in VLBW infants admitted to the NICU.

Flenady, V., & Woodgate, P. (2005). Radiant warmers versus incubators for regulating body temperature in newborn infants. *Cochrane Neonatal Group*, 4 (CD000435), 1-44.

A variety of methods are currently employed for the provision of a thermoneutral environment in the care of newborns. This review was done to assess the effects of radiant warmers versus incubators on neonatal fluid and electrolyte balance, morbidity and mortality.

- LBW babies have higher chance of survival if they are kept warm.
- Incubators have been used for maintaining body temperature.
- Babies who require more hands-on care are in open cots with radiant warmers.
- Not enough evidence to show the effects of radiant warmers versus incubators for regulating body temperature in newborn babies.
- Review found that radiant warmers increased water loss in LBW babies in the newborn period when compared to incubators. This needs to be accounted for in daily fluid intake. It is still unclear which method of maintaining body temperature is best for newborn babies.

Fletcher, A. (2008). Health loss prevention in neonates. *Journal of Perinatology, 28*, 857-859.

Maintaining a neutral thermal environment is crucial to minimizing the risk of hypothermia and improving clinical outcomes for the newborn. A number of interventions were studied for greater understanding on the prevention of heat loss:

- Delivery room temperature control
- The benefit of polyethylene occlusive skin wrap.
- Heating delivery room
- Stockinet cap
- Skin to skin contact
- Use of isolette
- Warming mattress

Friddle, K., & Smith, S. L. (2009). A simulation study of gel pillows and health conductance. *Advances in neonatal care*, 9(5), 240-248.

The gel pillow has known thermal conductive properties when used in an open crib. The simulation used a Squishon 2 gel pillow in an open crib to determine the potential cooling effects on mannequin infants.

The results suggested that use of the gel pillow outside of thermally controlled environment and in an open crib environment may increase energy used to maintain thermo neutrality. The Squishon 2 gel pillow conducts heat from the mannequin head and may increase kilocalories per day consumption in the preterm infant. A hat helps conserve energy.

Gabriel, M., Matrin, I., Escobar, A., Villalba, E., Blanco, I., & Pol, P. (2009). Randomized controlled trial of early skin-to-skin contact: effects on the mother and the newborn. *Acta Paediatrica, 99*, 1630-1634.

RCT- Greater thermal stability in the skin to skin contact group as evidence by average skin temperature rise of 0.07 C.

This study did not support temperature correlation and breastfeeding success, however, skin to skin contact has been associated with greater breastfeeding success.

Skin to skin contact mothers expelled the placenta in a shorter time. No observation of skin to skin contact and post partum depression or anxiety.

Gray, P. H., & Flenady, V. (2011). Cot-nursing verses incubator care for preterm infants. *Cochrane Neonatal Group*, 8(CD 003062), 1-35.

Cot nursing using a heated water filled mattress has similar effects to incubator care with regard to temperature control and weight gain. Outcomes need to be investigated further using RCT. Space heated rooms were used.

When compared to incubator care, cot nursed infants had no difference in mean body temperature. No difference in weight gain. In the cot nursing group, fewer infants were breast fed on discharge, and fewer infants died. Cot nursing with warming of the nursery resulted in statistically significant smaller weight gain during week one compared to the incubator group in one trial. No difference between week two and three.

Mothers of the cot nursed infants felt they had more access, however, additional warmth is needed to maintain the infant's body temperature such as clothing, bedding and heated room. Cot nursing with warming of the nursery during week one with compared to incubator care revealed poorer weight gain.

Episodes of hyperthermia in the cot nursing group were reported more frequently on one trial. There was a strong trend towards less death prior to hospital discharge.

Halloran, O. J. (2009). Editorial Warming our Cesarean section patients: why and how? *Journal of Clinical Anesthesia*, 21, 239-241.

While a strong body of evidence suggests that perioperative warming improves clinical outcomes, there is a need for more evidence for elective Cesarean patients. A review of 4 small studies suggested the potential for improved clinical outcomes with active perioperative warming. Warming led to improvement in neonatal physiologic parameters in two of 4 studies.

Holland, B. M., Bates, R. A., Gray, O. P., Pearson, J. F., & Wardrop, C. A. (1985). New insulating material in maintenance of body temperature. *Archives of disease in childhood*, 60, 47-50.

Flectalon, a web of aluminized polyvinylchloride fibers has been formulated to minimize radiant heat loss and to provide conventional insulation. It was tested against Thinsulate to reduce critical temperatures in babies. Flectalon was found to be a more efficient insulator.

Jaffe, C. A. (2009). Routine assessment of temperature in healthy newborns: Lack of evidence for its clinical utility. *Archives of Pediatrics & Adolescent Medicine, 160*(3), 283.

Polyurethane occlusive wrapping was applied upon delivery. Giraffe Radiant Warmer (GE Tech) warmer was computer controlled, and humidity was added at 60-80%. This study found no benefit to measuring temperature as a guide for indication of illness or problem with infant. No consistent patterns of abnormality.

Kattwinkel, J., Perlman, J., Aziz, K., Colby, C., Fairchild, K., Gallagher, J., A. H. (2010, November). Neonatal resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Pediatrics, 126*(5), e1400-13.

AAP: The initial steps to resuscitation *are to provide warmth* by placing the baby under a radiant heat source, and positioning the head in the sniffing position to open the airway, clearing the airway if necessary with blub syringe or suction catheter, then drying the baby and stimulating breathing.

AAP recommends pre warming the delivery room to 26^0 C, covering the baby in plastic wrapping (food or medical grade, heat resistant plastic) (Class I, LOE A). Monitor frequently, and be aware of risk for hyperthermia.

Other techniques have been used: pre warming the linen, drying and swaddling, placing the baby skin to skin with mother and covering both with a blanket and are recommended, but they have not been studied specifically (class IIB, LOE C).

All further resuscitation procedures, including endotracheal intubation, chest compression, and insertion of intravenous lines, can be performed with these temperature controlling interventions in place (Class IIB, LOE, C).

Kent, A. L., & Williams, J. (2008). Increasing ambient operating theatre temperature and wrapping in polyethylene improves admission temperature in premature infants. *Journal of Paediatrics and Child Health*, 44(6), 325-31.

Study conducted to determine if increasing the ambient temperature in the operating theatre and wrapping in polyethylene wrap at caesarean section would improve admission temperatures of preterm infants ≤ 31 weeks gestation. Results demonstrated improvements in admission temperatures but suggested additional studies to determine benefit with respect to morbidity and mortality.

Kim, S. M., Lee, E. Y., & Ringer, S. A. (2010). Improved care and growth outcomes by using hybrid humidified incubators in very preterm infants. *Pediatrics*, 125(1), e137-45.

Use of a humidified hybrid incubator improved care for extremely low birth weight (ELBW) infants by making it possible to decrease fluid intake, improve electrolyte balance, and enhance growth velocity (GV) without a disturbance of body temperature (BT) compared with conventional care.

