CAPQuaM Perinatal Measure #4 Appendix
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Appendix A

All References (Literature Cited)

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Appendix B

Literature Review- Phase I and Phase II

CAPQuaM Perinatal Construct

Literature Review

March 19, 2012

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The Joint Commission

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.

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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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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.

CAPQuaM

Care and Regulation of Temperature in the Neonate

Phase II Literature Review

August 24, 2012

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

Executive Summary

A review of the literature was conducted to identify information respecting the care and regulation of temperature in the neonate. Four key research questions were identified to focus the literature review. This review of the literature indicates that failure to intervene and prevent hypothermia in the premature, low birth weight neonate upon admission to the Neonatal Intensive Care Unit (NICU), is associated with undesirable outcomes. Hypothermia upon admission to the NICU and its relationship with morbidity and mortality is still under investigation.

This review established that there is a variation in the outcomes of this population. It was determined that there is a correlation with improved neonatal outcomes and the amount of resources used respecting resuscitation, thermal control, and neonatal transport. Also, improved outcomes, specifically growth and feeding were associated with those infants who maintained normothermia.

The cited literature, in addition to national and international guidelines, supported a number of known interventions to protect Extremely Low Birth Weight (ELBW), Very Low Birth Weight (VLBW), and 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 goals. These interventions have been found to decrease the incidence of hypothermic temperatures on admission to a NICU unit in low birth weight (1500 grams), very low birth weight (<1000 grams), preterm (<31 weeks), and premature (<27 weeks) infants.

Identification of accurate techniques for measurement of temperature, timing of temperature measurement and the comprehensiveness of temperature assessment was also examined in this literature review. Information found supported the use of skin thermometers, axillary thermometers, rectal thermometers, and core thermometers, were all acceptable locations for measuring temperature in this population. Rectal temperatures have been noted as the most accurate site of measurement to assess core temperature. However, in this review, most studies supported the axillary site for temperature assessment based on the rapid easy access in the newborn. Axillary temperature measurement has also been recommended as the standard of care for neonates by the American Academy of Pediatrics and the National Association of Neonatal Nurses.

This literature review sought out recommendations for length of time to accurately assess body temperature. Mercury-in-glass thermometers yielded the most accurate result of measurement, with a time between 3 to 5 minutes. However, delayed time in obtaining results can adversely affect the care provided to infants, thus, the tympanic infrared digital thermometers were identified as delivering rapid accurate results, and were therefore recommended.

The comprehensiveness of temperature assessment in the premature neonatal infant population was inspected as well. It was determined that the majority of the population

assessed in the research studies had their temperatures recorded. The temperature was not assessed in neonatal death, neonatal distress, abnormal otic or rectal structures, isolation for infectious diseases, and any circumstances that could negatively impact the care or health of the infant.

This literature review sought to examine information regarding equity of care across populations, or that identify populations with disparities. Variations that were found to affect thermoregulation are those characteristics such as birth weight, age, gender, ethnic diversity, delivery room setting, acuity of infant and need for resuscitation.

Organizational variation also effect disadvantaged populations, specifically low resource areas serving this population. Infant exposure to hypothermia in low resource organizations was related to electricity cuts or malfunctioning of the incubators.

Review of the grey literature revealed global, national and organizational initiatives to reduce incidence of neonatal hypothermia of the premature infant upon admission to the NICU. Review of the NICE summaries included skin-to-skin contact to reduce hypothermia. However, within the United States, this literature review found additional recommended interventions that are used. Professional organizations and professional societies such as American Congress of Obstetricians and Gynecologists (ACOG)/American Academy of Pediatrics (AAP) and Association of Women's Health, Obstetric and Neonatal Nurses (AWON) cited contradicting recommendations to warm prior to resuscitation.

Further national initiatives were examined, including the works of The California Maternal Quality Care Collaborative (CMQCC), the National Quality Forum (NQF), The Health and Human Services on Women's' Health, The Association of Maternal & Child Health Programs (AMCHP), The California Perinatal Quality Care Collaborative, and the Texas Department of Health and Services.

Table of Contents

I. Search Methodology

Phase I Methodology:

The work began with a review of the Perinatal Construct Table regarding care and regulation of temperature in the neonate. 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" [Mesh]
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 and National Measures Clearinghouse site was searched.

Search Considerations

- Some resources were not used as 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 Small for Gestational Age (SGA), Low Birth Weight (LBW), Very Low Birth Weight (VLBW), and Extremely Low Birth Weight (ELBW).
- Resources citing long term outcomes were limited. There was one study that considered infants through 18 months of age.

Phase II Methodology:

The work began with a review of the Perinatal Gap Analysis. The search process was guided by 5 revised research questions:

1. What is the evidence that the failure to maintain a normal body temperature (including hypothermia) in low birth weight infants is associated with adverse outcomes?
2. What specific practices are used to maintain appropriate temperature for individual patients, specific labor and delivery units or hospital/system level and how effective are they? **
3. What are relevant issues regarding measurement, including:
    a. Techniques
    b. Timing
    c. Comprehensiveness
4. Is there evidence of systematic variation that disadvantage any specific race or ethnic group, insurance type, or maternal demographic characteristic?
5. Grey Literature

**The revised Question 2 was sufficiently searched and supported by literature obtained during Phase I of the perinatal literature search; additional search was not needed.

The Phase II search was conducted from July 2012-August 2012. 5,264 citations were retrieved.

PubMed Search
The following strategies were used:

Question1
Search Terms:
("infant, low birth weight"[mesh] OR "infant, premature"[mesh] OR "premature birth"[mesh] OR preterm OR "low birth weight") AND ("body temperature"[mesh] OR hypothermia[mesh] OR rewarming [mesh] OR fever[mesh] OR thermoregulation OR warming OR normothermia OR hypothermia OR temperat*) AND ("outcome assessment (health care)"[mesh] OR outcome* OR adverse) Limits Publication dates from 1980/01/01 to 2012/12/31; Humans; English

Question 3
Search Terms:
("body temperature"[mesh] OR thermometers[mesh] OR thermography[mesh] OR fever[mesh] OR temperat* or thermometer* OR thermography) AND ("infant, newborn" [mesh]) Limits Publication dates from 1980/01/01 to 2012/12/31; Humans; English.