Knauth, A., Gordin, M., McNelis, W., & Baumgart. (1988). Artificial skin for the premature neonate. *Pediatrics*, 8(6), 945-952.

Semipermiable polyurethane membrane applied to premature neonates as artificial skin to reduce transepidermal water loss without inhibiting natural infant skin development during the first few days of life.

Tests were done on 18 neonates with birth weight means 1.39 - 0.12 kg, age 31 weeks. Two 3 x 3 patches were put on chest and abdomen. This produced an accurate and significant reduction in transepidermal water loss.

Knobel, R., & Holditch-Davis, D. (2007). Thermoregulation and heat loss prevention after birth and during neonatal intensive-care unit stabilization of extremely low-birth weight infants. *Journal of Obstertic, Gynecolgic, and Neonatal Nursing, 36*, 280-287.

Low birth-weight infants' temperatures decrease with caregivers procedures. Nursing interventions should be undertaken to prevent heat loss during procedures:

- Pre warming the delivery room
- Use of plastic bag (polyethylene, polyurethane) wrap in delivery room
- Hat wrap
- Warm blanket
- Warmer table
- Radiant heat on the infant during transport

Konopova, P., Janota, J., Termerova, J., Burianova, I., Paulova, & Zach, J. (2008). Successful treatment of profound hypothermia of the newborn. *Acta Paediatricia*, 98, 190-198.

Report citing a case of accidental profound hypothermia:

- Slow re-warming rate of 0.5^0 -1.0^0 C per hour in incubator
- Boluses of warmed NS and sodium bicarbonate

- Dopamine
- Phenobarbital used for sedation
- Core temperature over 24 hours (25^0 C - 44^0 C)
- Antibiotics
- Heparinization

Rapid warming has caused massive peripheral vasodilatation, decreasing peripheral vascular resistance, hypotension, decreasing coronary perfusion, and shunting cold blood and metabolites from the peripheral to the myocardium.

Report concluded significant decisions involved determination of the most appropriate method and speed of re-warming. In addition, gradual re-warming of a severely hypothermic newborn is supported.

Laptook, A., Salhab, W., & Bhaskar, B. (2007). Admission temperature of LBW infants: Predictors and associated morbidities. *Pediatrics, 119*(3), e643-e649.

Study of infants without major congenital anomalies and birth weights ranging 401 – 1499 grams. Associations between antepartum/birth variables and admission temperature and selected morbidities/mortality and admission temperature were examined.

The most effective interventions to minimize extent of heat loss seem to be:
- Occlusive wraps
- Polyethylene wraps
- Polyurethane bags better when compared to drying
- Caps

Lewis, D. A., Sanders, L. P., & Brockopp, D. Y. (2011). The effect of three nursing interventions on thermoregulation in low birth weight infants. *Neonatal Network*, 30.3(May/Jun), 160-164.

Study conducted to evaluate the use of three nursing interventions--occlusive wrap, chemical mattress, and regulation of delivery room temperature--singly and in combination in consecutive years on thermoregulation in six groups of low birth weight infants. The outcome variable was NICU admission temperatures of infants weighing <1,500 grams divided into two groups: those weighing <1,000 g and those weighing between 1,000 and 1,500 grams. For each of the three interventions, the percentage having a normal NICU admission temperature in each intervention group exceeded the control group percentage, but the increase was not significant. Use of each intervention--occlusive wrap alone, occlusive wrap in addition to chemical mattress, and occlusive wrap in addition to chemical mattress and increased delivery room temperature--appeared to influence thermoregulation positively.

McCall, E., Alderdice, F., Halliday, H., Jenkins, J., & Vohra, S. (2010). Interventions to prevent hypothermia at birth in preterm and/or low birthweight infants. *Cochrane Database of Systematic Reviews*(3). doi:10.1002/14651858.CD004210.pub4.

Skin-to-skin care (SSC) was shown to be effective in reducing the risk of hypothermia when compared to conventional incubator care for infants (1 study, n = 31; RR 0.09; 95% CI 0.01, 0.64). The transwarmer mattress reduced the incidence of hypothermia on admission to NICU in VLBW infants (1 study, n = 24; RR 0.30; 95% CI 0.11, 0.83).

Plastic wraps or bags, plastic caps, SSC and transwarmer mattresses all keep preterm infants warmer leading to higher temperatures on admission to neonatal units and less hypothermia. However, the small numbers of infants and studies and the absence of long-term follow-up mean that firm recommendations for clinical practice cannot be given.

In an attempt to maintain core body temperature within the normal range of 36.5° C to 37.5° C (skin temperature of 0.5° C to 1.0° C lower), the term infant responds by production of heat from the breakdown of brown fat.

When skin temperature falls to 35° C to 36° C, non-shivering thermogenesis is initiated (Bruck 1961). The World Health Organization classifies a core body temperature for newborns of 36 to 36.4° C as mild hypothermia, 32° C to 35.9° C as moderate and < 32° C as severe (WHO 997). Currently, there is no accepted formal definition of 'normal' temperatures for preterm infants and methods and accuracy of temperature measurement continue to be debated (Bailey 2000; Smith 2004).

Standard care includes providing a warm delivery room at a minimum of 25° C (although rarely achieved in practice) (WHO 1997), drying the infant thoroughly, immediately after birth (especially the head) (Bloom 1994), removing any wet blankets, wrapping in a prewarmed blanket, prewarming any contact surfaces, eliminating draughts and close proximity to outside walls (Capobianco 1980). If available, radiant warmers for resuscitation and stabilisation allow easy access and are effective in preventing heat losses, provided that the infant is immediately dried and placed under the prewarmed heater (Du 1969; Dahm 1972).

Interventions should either decrease total heat losses or provide external heat without compromising accessibility during resuscitation and should have minimal side effects (such as hyperthermia, burns, maceration, or infection).

Neonatal hypothermia after birth is a world-wide issue (Costeloe 2000) across all climates (Christensson 1988; Johanson 1992; Tafari 1973; Laptook 2007; Kumar 2009) and, if prolonged, can lead to harm and in severe cases death. Silverman 1958 and Day 1964 showed that reducing heat losses in preterm infants in the first few days after birth increased survival rates

Despite the variations in interventions applied, definitions of 'routine care', definitions of hypothermia and groups of infants included, across all studies there is a similar pattern emerging showing that infants in the intervention group are significantly warmer (or show a non-significant trend in that direction) when compared to infants receiving 'routine care'. There is also an indication from these studies that the effect is greater in the lightest and most immature infants. Babies of < 28 weeks or those weighing ≤ 1500 grams appeared to derive most benefit from interventions in the delivery suite to prevent hypothermia. These are also the infants most likely to suffer from the adverse effects of hypothermia and in whom further studies should be undertaken.

Mance, M. J. (2008). Foundations in Newborn Care: Keeping Infants Warm: Challenges of Hypothermia. *Advances in Neonatal Care*, 8(1), 6–12.