Question 4
Search Terms:
("infant, low birth weight"[mesh] OR ("infant, premature"[mesh] OR "premature birth"[mesh] OR preterm OR "low birth weight") AND ("body temperature"[mesh] OR hypothermia [mesh] OR rewarming[mesh] OR fever [mesh] OR thermoregulation OR warming OR normothermia OR hypothermia OR temperate*) AND ("ethnic groups"[mesh] OR "minority health"[mesh] OR

"socioeconomic factors" [mesh] OR "maternal characteristics" OR race OR "healthcare disparities"[mesh] OR "health status disparity" [mesh] OR insurance[mesh] OR dispar* OR variation OR differen* OR "health equity") Limits Publication dates from 1980/01/01 to 2012/12/31; Humans; English.

CINAHL Search
The following strategies were used:

Question 1
Search Terms:
(MH "body temperature" OR MH hypothermia OR MH "warming techniques" OR MH fever OR thermoregulation OR warming OR normothermia OR hypothermia OR temperat*) AND (MH "outcomes (health care)" OR outcome* or adverse) AND (MH "infant, low birth weight" OR MH "infant, premature" OR MH "childbirth, premature" OR preterm OR "low birth weight") Limits Exclude MEDLINE records, Publication dates 1991-2012

Question 3
Search Terms:
MH "infant, newborn" AND MH "body temperature determination" Limits Exclude Medline records, Publication dates 1991-2012

Question 4
Search Terms:
(MH "body temperature" OR MH hypothermia OR MH "warming techniques" OR MH fever OR thermoregulation OR warming OR normothermia OR hypothermia OR temperat*) AND (MH "infant, low birth weight" OR MH "infant, premature" OR MH "childbirth, premature" OR preterm OR "low birth weight") AND (MH "healthcare disparities" OR MH "health status disparity" OR MH "ethnic groups" OR MH "minority groups" OR MH "socioeconomic factors" OR "maternal characteristics" OR race OR variation OR "health Equity" OR dispar*) Limits Exclude Medline records, Publication dates 1991-2012

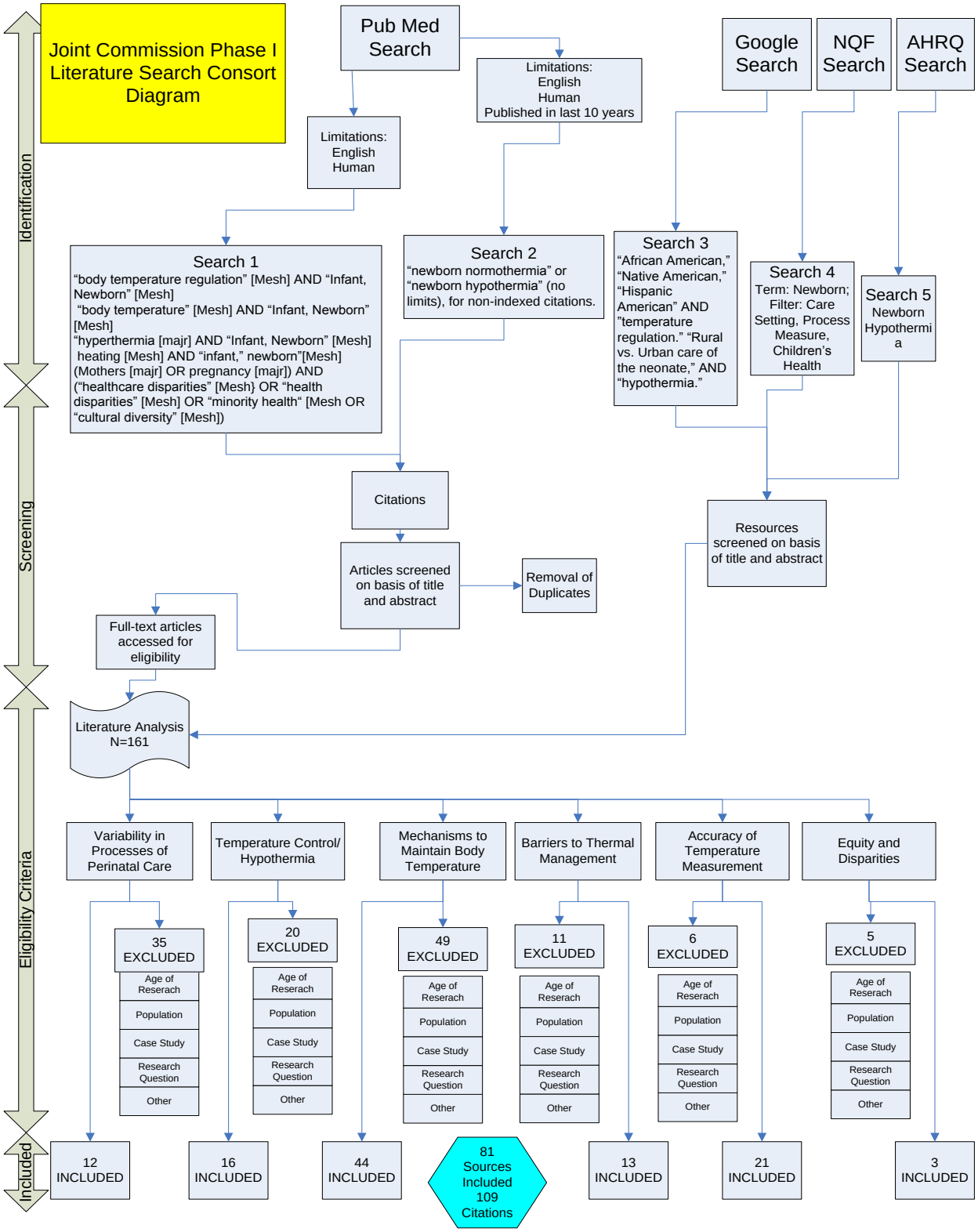
Grey Literature Search
The following strategies were used:

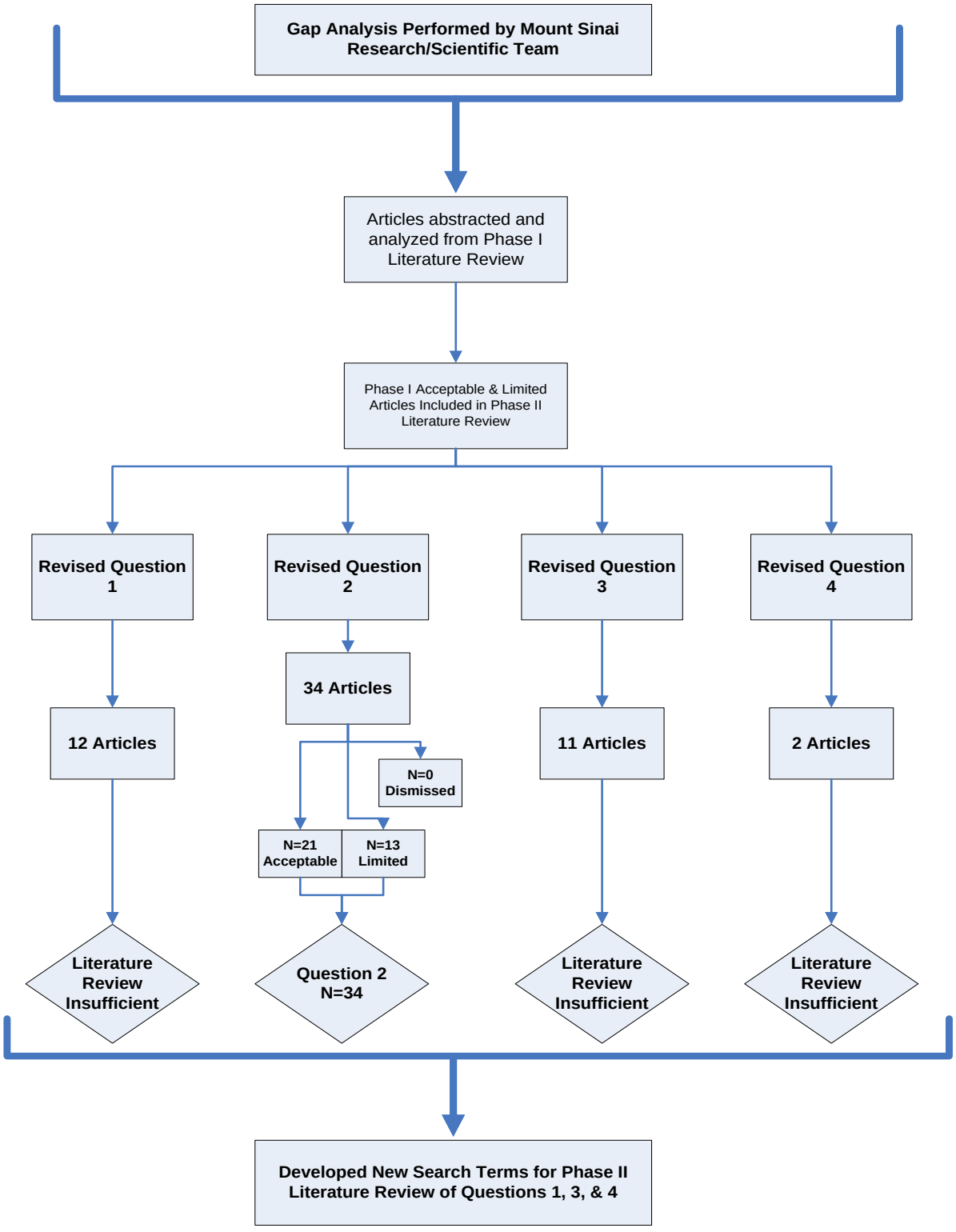
Searched
Key organizations and academic institutions were hand searched for articles pertaining to the Perinatal measures

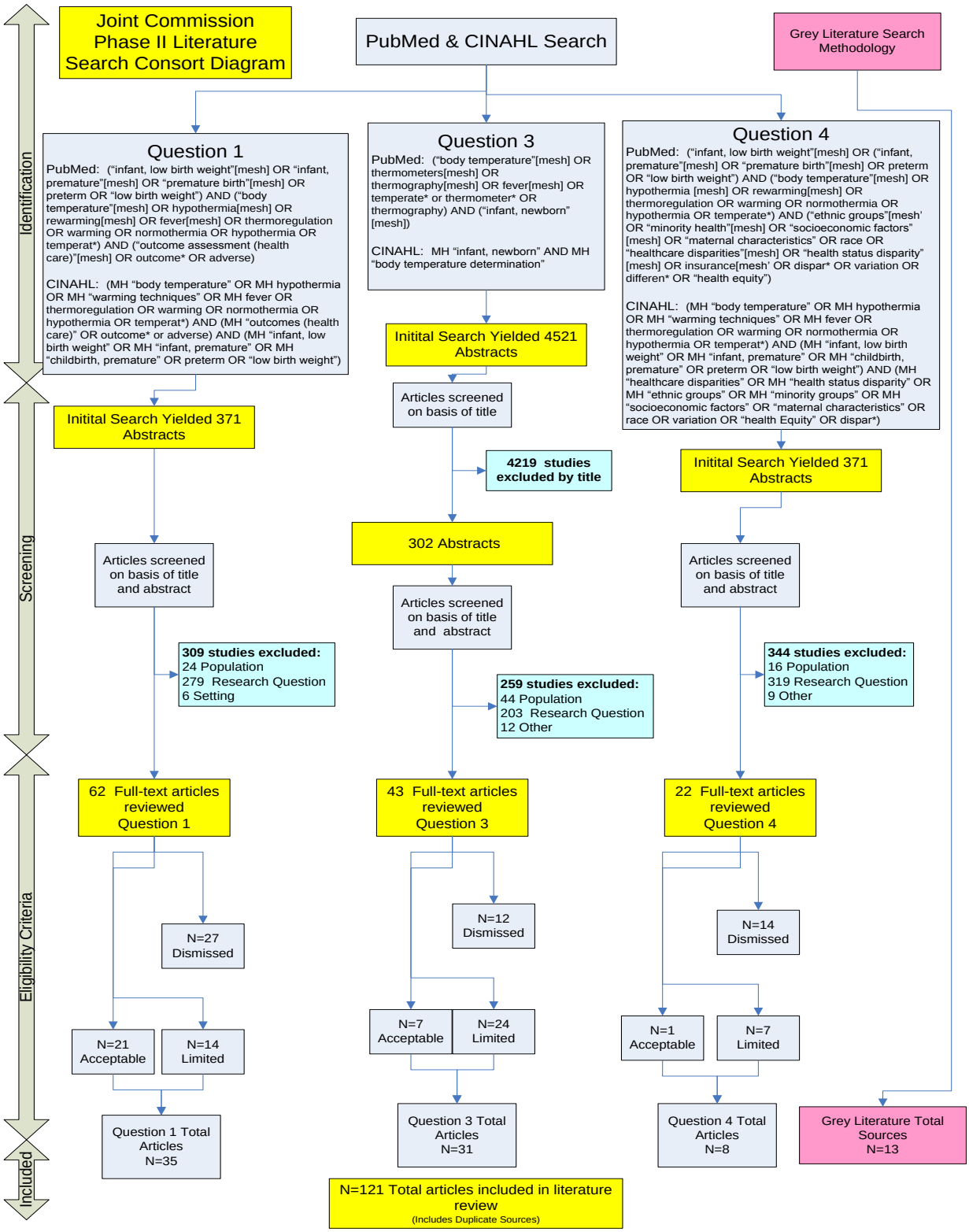
State Health Departments were selected based on their previous work in the area high risk obstetric and neonatal quality