Review of the consequences of hypothermia, mechanisms of heat exchange and heat production in full-term and low birth-weight infants, and discussion of interventions in the delivery room to alleviate hypothermia. A warm delivery room environment in conjunction with prompt interventions of routine care, i.e., utilizing polyethylene occlusive wraps and environmental humidity for LBW infants, can help maintain body temperature.

Mullany, L. C. (2010). Nenoatal hypothermia in low-resource settings. *Semin Perinatol*, 34(6), 426-433.

WHO - Warm-Chain for low birth weight or premature babies in low resource settings.
The warm-chain consists of 10 steps to minimize risk of exposure and includes the following: keeping the delivery room warm, drying immediately, skin-to-skin contact, breastfeeding, delayed bathing, appropriate clothing, warm transport (if necessary), keeping mother and baby together, warm resuscitation, and improved awareness and recognition of hypothermia risk.

National Collaborating Centre for Women's and Children's Health. (2007). Intrapartum Care care of healthy women and their babies during childbirth. *NICE Clinical Guideline 55*, 1-65.

NICE Guideline : In order to keep the baby warm, he or she should be dried and covered with a warm, dry blanket or towel while maintaining skin-to-skin contact with the woman.

Association of Women's Health, Obstetric and Neonatal Nurses. (2007). Neonatal Skin Care, Second Edition. *Evidence –based Clinical Practice Guideline*, 87.

Temperature is not assessed until later in the resuscitation plan, along with the use of supplemental conductive heat from water filled pads or heated mattresses to reduce heater output from radiant warmers.

Use polyethylene coverings to reduce TEWL and evaporative heat loss if unable to provide a humidified is encouraged. Plastic wraps should not be in contact with skin surfaces for prolonged periods.

New, K., Flenady, V., & Davies, M. W. (2011). Transfer of preterm infants from incubator to open cot at lower versus higher body weight. *Cochrane Database of Systematic reviews*, Sep 7,9:CD004214.

Cochrane Review: To determine the effects of body weight in transferring preterm infants from incubators to unheated open cots. Four eligible studies identified; randomized and quasi-randomized controlled trials.

Conclusion: Medically stable preterm infants can be transferred to unheated open cots at a lower body weight of 1600 grams without adverse effects on temperature stability or weight gain. Earlier transfer does not necessarily result in earlier discharge.

Purcell, N., & Beeby, P. (2009). The influence of skin temperature and skin perfusion on the cephalocaudal progression of jaundice in newborns. *Journal of Paediatrics and Child Health*, 45, 582-586.

Testing the progression of jaundice related to regional differences in skin temperature and skin perfusion. There is a relationship with skin temperature and capillary refill when compared to patterns of jaundice in the head, chest and soles of the foot.

Transcutaneous billirubin was compared to skin temperature and capillary refill time.

It was hypothesized then, that newborns preferentially perfuse the head and proximal parts of their body in the first few days of life, leading to higher temperatures and increased billirubin deposition at these sites.

Raghuveer, R. a. (2011, April 15). Neonatal Resuscitation: An Update. *American Academy of Family Physician, 83*(8), 865.

Steps of resuscitation: Infant is brought to the warmer first, then sniffing position to open the airway, airway is cleared, infant is dried, gentle rubbing on the infant's back with drying. Wet towels are removed. Then assess respirations, count heart rate with umbilical cord pulsation, or by auscultation the heart.

Hypothermia at birth is associated with increased mortality in preterm infants. Wrapping in addition to radiant heat, improves admission temperature of preterm infants. It is recommended to cover preterm infants less than 28 weeks gestation in polyethylene wrap after birth and placed them under radiant warmers. Hypothermia should be avoided. Delivery room temperature should be set at least 78.8F (26 C) for infants less than 28 weeks gestation.

Reddy, N. O., Mathur, G., & Hariharan, S. I. (2009). Toward a fuzzy logic control of the infant incubator. *Annals of Biomedical Engineering*, 37(10), 2146-52.

Study to address the question of whether both the infant's skin temperature and the incubator air temperature can simultaneously be used to control heating. The fuzzy logic control system resulted in significantly reduced fluctuations in incubator heating.

Sobel, H. L., Silvestre, M. A., Mantaring, J. B., Oliveros, Y. E., & Nyunt, U. S. (2011). Immediate newborn care practices delay thermoregulation and breastfeeding initiation. *Acta Paediatrica*, 100, 1127-1133.

Drying, weighing, eye care and vitamin K injections prevented 93% of newborns from immediate skin to skin contact, and limited breastfeeding opportunity.

Although thorough drying, direct skin to skin contact immediately upon delivery, and covering with a blanket and bonnet prior to cord clamping mitigated the threat of hypothermia, stimulated breathing, studies found that sustained skin to skin contact also initiates colonization of the newborn with maternal flora, and hospital flora and facilitates olfactory learning, successful intake of colostrums and sustained breastfeeding.

Bathing the baby exposes them to hypothermia, removes maternal bacteria and the vernix caseosa when it is a potent inhibitor of Escherichia coli and eliminates the crawling reflex.

Sokolover, N., Merlob, P., & Klinger, G. (2008). Neontatal recurrent prolonged hypothermia associated with maternal mirtazapine treatment during pregnancy. *Canadian Journal of Clinical Pharmacology*, 15, e188-190.

Recurrent hypothermia from twins born to a mother treated with mirtazapine. It is an acute antidepressant tricyclic agent with nonadrenergic and serotoninergic activity by blocking alpha 2 receptors and antagonizing the serotonin receptors. It also antagonizes histamine and peripheral adrenergic and muscarine antagonist. It has a low molecular weight and transplacental transfer to the fetus in measureable amounts is anticipated. It has been shown to affect thermoregulation in animals and humans.

At birth, the twins were assessed and placed in incubators, at 24 hours, they were transferred to warmed bassinets, at two days they were transferred to open cot. After 14 hours without warmth, they both had marked temperature loss. This continued for 10 days.

Templeman, M. C., & Bell, E. F. (1986). Head Insulation for Premature Infants in Servocontrolled Incubators and Radiant Warmers. *American Journal of Diseases of Children*, 140(9), 940-2.

Study to evaluate the safety of insulating the heads of premature infants in servocontrolled thermal environments. The insulated headwrap increased the scalp temperature of incubator infants but not radiant warmer infants. Head insulation reduced variability in scalp temperature for radiant warmer infants. There was no evidence found of overheating in these infants. The findings did not support routine use of head insulation.

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van der Spek, R. D., Van Lingen, R. A., & van Zoeren-Grobben, D. (2009). Body temperature measurement in VLBW infants by continuous skin measurement is a good or even better alternative than continuous rectal measurement. *Acta Paediatrica* 98(2), e282-5.