Search Terms:
"Body temperature regulation" AND (infant, newborn, neonate, perinatal, very low birth weight, neonatal intensive care unit, premature, preterm)
"Body temperature" AND (infant, newborn, neonate, perinatal, very low birth weight, neonatal intensive care unit, premature, preterm)

Hypothermia AND (infant, newborn, neonate, perinatal, very low birth weight, neonatal intensive care unit, premature, preterm)
Thermoregulation AND (infant, newborn, neonate, perinatal, very low birth weight, neonatal intensive care unit, premature, preterm)


Joint Commission Phase I Literature Search Consort Diagram
Identification
Screening
Eligibility Criteria
Included
Pub Med Search
Limitations: English Human
Limitations: English Human Published in last 10 years
Google Search
NQF Search
AHRQ Search
Search 1
"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"[Mesh]
(Mothers [majr] OR pregnancy [majr]) AND ("healthcare disparities" [Mesh} OR "health disparities" [Mesh] OR "minority health" [Mesh OR "cultural diversity" [Mesh])
Search 2
"newborn normothermia" or "newborn hypothermia" (no limits), for non-indexed citations.
Search 3
"African American," "Native American," "Hispanic American" AND "temperature regulation." "Rural vs. Urban care of the neonate," AND "hypothermia."
Search 4
Term: Newborn; Filter: Care Setting, Process Measure, Children's Health
Search 5
Newborn Hypothermia
Citations
Articles screened on basis of title and abstract
Removal of Duplicates
Resources screened on basis of title and abstract
Full-text articles accessed for eligibility
Literature Analysis N=161
Variability in Processes of Perinatal Care
Temperature Control/ Hypothermia
Mechanisms to Maintain Body Temperature
Barriers to Thermal Management
Accuracy of Temperature Measurement
Equity and Disparities
35 EXCLUDED
20 EXCLUDED
49 EXCLUDED
11 EXCLUDED
6 EXCLUDED
5 EXCLUDED
Age of Reserach
Population
Case Study
Research Question
Other
12 INCLUDED
16 INCLUDED
44 INCLUDED
81 Sources Included 109 Citations
13 INCLUDED
21 INCLUDED
3 INCLUDED


Gap Analysis Performed by Mount Sinai Research/Scientific Team
Articles abstracted and analyzed from Phase I Literature Review
Phase I Acceptable & Limited Articles Included in Phase II Literature Review
Revised Question 1
Revised Question 2
Revised Question 3
Revised Question 4
12 Articles
34 Articles
11 Articles
2 Articles
N=0 Dismissed
N=21 Acceptable
N=13 Limited
Literature Review Insufficient
Question 2 N=34
Literature Review Insufficient
Literature Review Insufficient
Developed New Search Terms for Phase II Literature Review of Questions 1, 3, & 4


Joint Commission Phase II Literature Search Consort Diagram
PubMed & CINAHL Search
Grey Literature Search Methodology
Identification
Screening
Eligibility Criteria
Included
Question 1
PubMed: ("infant, low birth weight"[mesh] OR "infant, premature"[mesh] OR "premature birth"[mesh] OR preterm OR "low birth weight") AND ("body temperature"[mesh] OR hypothermia[mesh] OR rewarming[mesh] OR fever[mesh] OR thermoregulation OR warming OR normothermia OR hypothermia OR temperat*) AND ("outcome assessment (health care)"[mesh] OR outcome* OR adverse)
CINAHL: (MH "body temperature" OR MH hypothermia OR MH "warming techniques" OR MH fever OR thermoregulation OR warming OR normothermia OR hypothermia OR temperat*) AND (MH "outcomes (health care)" OR outcome* or adverse) AND (MH "infant, low birth weight" OR MH "infant, premature" OR MH "childbirth, premature" OR preterm OR "low birth weight")
Question 3
PubMed: ("body temperature"[mesh] OR thermometers[mesh] OR thermography[mesh] OR fever[mesh] OR temperate* or thermometer* OR thermography) AND ("infant, newborn" [mesh])
CINAHL: MH "infant, newborn" AND MH "body temperature determination"
Question 4
PubMed: ("infant, low birth weight"[mesh] OR ("infant, premature"[mesh] OR "premature birth"[mesh] OR preterm OR "low birth weight") AND ("body temperature"[mesh] OR hypothermia [mesh] OR rewarming[mesh] OR thermoregulation OR warming OR normothermia OR hypothermia OR temperate*) AND ("ethnic groups"[mesh' OR "minority health"[mesh] OR "socioeconomic factors" [mesh] OR "maternal characteristics" OR race OR "healthcare disparities"[mesh] OR "health status disparity" [mesh] OR insurance[mesh' OR dispar* OR variation OR differen* OR "health equity")
CINAHL: (MH "body temperature" OR MH hypothermia OR MH "warming techniques" OR MH fever OR thermoregulation OR warming OR normothermia OR hypothermia OR temperat*) AND (MH "infant, low birth weight" OR MH "infant, premature" OR MH "childbirth, premature" OR preterm OR "low birth weight") AND (MH "healthcare disparities" OR MH "health status disparity" OR MH "ethnic groups" OR MH "minority groups" OR MH "socioeconomic factors" OR "maternal characteristics" OR race OR variation OR "health Equity" OR dispar*)
Initital Search Yielded 371 Abstracts
Initital Search Yielded 4521 Abstracts
Initital Search Yielded 371 Abstracts
Articles screened on basis of title and abstract
Articles screened on basis of title
4219 studies excluded by title
302 Abstracts
Articles screened on basis of title and abstract
Articles screened on basis of title and abstract
309 studies excluded:
24 Population
279 Research Question
6 Setting
259 studies excluded:
44 Population
203 Research Question
12 Other
344 studies excluded:
16 Population
319 Research Question
9 Other
62 Full-text articles reviewed Question 1
43 Full-text articles reviewed Question 3
22 Full-text articles reviewed Question 4
N=27 Dismissed
N=12 Dismissed
N=14 Dismissed
N=21 Acceptable
N=14 Limited
N=7 Acceptable
N=24 Limited
N=1 Acceptable
N=7 Limited
Question 1 Total Articles N=35
Question 3 Total Articles N=31
Question 4 Total Articles N=8
Grey Literature Total Sources N=13
N=121 Total articles included in literature review
(Includes Duplicate Sources)

II. Research Question 1
What is the evidence that the failure to maintain a normal body temperature (including hypothermia) in low birth weight infants is associated with adverse outcomes?

Summary

This review of the literature indicates that variation in interventions associated with hypothermia in the neonate upon admission to the Neonatal Intensive Care Unit, is associated with poor outcomes. Temperatures less than 36 degrees Celsius upon admission to the NICU were associated with a greater risk of death, impaired blood glucose, impaired oxygen saturation related to an increased oxygen consumption, increased energy consumption and depression of cardiovascular and neurological systems, subsequently increasing the incidence of illness in this vulnerable population.

Infant characteristics such as birth age, gestational age, and weight contribute to the incidence and prevalence of hypothermia upon admission to the NICU. Hypothermia upon admission to the NICU and its relationship with mortality is still under investigation, as well as the relationship of hypothermia and intraventricular hemorrhage and death.

The studies reviewed summarized the relationship between healthcare organizations in which adequate or superior resources with regard to resuscitation, thermal control, and neonatal transport, had better-quality outcomes. Improved outcomes, specifically growth and feeding were associated with those infants who maintained normothermia.

Bibliography

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.

Impact Factor: 0.91
Quality of Evidence: Acceptable

n=115 infants weighing less than 1500 grams and admitted to NICU.
The objective was to describe the ability of a transport mattress to reduce hypothermia in LBW infants. Study design was nonrandomized experimental design comparing TransWarmer mattress to standard care. Hypothermia was significantly lower in the mattress group than control group.
Includes citation from Costeloe et al, 2000, where hypothermia in the newborn infant is associated with adverse outcome.

Antonucci, R., Annalisa, P., & Fanos, V. (2009). The infant incubator in the neonatal intensive care unit: unresolved issues and future developments. *Journal of Perinatal Medicine, 37,* 587-598.

Impact Factor: 1.74
Quality of Evidence: Acceptable

Multiple studies historically have provided the community with evidence that warmth and humidity lowers the death rate in preterm infants.

Araujo, B.., Zatti, H., Oliveira Filho, P., Coelgo, M., Olmi, F., Buaresi, T., & Madi, J. (2011). Effect of place of birth and transport on morbidity and mortality of preterm newborns. *Journal de Pediatricia, 87:*3, 257-262.

Impact Factor: Not Available
Quality of Evidence: Acceptable

n= 184, NRCT: Preterm newborns transferred to NICU from primary institute: compared outcomes of (primary) death, (secondary) temperature, blood glucose, oxygen saturation, and incidence of illness. Temperature of <36 degrees was measured and noted. Twenty-four babies were less than 36 degrees during transport. This study supported that deficiencies in care created a trend towards an increase in the number of deaths for this population.

Audeh, S., Smolkin, T., Bental, Y., Haramati, Z., Blazer, S., Litiq, E., Biton, R., Dolberg, A., & Makhoul, I. (2011). Does admission hypothermia predispose to intraventricular hemorrhage in very-low-brith-weight infants? *Neonatology, 100*; 373-379.

Impact Factor: 2.66
Quality of Evidence: Acceptable

n= 271, NRCT: Results show that admission hypothermia (ATH) is not associated with VLBW infants. "AHT in premature infants is unintentional and occurs in 33–48% of premature infants at 26 weeks' gestation and the effect of such hypothermia on the brain of the very-preterm infants and IVH is still being investigated" Multiple studies reviewed showed conflicting evidence between the relationship of hypothermia and the adverse outcome of intra ventricular hemorrhage (IVH).

Bailey, S. (2012). Kangaroo Mother Care. *British Journal of Hospital Medicine, 73;5*, 278-281

Impact Factor: Not Available
Quality of Evidence: Limited

NRCT, review of literature. Discussion includes reduction of hypothermia with intervention of kangaroo care. Hypothermia correlates with increased oxygen consumption, increased energy consumption and depression of cardiovascular and neurological system. This in turn leads to poor outcome with increased morbidity and mortality.

Basu, S., Rathore, P., & Bhatia, B.D. (2008). Predictors of mortality in very low birth weight neonates in India. *Journal of Singapore Medicine, 49;* 7, 556-560.