Study of low birth weight preterm newborns conducted comparing continuous rectal temperature monitoring with continuous skin probe (zero heat flow) temperature monitoring. Analysis of 1205 out of 1248 temperature measurements demonstrated that the zero heat flow method was as reliable as the rectal method with less complications and no discomfort.

Vermont Oxford Network. (n.d.). *Heat Loss Prevention (HeLP) Trial.* Retrieved March 15, 2011, from http://www.vtoxford.org/research/help/help.aspx

EPICure study determined that 36% of premature infants (24-25 weeks) had an admission temperature of less than 35^0 C.

Hypothermia is associated with an increased risk of morbidity and mortality. Pilot studies have shown that wrapping the infant of less than 28 weeks gestation in polyethylene occlusive wrap after birth improves admission temperature.

The HeLP (Heat Loss prevention) trial was conducted to determine if the application of polyethylene wraps in infants between 24-27 weeks gestation would result in decreased mortality, when compared with conventional method of drying. Follow-up planned for 18 months after birth.

Trial delivery room management consisted of:

- Turn warmer to full power
- Prepare wrap under warmer with blankets underneath
- Record delivery room temperature
- Place infant on wrap
- Dry head, put hat on close wrap, apply Sa02.
- Record age in seconds
- Apply wrap
- Proceed with resuscitation
- Weigh infant
- If less than 15 min apply servo probe
- Transport to NICU
- Admit to NICU and record axilla baseline through wrap
- If temperature less than 35.5 adjust with more warming material
- When stable, remove wrap, dry wrap, take axilla post stable temperature.

Visscher, M. O., Narendran, V., Pickens, B. S., LaRuffa, A. A., Meinzen-Derr, J., Allen, K., & Hoath, K. (2005). Vernix Caseosa in Neonatal Adaptation. *Journal of Perinatology*, 25, 440–446.

Study conducted in which vernix distribution was tested to assess if it is beneficial to thermoregulation of the neonate, along with skin hydration, acid mantle development and vernix antioxidant properties. It was determined that vernix retention had no effect on axillary temperatures. Skin hydration was significantly higher for vernix- retained skin; skin pH and erythema were lower with retention.

Vohra, S., Roberts, R., Zhang, B., Janes, M., & Schmidt, B. (2004). Heat loss prevention (HELP) in the delivery room: a randomized controlled trial of polyethylene occlusive skin wrapping in very preterm infants. *The Journal of Pediatrics, 145*, 750-753.

Plastic wraps or bags were effective in reducing heat losses in infants of < 28 weeks gestation (4 studies, n = 223; WMD 0.68° C; 95% CI 0.45, 0.91), but not in infants between 28 to 31 weeks gestation. Plastic caps were effective in reducing heat losses in infants of < 29 weeks gestation (1 study, n = 64; MD 0.80° C; 95% CI 0.41, 1.19). There was insufficient evidence to suggest that either plastic wraps or plastic caps reduce the risk of death within hospital stay.

There was no evidence of significant differences in other clinical outcomes for either the plastic wrap/bag or the plastic cap comparisons. Stockinet caps were not effective in reducing heat losses.

Yokoyama, K., Suzuki, M., Shimada, Y., Matsushima, T., Bito, H., & Sakamoto, A. (2010). Effect of Administration of Prewarmed Intravenous Fluids on the Frequency of Hypothermia Following Spinal Anesthesia for Cesarean Delivery. *Obstetric Anesthesia Digest*, 30(2), 122.

Randomized, double-blind, placebo controlled study. Study to determine if administration of pre-warmed colloid followed by pre-warmed crystalloid solution prevents development of hypothermia in patients undergoing Caesarean delivery. Results demonstrated core temperature significantly higher in the group administered warmed fluid from the time of delivery to 45 minutes after delivery. Apgar scores of the infants at one minute after delivery and umbilical arterial pH were higher in the warmed fluid group.

V. Barriers to Thermal Regulation

Summary

From this literature search it has been determined that barriers exist which influence the thermal management of the neonate. The physiological state of the newborn affect its ability to self regulate temperature.

Interventions that create a barrier to thermal management include those interventions that are necessary due to the acuity of the neonate, specifically the need to resuscitate. The type of bathing used as well as the type of diaper used and position of the baby also interfere with thermal management. Infant exposure during nursing interventions that necessitated opening of incubator doors and instillation of normal saline at room temperature for oligohydramnios constituted a barrier to thermal regulation.

This literature search concludes that skin to skin contact is not a barrier to the management of temperature, and does not interfere with temperature regulation when done correctly. It was also determined that care interventions that produce sleep disturbances are not considered to be a barrier in thermal regulation.

Bibliography

Ahmed, S., Mitra, S. N., Chowdhury, A. M., Camacho, L. L., Winikoff, B., & Sloan, N. L. (2011). Community Kangaroo Mother Care: implementation and potential for neonatal survival and health in very low-income settings. *Journal of Perinatology, 31*, 361-367.

Research of Skin to Skin Care begins in very low income countries to promote thermal regulation, breastfeeding and maternal newborn boding. RCT of Community based kangaroo mother care (CKMC) in Bangladesh are studied.

Results found that newborns held at STS (skin to skin) less than 7 hours per day in the first 2 days of life do not experience better health or survival than babies without being held STS.

90% gave birth at home.

Arora, S. (2008). Kangaroo Mother Care. *The Nursing Journal of India*, XCIX(11), 248-250.

Studies carried out in low income countries showed that a prolonged skin to skin contact between the mother and her preterm LBW infant provides effective thermal control and it is associated with a reduced risk of hypothermia. KMC results in normal temperature during the procedure without any risk of hypothermia. Study limited to LBW 1800 grams.

If 1200-1799 grams, they transported to special facility keeping them in continuous skin to skin contact with mother.

Bach, V., Telliez, F. E., Leke, A., & Libert, J. P. (2000). Gender-related sleep differences in neonates in thermo neutral and cool environments. *J Sleep Res*, 9, 249-54.

Study conducted to determine if there are gender related differences in thermoregulation and sleep for neonates.

- Healthy preterm neonates (21 boys and 17 girls) 37 + 2 weeks post conception age.
- They were exposed to thermoneutral and cool conditions.
- Sleep was analyzed for continuity and structure.
- Cool exposure did not strongly impair body homeothermia, sleep was altered but without any significant gender difference.
- When data recorded under each of the thermal conditions were pooled however, some gender differences emerged.
- Boys slept less quietly.
- Sleep continuity parameters exhibited greater variability in boys than girls.

Bach, V., Telliez, F., Zococcoli, G., Lenzi, P., Leke, A., & Libert, J. P. (2000). Individual differences in thermoregulatory response to cool exposure in sleeping neonates. *European Journal of Applied Physiology*, 81, 455-462.

Response of thermo regulatory effects vary greatly among neonates.

It is assumed that a small decrease in air temperature from thermo neutrality induces various thermo regulatory responses within neonates that represent an energy cost due to the cold defense processes.

26 neonates were explored at thermo neutrality and cool environments (-1.5^0 C from thermo neutrality) similar to that which occurs currently in a clinical procedure.

Oxygen consumption (VO_2), esophageal and skin temperature as well as sleep parameters were recorded.

Analysis revealed that cool exposure induced thermal and sleep disturbances, VO_2 did not increase and was not relatively correlated to body temperature.

Large variability in body temperature regulation. The neonates could be assigned to three groups according to the direction of the individual changes of VO_2 versus esophageal or skin temperature.

All groups differed according to sleep changes in the cool condition.

Baumgart, S. (1985). Partitioning of health losses and gains in premature newborns infants under radiant warmers. *Pediatrics, 75*(1), 89-99.

Partition of heat loss into convective and evaporative components and heat gain into metabolic rate of production and radiant heat needed to maintain thermal equilibrium was determined in 10 babies.

Convective heat loss comprised the major component of net heat loss.

Evaporative heat loss increased with servo control temperature.

Metabolic rate decreased with increased servo control temperature but this decrease was not significant.

Radiant heat delivered by the warmer to infants was directly proportional to the heat need calculated from the partition.

Convection warmed incubator reduces body heath losses through convection, radiation and evaporation, but circulating warm air.

Radiant warmer positioned over an open bed platform causes increased infant heat loss through convection and evaporation when compared with the enclosed incubator.

Radiant warmers allow for the infants to receive a net radiant heat gain from the radiant warmer, whereas the incubator serves only to reduce heat loss. Purpose of the study was to measure the partition of infant heat loss and heat gain under a radiant warmer.

Abdominal skin temperature was observed.

Convection comprised the majority component of net heat loss, exceeding the heat lost through evaporation by more than 200%.

Radiant heat increased skin heat, resulting in an increase in convective heat transfer to the cooler ambient air. Metabolic rate and evaporative water loss did not change with increases in temperature.

Evaporative heat loss was the same in both incubators. Radiant heat loss was greater in the single walled incubator, and convective heat loss was less. BMR did not change.

The babies under the radiant warmer had a greater convective and evaporative heat loss, and these losses greatly exceed the rate of metabolic heat production.

The linear correlation between radiant heat need calculated from the partition of heat losses and metabolic heat production described and the measure radiant head delivered to the infant indicates a clear relationship between radiant warmer servo control function and the infant thermal physiology.

Bissinger, R., & Annibale, D. (2010). Thermoregulation in very low birth weight infants during the golden hour, results and implications. *Advances in Neonatal Care, 10*(5), 230-238.

Thinness and lack of keratin leads to high amount of trans epidermal water loss.

Bohnhorst, B. (2010). Skin to skin care in the neonatal intensive care unit: More data regarding seriously ill infants are badly needed. *Neonatology*, 97, 318-320.

Kangaroo care came from Colombia 1970, moved throughout Europe quickly, but not so fast in the US where access to high tech equipment is not so desperate. Now accepted and called Skin to Skin care. (SSC). Past literature focuses on psychological effects rather than physiological effects, and even less on temperature regulation. This article reviewed Heiman's previous article about supine position in SSC and declares more evidence that in terms of thermoregulation, the neonate tolerates SSC well. There is still a need for further study with SSC and the critically ill infant.

Bryanton, J., Walsh, D., Barrett, M., & Gaudet, D. (2003). Tub Bathing versus traditional sponge bathing for newborns. *Journal of Obstetric Gynecologic and Neonatal Nursing*, 33(4), 704-712.

Tub bathing vs. traditional sponge bathing in healthy term newborns and ratings of mothers' pleasure and confidence of the bath.

RCT N= 102

Newborn axillary temperatures were assessed by recording pre and post bath.

Umbilical cord healing was identified by daily observation and infection control surveillance.

Infant contentment was quantified by applying the Brazelton Neonatal Behavioral Assessment Scale and maternal pleasure with bath and confidence with bathing at discharge were self rated.

Results:

- Tub bathed babies experience significantly less temperature loss ($t = 4.79$) and were significantly more content than those who were sponge bathed.
- No difference in cord healing
- Mothers of tub bathed babies rated their pleasure with the bath significantly higher than did mothers of sponge bathed babies. No difference in maternal confidence was noted.
- Tub bathing is safe and pleasurable alternative to sponge bathing in healthy term newborns.

Gabriel, M., Matrin, I., Escobar, A., Villalba, E., Blanco, I., & Pol, P. (2009). Randomized controlled trial of early skin-to-skin contact: effects on the mother and the newborn. *Acta Paediatrica, 99*, 1630-1634.

RCT- Greater thermal stability in the skin to skin group as evidence by average skin temperature rise of 0.07^0 C was observed.

This study did not support temperature correlation and breastfeeding success, however, skin to skin has been associated with greater breastfeeding success.

Laptook, A., Salhab, W., & Bhaskar, B. (2007). Admission temperature of LBW infants: Predictors and associated morbidities. *Pediatrics, 119*(3), e643-e649.

Study of infants without major congenital anomalies and birth weights ranging 401 – 1499 grams. Associations between antepartum/birth variables and admission temperature and selected morbidities/mortality and admission temperature were examined.

Changes that impact the body temperature of the newborn:

- Multiple routes of heat loss (evaporative, convective and conductive)
- Intubation and management
- Increase in oxygen consumption due to consequent heat production
- Limited vernix caseosa, sub-cutaneous fat, increased surface area/weight ratio and immature epidermal barrier

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Maastrup, R., & Griesen, G. (2010). Extremely preterm infants tolerated skin to skin contact during the first weeks of life. *Ach Paediatrics*, 99, 1145-1149.

22 stable infants, with mean gestational age of 25 weeks and 4 days, post natal ages of 8 days, with mean actual weight at 702 grams. Skin to skin contact was 98 minutes.

There were no significant differences in mean skin temperature, heart rate, respiratory rate, or oxygen saturation before, during and after skin to skin contact. Mean skin temperature increased 0.21^0 C during skin to skin contact with mother and decreased 0.3^0 C during skin to skin contact with father.

Mok, Q., Bass, C. A., Ducker, D. A., & McIntosh. (1991). Temperature instability during nursing procedures in preterm neonates. *Archives of Disease in Childhood*, 66, 783-786.

249 infants were observed for temperature changes during nursing care the first week of life. 25 preterm infants weighing less than 1500 grams, 16 of whom weighed less than 1100 rams.

Large drops in both central and peripheral temperature occurred with widening of the central – peripheral temperature gap.

Recovery of temperature took 2 hours.

Routine nursing procedures carried out every four to six hours cause an important alteration in the environmental temperature with consequent thermal stress to the infants that may influence ultimate outcome

Humidified incubators were used.

Babies routinely nursed naked and covered by a single layer of bubble plastic in closed incubators, the air in which was controlled at the temperature of the infant's neutral thermal environment.

Nursery was at 28^0 C with humidity at 40%.