Impact Factor: 0.73
Quality of Evidence: Acceptable

n= 260 (36.9 % death) Retrospective Cohort of VLBW (> 500g) (>26 weeks). Measured outcome of death. Hypothermia was identified as a contributor of death (in 1.132 logistic regression equation). Study considered hypothermia a risk in predicting infant death.

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.

Impact Factor: 0.91
Quality of Evidence: Limited

Reviewed evidence related to thermoregulation at birth in VLBW infants. Found delivery room management that focuses on the adaptation of the infant, as well as early interventions that improve long-term outcomes may emphasize the "golden hour" of care and improve outcomes in this extremely vulnerable population.

Bredemeyer, S., Reid, S., & Wallace, M. (2005). Thermal management for premature births. *Issues and Innovations in Nursing Practice*, *52:5,* 482-489.

Impact Factor: Not Available
Quality of Evidence: Acceptable

n= 141. NRCT: Testing effect on admission temperatures when using polyethylene wrap after birth of extremely premature infants. Use of wrap resulted in higher admission temps for infants (<27 weeks) only.

Doctor, B, O'Riordan, M., Kirchner, L., Shah, D., & Hack, M (2001). Perinatal correlates neonatal outcomes of small for gestational age infants born at term gestation. *American Journal of Obstetrics and Gynecology, 185;* 3, 652- 659.

Impact Factor: 3.56

Quality of Evidence: Limited- Small for gestational age

n=372 Non Randomized Control Trial (NRCT). Comparison study, SGA (small for gestational age) infants had higher rate of hypothermia 18% versus 6%. Factors that affect SGA babies, including the higher incidence of hypothermia contribute to the outcomes of this population.

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

Impact Factor: 5.65
Quality of Evidence: Acceptable

Using standard search strategy of Cochrane Neonatal Group, assessed the effects of radiant warmers vs. incubators on neonatal fluid and electrolyte balance, morbidity and mortality. . Eight studies included (six used crossover design) with radiant warmers resulting in increased water loss compared to incubators. Also determined that LBW babies have a higher chance of survival if they are kept warm, but found insufficient evidence to show effects of radiant warmers vs. incubators for regulating body temperature in newborns.

Ibrahim, C. P., & Yoxall, C. W. (2010). Ue of self-heating gel mattresses eliminates admission hypothermia in infants born below 28 weeks gestation. *European Journal of Pediatrics*, *169*, 795-799.

Impact Factor: 1.28
Quality of Evidence: Acceptable

Retrospective audit of n=105 pre term infants (< 28 weeks). Evaluation of hypothermia <36C upon admission to NICU was assessed. Conclusion that self-heating acetate gel mattresses are highly effective in reducing admission hypothermia. Previous studies showed association between hypothermia on admission to NICU and outcome.

Kaushal, M., Agarwal, R., Aggarwal, R., Singal, A., Upadhyay, M., Srinivas, V., Paul, K., & Deorari, A. K. (2005). Cling wrap, an innovative intervention for temperature maintenance and reduction in insensible water loss in very low-birthweight babies nursed under radiant warmers: a randomized controlled trial. *Annals of Tropical Paediatrics*, *25*, 111-118.

Impact Factor: 0.9
Quality of Evidence: Acceptable

n=51,Randomized Controlled Trial,. Low birth weight (<1250 grams 1251-1500 grams). The primary outcome was to measure incidence of hypothermia via axillary temp <36 C. after initial stabilization. Babies who were hypothermic upon admission to NICU took a longer time to reach normal temperature in the Cling wrap group.

Secondary outcomes measured were hypotension, dehydration, sepsis and other morbidities, as well as neonatal mortality, were not significantly different between the groups.

Kim, S. M., Lee, E. Y., Chen, J., & Ringer, S. A. (2009). Improved care and growth outcomes by using hybrid humidified incubators in very preterm infants. *Pediatrics*, *125*, e137-146.

Impact Factor: 4.47
Quality of Evidence: Limited

n=182, Retrospective audit: Body Temperature (BT), fluid and electrolyte and growth velocity of ELBW (< 749 grams) infants at Brigham Women's Hospital. Babies were initially nursed under radiant warmers followed by double-walled incubators, humidity added to the Intervention group, and warm air in the controlled group.

Care was given to ensure abdominal temperature remained 36.5 -37.5 degrees Celsius. Initial admit BT was collected. Instability was defined as <35 degrees Celsius during the first week. Body temperature was compared each day, and those with body weight of <750 grams had higher incidence of admission hypothermic temperatures. Birth weight was a strong predictor of body temperature regulation. No findings confirmed differences in body temperature with humidified incubator.

Knobel, R. B, Vohra, S., & Lehmann, C. U. (2005). Heat loss prevention in the delivery room for preterm infants: a national survey of newborn intensive care units. *Journal of Perinatology*, *25*, 514-518.

Impact Factor: 1.59
Quality of Evidence: Acceptable

Objective is to describe current NICU practices. Initiate education and evaluate a change in practice.

Research question not related to effect of hypothermia and infant outcomes. 70% reported an improvement in admission temperature.

Knobel, R. B., Wimmer, J. E., & Holbert, D. (2005B). Heat loss prevention for preterm infants in the delivery room. *Journal of Perinatology*, *25,* 304-308.

Impact Factor: 1.59
Quality of Evidence: Limited

Secondary outcomes were improved with use of polyurethane bag:
Decreased duration of oxygen
Decreased LOS
Decreased Mortality

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.

Impact Factor: 2.07
Quality of Evidence: Limited

n=1 Case study of severely hypothermic newborn. Full-term infant accidentally exposed to temperature of minus3 degrees Celsius for approximately 30 minutes. Slow re-warming was used and is advocated as it replicates the normal physiological process in a neonate.

Infant was transported within 15 minutes to NICU and wrapped in aluminum foil. Core temperature at admission was 25 degrees Celsius. Over a 24-hour period, core temperature rose from 25-44 degrees Celsius.

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

Impact Factor: 4.47
Quality of Evidence: Acceptable

Studies of children weighing 401-1499 grams (without congenital abnormalities) were examined. NICU admission temp was inversely related to mortality. Temperature up/mortality down. Temperature up/sepsis down.
Concluded that efforts to limit heat loss are important initial steps in the stabilization of newborns immediately after birth.