Temperature measured peripherally changed 3 degrees, temperature measured core changed 2-4 degrees.

Questions remain about whether the temperature was regained by an increase in metabolic rate or by a decrease in the rate of heat loss to the surroundings thus allowing the heat generated by the babies' stable metabolic rate to accumulate.

Monterosso, L., Percival, P., Cole, J., & Evans. (1999). Effect of nappy liners on temperature stability in very preterm infants. *Journal of Paediatrics and Child Health*, 35, 363-366.

To determine if absorbent liners used in posturally supportive cloth nappies influenced temperature control in infants less than 31 weeks gestation.

There was no change in temperature measurement over time. Infants nursed with the liner demonstrated a higher skin temperature and lower incubator temperature. A drop in skin temperature and an increase in incubator temperature occurred following handling of infants.

Use of absorbent liner with a cloth postural support nappy promotes better temperature regulation in infants less than 31 weeks gestation by reducing incubator temperature and increasing skin temperature.

This was done to accommodate for the different diapers in use. Different diapers used to prevent external rotation of the legs, because the babies have to be flat on their back to keep up with their temperature.

It was found that this liner keeps the wetness away from the body.

Petrikovsky, B., & Silverstein, M. (1997). Neonatal shivering and hypothermia after intrapartim amnioinfusion. *Lancet*, 350(9088), 1366-1368.

Complications of hypothermia after birth of baby who was exposed to room temperature saline solution during labor for treatment of oligohydramnios. (lack of amniotic fluid or thick meconium). Baby delivered was noted to be shivering at 35.2 degrees.

VI. Accuracy of Temperature Measurement

Summary

From this literature search it has been determined that temperature assessment in the neonate is a critical intervention. Measurement is varied based on the site chosen for assessment, the correlation of this site and core temperature, as well as the type of thermometer used, the timing and frequency of temperature assessment, and infant characteristics such as position, age and weight.

This literature search found conflicting information in site recommendations. Most studies supported the axillary site for temperature assessment based on the rapid easy access in the newborn. However, some studies also discouraged the use of axillary sites due to their low correlation with core temperature readings, and extraneous uncontrolled factors such as probe depth and correlation with peripheral skin temperature. Indwelling rectal temperatures were most accurate for core temperature assessment, but were not recommended due to the need to expose the infant during assessment, and potential danger of perforation of delicate tissue.

The radiant warming sources as well as incubator warming sources, when used, commonly utilize skin thermometers to regulate temperature and rate of radiant heat. Studies supported the use of those devices to assist with control of heat, but found that they were not accurate in measurement of infant core temperature.

Factors that affect the measurement of temperature are defined as room temperature, incubator types, exposing the baby and opening the incubator, the timing of temperature assessment and the frequency of monitoring. Infant body position affects measurement; infants in the prone position have higher body temperatures.

Assessment of the core temperature does not reflect true hypothermic state, as the peripheries may continue to be sub therapeutic in temperatures.

Radiant warmers were found to affect infant thermal physiology.

Repeated axillary temperatures were not shown to improve control of hypothermia. Nor was the use of experienced nurses in the manual management of incubator temperatures.
Although hypothermia upon admission to NICU is directly correlated with poor outcomes, studies concluded that accurate measurement of temperature helps to manage hypothermia, but does not affect outcome of babies.

Bibliography

Adams, A., Nelson, R., Bell, E., & Egoavil, C. (2000). Use of infared thermographic calorimetry to determine energy expenditure in preterm infants. *The American Journal of Clinical Nutrition, 71*, 969-977.

Measurement of infant energy expenditure in the clinical setting is difficult. Both indirect and direct calorimetry requires long measurement periods and frequent calibration. Objective is to validate in infants a newly developed method of determining energy expenditure, infrared

thermographic calorimetry (ITC), against an established method, respiratory indirect calorimeter (IC).

ITC was used in conjunction with heat loss theory to calculate radiant, convective, evaporative and conductive heat loss and therapy determining total energy expenditure.

ITC is an accurate, noninvasive method for measurement of heat loss and energy expenditure in healthy pre-term infants, and therefore it may be useful for both clinical and research purposes.

Infrared cameras were used to track heat.

Heat loss equation was calculated. This is the only study that compared heat loss and heat production in infants. It validated ITC as accurate.

Heat production and heat loss are in constant flux in pre-term infants

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Amari, A., Schulze, K., Ohira-Kist, K., Kashyap, S., Fifer, W., Myers, M., & Sahni, R. (2009). Effects of body position on thermal, cardiorespiratory and metabolic activity in low birth weight infants. *Journal of Early Human Development, 85*, 497-501.

Surface temperatures were recorded from 4 body sites: forehead, right flank, right forearm and right leg using Incutemp thermistors. Care was taken to ensure accuracy of position and temperature measurement. Room temperature was recorded using the same Incutemp sensors. Temperature was recorded every 8 seconds with a device that logged measurement for each thermistor to a dedicated computer. The study panel found that this technique to measure temperature was accurate and reliable.

Long periods of indwelling rectal temperature monitoring are not feasible in the infant population.

Antonucci, R., Porcella, A., & Fanos, V. (2009). The infant incubator in the neonatal intensive care unit: unresolved issues and future developments. *Journal of Perinatal Medicine*, 597-598.

This study involved recorded skin, air, and wall temperature readings in the incubator with the readings entered into a computer algorithm to control heat production.

SCS or servocontrolled skin temperature derivate heating device is best to ensure quieter infant sleep, and reduced body movements.

HeatBalance (trade) uses basic physical principles to calculate heat gains and losses, and indicated incubator temperature and humidity settings to keep babies in thermal balance, continuous monitoring is required.

This study recommends the anterior abdominal wall for temperature measurement.

Aylott, M. (2006). The neonatal triangle. Part 2: Thermal regulatory and respiratory adaptation. *Paediatric Nursing, 18*(6), 38-42.

A pre-term (less than 35 weeks gestation) baby can have a normal core temperature (axilla) and still be cold stressed as indicated by low skin temperature. Both should be continuously monitored.
Optimal is 35.5^0-36.5^0 C skin or peripheral. Axillary is 36.3^0-37.2^0 C

Baumgart, S. (1985). Partitioning of health losses and gains in premature newborns infants under radiant warmers. *Pediatrics, 75*(1), 89-99.

Partition of heat loss into convective and evaporative components and heat gain into metabolic rate of production and radiant heat needed to maintain thermal equilibrium was determined in 10 babies.

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Radiant warmer positioned over an open bed platform causes increased infant heat loss through convection and evaporation when compared with the enclosed incubator.

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The babies under the radiant warmer had a greater convective and evaporative heat loss, and these losses greatly exceed the rate of metabolic heat production.

The linear correlation between radiant heat need calculated from the partition of heat losses and metabolic heat production described and the measure radiant heat delivered to the infant indicates a clear relationship between radiant warmer servo control function and the infant thermal physiology.

Bell, E., & Rios, G. (1983). A double walled incubator alerts partition of body heat loss of premature infants. *Pediatric Research, 17*, 135-140.

This landmark study provided raw data to support the use of double walled incubator in reduction of hypothermia for premature infants. The study chose to use the Servo Control for abdominal wall measurement.

Cramer, K., Wiebe, N., Hartling, L., Crumley, E., & Vohra, S. (2005). Health loss prevention: A systematic review of occlusive skin wrap for premature neonates. *Journal of Perinatology, 25*, 763-769.

3 RCT and 5 historical controlled trials were included. Meta analysis shows wrapped infants had significantly higher admission temperatures than unwrapped infants. A statistically significant difference in mortality was not found between wrapped and unwrapped infants in the RCT or the HCT.

DeCurtis, M., Calzolari, F., Marciano, A., Cardilli, V., & Barba, G. (2008, January). Comparison between rectal and infared skin temperature in the newborn. *Archives of Disease in Childhood Fetal and Neonatal Edition, 93*(1), F55-F57.

Study conducted to validate the accuracy and effectiveness of a non-invasive infrared skin thermometer in neonatology when compared to rectal temperature measurement.

Conclusion: Use of the infrared skin thermometer is a comfortable and reliable way of measurement of body temperature in newborns. It was recognized that the infrared skin thermometer cannot be substituted for rectal temperature in all cases however; the differences between the two modalities were modest.

De LA Fuente, L., Campbell, D., Rios, A., Grieg, A., Graff, M., & Brion, L. (2006). Frequency analysis of air and skin temperatures in neonates in servo-controlled incubators. *Journal of Perinatology, 26*, 301-305.

Testing the new digital recording of skin and air temperature thereby allowing analysis of cyclic changes in temperature in neonates in servo-controlled incubators.

Cyclic changes in skin and air temperatures in neonates in the servo controlled incubators. The most important changes in skin and air temperatures in asymptomatic neonates occur at a period of 1.5-3hours which is similar to that previously described for neonatal temperature.

Diego, M., Field, T., & Hernandez-Reif. (2008). Temperature increases in preterm infants during massage therapy. *Infant Behavior and Development, 31*, 149-152.

Site used was right outer calf; temperature probe was used and attached with surgical tape. Air Servo control method monitored heat. Study of 72 pre-term infants indicates that massage therapy is safe to use in pre-term infants in isolettes. Additionally the findings highlight the contribution of human touch.

Duran, R., Vatansever, U., Acunas, B., & Sut, N. (2009). Comparison of temporal artery, mid forehead skin termperature *Child Health, 45*, 444-447.

Objective is to evaluate the performance of non-invasive infrared thermometer applied to the mid forehead and temporal artery in comparisons with axillary temperature recordings by mercury in glass thermometer, and to determine the discomfort caused by these procedures in preterm infants on incubator care.

Mid forehead temperature, artery, and axillary temperatures were all tested. No statistical difference was noted between the means of mid forehead and axillary temperature. The mean temporal artery temperature was statistically higher than the means of the mid forehead and axillary temperatures. The PIPP score of the mid forehead temperature artery and axillary temperature measurements was statistically higher than the means of the mid forehead and temporal artery measurements.

Infrared skin thermometers applied to the mid forehead are as useful and valid device for easy and less painful measurement of skin temperature in the preterm infants of less than 1500 grams.

Gabriel, M., Matrin, I., Escobar, A., Villalba, E., Blanco, I., & Pol, P. (2009). Randomized controlled trial of early skin-to-skin contact: effects on the mother and the newborn. *Acta Paediatrica, 99*, 1630-1634.

Temperature was measured with a digital thermometer at the axilla – healthy newborns

RCT on 137 infants to estimate the influence of skin-to-skin contact on thermal regulation and the rate of breast feeding. Greater thermal stability was found in the skin-to-skin care group.

George, G., & Mishra, S. (2009). Routine axillary temperature monitoring in neonates cared under radiant warmer- is it necessary. *Indian Journal of Pediatrics, 76*, 1281-1282.

RCT- the servo-controlled mode of radiant warmers may be sufficient for routine temperature monitoring of neonates, rendering regular axillary temperature measurement unnecessary.

Hissink, M., van Berkel, L., & de Beaufort, A. (2008). Axillary and rectal temperature measurements poorly agree in newborn infants. *Neonatology, 94*(1), 31-34.

Aim was to evaluate the agreement between axillary temperature measurements and rectal temperature measurements in neonates. The axillary temperature was significantly lower than the rectal temperature (mean +/- SD 0.27 +/- 0.20 degrees C, $p < 0.05$). Due to the wide variation between the mean difference of axillary and rectal temperature, axillary temperature measurements cannot be used interchangeably with rectal measurements in neonates.

Hutton, S., Probst, E., Kenyon, C., Morse, D., Friedman, B., Arnold, K., & Helsley, L. (2009). Accuracy of different temperature devices in the postpartum population. *Journal of Obstetric Gynecologic and Neonatal Nursing, 38*(1), 42-49.

Study to determine if different temperature monitoring devices routinely used in postpartum provide similar temperatures and also a comparison of the rectal and axillary routes for temperature monitoring in newborns. It was concluded that the statistically significant temperature differences between the axillary and rectal temperatures in newborns emphasized that axillary temperatures are not similar to rectal temperatures. The variability between temperatures obtained with different devices demonstrates a need to use a consistent temperature device when monitoring temperature.

Jaffe, C. A. (2009). Routine assessment of temperature in healthy newborns: Lack of evidence for its clinical utility. *Archives of Pediatrics & Adolescent Medicine, 160*(3), 283.

Polyurethane occlusive wrapping was applied upon delivery. Giraffe Radiant Warmer (GE Tech) warmer was computer controlled, and humidity was added at 60-80%. This study found no benefit to measuring temperature as a guide for indication of illness or problem with infant. No consistent patterns of abnormality. Temperature was recorded every 30 minutes until stable for 2 hours. The study group preferred temperature measured from the axilla.

Knobel, R., Holditch-Davis, D., Schwartz, T., & Wimmer, J. (2009). Extremely low birth weight preterm infants lack vasomotor response in relationship to cold body temperatures at birth. *Journal of Perinatology, 29*(12), 814-821.

Abdomen, foot and axillary temperatures were compared.

ELBW infant temperatures decrease with caregiver procedures, i.e., umbilical line insertion, intubations, manipulating IV lines etc. It is important that all NICU care providers optimize the thermal environment for ELBW infants in the delivery room during NICU stabilization.

Lyon, A.J., and Oxley, C. (2001). HeatBalance, a computer program to determine optimum incubator air temperature and humidity. A comparison against nurse settings for infants less than 29 weeks gestation. *Early Human Development, 62*, 33-41.