Lewis, D. A., Sanders, L. P., & Brockopp, D. Y. (2011). The effect of three nursing interventions of thermoregulation in low birth weight infants. *Neonatal Network, 30;* 3, 160-164.

Impact Factor: Not Available
Quality of Evidence: Acceptable

Infants with rectal temperatures <36.4 degrees Celsius can experience hypoglycemia, respiratory distress, hypoxia, metabolic acidosis, coagulation defects, delayed adjustment from fetal to newborn circulation, acute renal failure, necrotizing enterocolitis, and death.
The Academy of Pediatrics, Neonatal Resuscitation Program advocates for prevention of heat loss by:
1. Place infant on preheated warmer
2. Dry with warm blanket
3. Place head covering

Infants <30 weeks are at risk of marked hypothermia on admission temperature (<36 degrees Celsius).

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

Impact Factor: 2.88
Quality of Evidence: Acceptable

This began with a historical overview on studies dating back to 1950, with a focus on temperature control and neonatal mortality. Highlighting how recent data again stress the importance of the thermal environment of the preterm infant. Suggests that a single measurement tells nothing about whether a baby is using energy for thermal balance. Instead, preterm baby should be monitored with continuous recordings.

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

Impact Factor: 0.91
Quality of Evidence: Limited

Reviews the consequences of hypothermia, mechanisms of heat production and heat exchange in full-term and LBW infants, and discusses interventions to alleviate hypothermia. A warm delivery room temperature 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.

McCall, E. M., Alderdice, F., Halliday, H. L., Jenkins, J. G., & Vohra, S. (2010). Interventions to prevent hypothermia at birth in preterm and/or low birthweight infants (Review). The *Cochrane Collaboration*, Issue 3.

Impact Factor: 5.56
Quality of Evidence: Acceptable

5 studies reviewed. Population included LBW <2500 grams, <37 weeks. Plastic bags were effective only in infants <28 weeks. There was no evidence to suggest that plastic wraps decrease incidence of death within the hospital stay.

Plastic wrap did lead to higher admission temperatures to NICU, firm recommendation cannot be given.

Mellien, A (2001). Incubators versus mothers arms: body temperature conservation in very – low-birth- wieght premature infants. *Journal of Obstertic, Gynecologic, and Neonatal Nursing, 30*, 157-164.

Impact Factor: 1.04
Quality of Evidence: Limited

n=20, NRCT, Convenience sample of preterm infants weighing 1095-1500 grams, at 30-37 weeks gestation. Temperatures were compared within the incubator, and in mothers' arms. No significant variation was found, infants were significantly warmer in mothers arms.

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

Impact Factor: 1.59
Quality of Evidence: Acceptable

Study conducted to evaluate the epidemiology of neonatal hypothermia (using WHO temperature criteria) and found that moderate and severe hypothermic conditions were associated with higher risk of intraventricular hemorrhage and higher risk of death. Use of WHO criteria can guide need for quality improvement initiatives targeted towards most vulnerable infants.

In bivariate analysis, blacks and Hispanics were associated with hypothermia and maternal hypertension.

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

Impact Factor: 0.36
Quality of Evidence: Limited

n=487 (23 studies) Meta-analysis to investigate whether skin-to-skin contact for newborn babies and their mothers affects body temperature. Found evidence of an increase in body temperature and found to be more evident in low income settings, but no clear explanation was found. This review concluded that skin-to-skin contact is effective in increasing body temperature of babies, particularly in resource-limited environments.

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

Impact Factor: 2.33
Quality of Evidence: Acceptable

Summarizes recent report that there is increased mortality associated with hypothermia on admission to the NICU. Many conventional approaches are outmoded. This review cites

contradictory guidance re: thermoregulation. For example, in 1994 World Health Organization (WHO) advised skin-to-skin contact greatly reduces risk of hypothermia.

Displays studies showing association between hypothermia and mortality risk in hospital and communities of low resource settings

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Nijokanma, F., & Fagbule, D. (1994). Outcome of referred neonates weighing less than 2500g. *Tropical and Geographical Medicine, 46;3*, 172-174.

Impact Factor: 0.9
Quality of Evidence: limited with mix of population preterm and full term

n= 103, NRCTneonates weighing <2500 grams, morbidity and mortality reviewed. Perinatal resuscitation, thermoregulation and transfer, was identified as the source of morbidity and mortality. Found the association between resuscitative interventions and outcomes. Notable to this study, is the finding that in superior environments with regard to resuscitation, thermal control and neonatal transport, that maternal fetal transfer to a NICU center is associated with a better outcome.

Raghuveer, R., & Cox, A. (2011). Neonatal Resuscitation: An Update. *American Academy of Family Physician, 83*(8), 865.

Impact Factor: 1.7
Quality of Evidence: Acceptable

This reviews the updated guidelines on neonatal resuscitation. Provides indications for chest compressions and for the use of intravenous epinephrine, and recommends not using sodium bicarbonate or naloxone during resuscitation. This review includes ventilation strategies for preterm infants.

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 place them under a radiant warmer. Hyperthermia should be avoided. Delivery room temperature should be set at least 78.8 degrees Fahrenheit (26 degrees Celsius) for infants less than 28 weeks' gestation.

Raju, T., Higgins, R., Stark, A., & Leveno, K. (2006). Optimizing care and outcome for late preterm (near term) infants: A summary of the workshop by the National Institute of Child Health and Human Development. *Pediatrics*, *118,* 1207-1214.

Impact Factor: 4.47

Quality of Evidence: Limited

Near Term infants, (34-36) weeks have greater incidence of respiratory distress, temperature instability, hypoglycemia, kernicterus, apnea, seizures, and feeding problems. Outcomes reviewed were after initial hospital discharge, or long term of 8 years old.

Reynolds, R., Pilcher, J., Ring, A., Johnson, R., & McKinley, P. (2009). The golden hour: care of the LBW infant during the first hour of life one unit's experience. *Neonatal Network*, *25*:4. 211-219.

Impact Factor: Not Available
Quality of Evidence: Limited

A new care process was initiated to increase outcome effects of LBW during the golden hour (the first hour of life). Evidence-based practice included the care processes to prevent hypothermia. Outcomes of this process improved admission temperatures from average 36.04 to 36.68 degrees Celsius.