Study to compare the effect of a computer program on temperature control of infants less than 29 weeks gestation with that achieved by experienced nurses. 20 babies during first 5 days of life were studied in incubators all using air mode control. The control group had temperature and humidity set by nurses who changed settings based on infant temperature on the monitor. In

the intervention group incubator settings were determined by the computer program. There were no differences in mean central temperature or extreme temperatures. It was concluded that similar results were achieved in temperature stability with both methods. The study additionally concluded the importance of continuous monitoring of the infants.

Lyon, A., & Freer Y. (2011). Goals and options in keeping preterm babies warm. *Archives of Disease in Childhood Fetal Neonatal Edition, 96*, F17-F74.

Historical overview on studies dating back to 1950 with a focus on temperature control and neonatal mortality.

- 1950 Silverman study that showed a series of RCT and a clear link between incubator humidification.
- 1970 Hammarlund and colleagues discussed fluid and heat fluxes due to transepidermal water loss.
- 1980's defined healthy temperatures for high need babies
- 1990's compared incubators to overhead radiant heaters
- 2000's temperature management during vulnerable times (resuscitation) and for very immature babies, inverse relationship of NICU admit temperature and mortality and late onset of sepsis.
- 2010 defining thermal stress.

Two problems identified:

- Trying to define a 'normal' temperature (which depends on how it is measured)
- A normal central temperature does not mean the baby is in a thermoneutral state.

Additional Considerations:

- Infant vulnerability
- Modes of measurement
- Delivery, stabilization, transport
- Warming devices

Goals: maintaining a normal temperature and avoiding thermal stress

Issue: varied options to achieve the desired outcomes

Future considerations:

- Development of a single warming device that maintains a stable thermal environment and can be used throughout the care of the baby from birth to discharge home.
- Temperature monitoring on admission and during transport should be done as part of quality of care during vulnerable periods.

Miller, S., Lee, H., & Gould, J. (2011). Hypothermia in very low birth weight infants: Distribution, risk factors and outcomes. *Journal of Perinatolgoy, 31*, S49-S53.

Utilizing WHO criteria, it was determined that hypothermia is prevalent among VLBW infants
WHO criteria:

1. Cold stress, or mild hypothermia –36.0^0-36.4^0 C (96.8-97.5 F)

2. Moderate hypothermia 32.0^0-35.9^0 C (89.6-96.6 F)
3. Severe hypothermia – below 32.0^0 C (89.6 F).

Rectal temperature preferred, but if unavailable, esophageal, tympanic or axillary temperature is recorded.

Strohm, B., & Azzopardi, D. (2010). Temperature control during therapeutic moderate whole-body hyperthermia for neonatal encephalopathy. *Archives of Disease in Childhood Fetal Neonatal Edition, 95*, F373-F375.

Hourly rectal temperature with servo controlled heating device.
Target rectal temperature is 33.5c for first 72 hours.

TOBY Cooling Register study group set up in UK to document the use of therapeutic cooling.

Yeh, T., Voora, S., Lillien, L., Matwynshym, J., Srinivasan, G., & Pildes, R. (1980). Oxygen consumption and insensible water loss in premature infants in single-versus double-walled incubators. *Journal of Pediatrics, 97*, 967-1.

The findings of this study were discussed in Larioa's Cochrane Review on double wall versus single wall incubators. Yeh's study supported the use of Servo Control with abdominal wall measurement for assessment of infant temperature regulation.

VII. Equity and Disparities

Summary

There are few literature sources that provide direct information regarding equity of care across populations, or that identify populations of disparities. Information is found on access to prenatal care in diverse populations, and attitudes of care in diverse populations.

Maternal variations that affect the thermoregulation of a newborn are related to those mothers delivering with acute illness themselves, the use of antibiotics, the use of tocolytics. Antenatal steroids and multiple births are found to be correlated with newborn hypothermia, as the use of steroids is associated with imminent birth of preterm or premature infants, and multiples are associated with premature births as well. Prolonged rupture of membranes is also associated with a greater incidence of hypothermia, as well as African American heritage. It is not known if this correlation is strictly related to access to prenatal care, or other associated phenomena, further study is indicated.

Infant variations that affect thermoregulation of a newborn are those characteristics such as birth weight, age, gender, delivery room treatment, acuity of infant and need for resuscitation. Studies have supported that hypothermic infants have umbilical artery pH alterations as well as increased base excess. Mode of delivery, specifically cesarean section has been associated with infant hypothermia as well.

Incidentally, it was found that during skin-to-skin care, there was an increase in body temperature that was more evident in middle-low-income settings than high-income settings but with no clear explanation for this. There are also variations in hypothermic infants in relation to their location of birth.

Bibliography

Laptook, A., Salhab, W., & Bhaskar, B. (2007). Admission temperature of LBW infants: Predictors and associated morbidities. *Pediatrics, 119*(3), e643-e649.

Study of infants without major congenital anomalies and birth weights ranging 401 – 1499 grams. Associations between antepartum/birth variables and admission temperature and selected morbidities/mortality and admission temperature were examined.

Maternal variations that affected newborn temperature:

- Antibiotics
- Tocolytics
- Antenatal steroids
- Multiple births
- Intrapartum variables- labor
- Ruptured membranes > 18 hours
- Mode of delivery

Infant Variations that affected newborn temperature:

- BW
  Age
- Gender
- Delivery room treatment - intubation
- Chest compression
- Apgar scores
- Umbilical artery pH, and base excess
- Site of temperature
- Age of temperature
- Network center of birth

Miller, S., Lee, H., & Gould, J. (2011). Hypothermia in very low birth weight infants: Distribution, risk factors and outcomes. *Journal of Perinatolgy, 31*, S49-S53.

Spontaneous labor, prolonged rupture of membranes and antenatal steroid administration were associated with decreased risk of hypothermia.

Cesarean mode of delivery, low Apgar scores, maternal hypertension, and black race carry higher odds of hypothermia.

Spontaneous labor, PROM and antenatal steroid administration were associated with lower odds of moderate to severe hypothermia, independent of birth weight.

Resuscitative efforts also improved chance of hypothermic events.

Mori, R., Khana, R., Pleadge, D., & Nakayama, T. (2010, April). Meta-analysis of physiological effects of skin-to-skin contact for newborns and mothers. *Pediatrics International, 52*(2), 161-170.

Meta-analysis to investigate whether skin-to-skin contact for newborn babies and their mothers affects body temperature, heart rate and oxygen saturation of the babies. There was evidence of an increase in body temperature and a decrease in saturation of babies during skin-to-skin care. The increase in body temperature was more evident in middle-low-income settings than high-income settings but with no clear explanation for this. Both the positive effect on body temperature and the negative effect on saturation were more marked in cold environments. It was concluded that skin-to-skin care is effective in increasing the body temperature of babies, especially where resources are limited and the environment is cold. Decreased oxygen saturation of the babies, however, warrants further prospective studies to confirm the findings. The results of the meta-analysis should not be applied to babies other than stable normal and low-birthweight infants.