Silverman, W., Fertig, J., & Berger, A. (1958). The Influence of the Thermal Environment upon the Survival of Newly Born Premature Infants. *Pediatrics 22*, 876-886.

Impact Factor: 4.47
Quality of Evidence: Acceptable

n=182, The influence of two contrasting environmental temperatures upon time survival rates of premature infants in the first 5 days of life was studied. Infants who were placed in incubators with an air temperature of 31.7 degrees Celsius (89 degrees Fahrenheit) had a higher survival rate than the control group who were in incubators maintained at 28.9 degrees Celsius (84 degrees Fahrenheit).

Sinclair, J. C. (2008). Servo-control for maintaining abdominal skin temperature at 36C in low birth weight infants (Review). *The Cochrane Collaboration*, Issue 3.

Impact Factor: 5.65
Quality of Evidence: Acceptable

n= 395,two studies reviewed. Incubator air temperature was evaluated and compared with abdominal skin temperature to reach 36 degrees Celsius, and to reduce the neonatal death rate, among LBW or VLBW infants.

Soll, R. F. (2008). Heat loss prevention in neonates. *J Perinatol, 28 Suppl 1*, S57-59. doi: 10.1038/jp.2008.51

Impact Factor: 1.59
Quality of Evidence: Limited

Informative article on mechanisms for heat loss, and possible significance to outcomes. Further studies are needed.

Suman Rao, P., Udani, R., & Nanavati, R. (2008). Kangaroo mother care for low birth weight infants: a randomized controlled trial. *Indian Pediatrics*, *45*, 17-22.

Impact Factor: 0.75
Quality of Evidence: Acceptable

Maintaining thermoregulation with kangaroo mother care improved outcomes specific to growth, and reduced mortality.

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tePas, A., Lopriore, E., Dito, I., Morley, C., & Walther, F. (2010). Humidified and heated air during stabilization at birth improves temperature in preterm infants. *Pediatrics, 125*, e1427-1432.

Impact Factor: 4.47
Quality of Evidence: Acceptable

Studied the use of heated and humidified air during respiratory support in very preterm infants, just after birth. The study objective was to reduce postnatal resuscitation hypothermia. Comparison of two cohorts prospectively with intervention of humidified heated air and admission rectal temperature taken in NICU. Normothermia occurred 12% less in the "cold" group. Moderate hypothermia occurred more often in the cold group. Secondary outcome of intubation occurred one time more in the cold group.

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

Impact Factor: 1.54
Quality of Evidence: Acceptable

Summarizes recent report respecting increased mortality associated with hypothermia on admission to the NICU. Many conventional approaches are outmoded. Cites contradictory guidance re: thermoregulation. For example, in 1994 WHO advised skin-to-skin contact to greatly reduce risk of hypothermia while American Association of Pediatrics (AAP) Neonatal Resuscitation Textbook cites that premature infant should be placed under radiant warmer and should not be covered to allow full visualization and to permit radiant heat to reach the baby.

III. Research Question 2
What specific practices are used to maintain appropriate temperature for individual patients, specific labor and delivery units or hospital/system level and how effective are they?

Summary

The cited literature, in addition to national and international guidelines supported the following known interventions to protect ELBW, VLBW, and 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
Consider use of “TransWarmer” or gel warmed mattress
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
Upon admission to the NICU, plastic wrap removed and infant placed on open cot, naked with radiant warming or closed incubator
Use of double walled incubator

The literature recommends continuous recording of body temperature while under radiant warmer or inside incubator.

These interventions have been found to decrease the incidence of hypothermic temperatures on admission to a 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’s 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.

Once infants were stabilized upon admission to the NICU, studies found that skin to skin contact or Kangaroo care post admission does not decrease body temperature, and in fact increases positive outcomes by facilitating breastfeeding and subsequently growth rate. In one study, massage therapy was encouraged in this population and was found to increase body temperature.

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.

Impact Factor: 3.73
Quality of Evidence: Limited

Assessed the time required to reach warming body temperature (38 degrees Celsius), heat stroke (40 degrees Celsius), or extreme value (43 degrees Celsius) in a mathematical model that involved calculating various local body heat losses. Simulated heat exchanges were based on body surface temperature distribution, measured in preterm neonates exposed to 33 degrees Celsius air temperature and covered (torso and limbs) with a transparent plastic bag. Also compared metabolic heat production, with body heat losses, when a bonnet (2 or 3.5 millimeter thick) covered 10%, 40%, or 100% of the head. Found plastic bag and bonnet may result in hypothermia, but only when metabolic heat production rises while skin production falls, as can happen with fever.

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.

Impact Factor: 0.91
Quality of Evidence: Acceptable

n=115 infants weighing less than 1500 grams and admitted to NICU.
Objective was to describe the ability of a transport mattress to reduce hypothermia in LBW infants. Study design was nonrandomized experimental design, comparing TransWarmer mattress to standard care. Hypothermia was significantly lower in the mattress group than controls.

Ammari, 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.

Impact Factor: 2.39
Quality of Evidence: Limited

n=32 Gestational age 26-35 weeks. Assessed effects of LBW infant body position on body temperature. Found babies sleeping in prone position had higher body temperatures.

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.

Impact Factor: 1.74
Quality of Evidence: Limited

During transport, thermo-control is lost and most infant incubators operate off less battery power and cannot modify humidity. For healthy skin development, VLBW infants should be kept at 80-90% humidity until their skin functions.

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

Impact Factor: 4.47
Quality of Evidence: Acceptable

n=10 babies. Determined 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. Radiant heat delivered by the warmer to infants was directly proportional to the heat need calculated from the partition. Radiant warmers allow the infants to receive a net radiant heat gain from the radiant warmer, whereas the incubator serves only to reduce heat loss.

Bell, E., & Rios, G. (1983). A double-walled incubator alters the partition of body heat loss of premature infants. *Pediatr Res, 17*, 135-140.

Impact Factor: 2.80
Quality of Evidence: Limited

n=8 Landmark study provided raw data to support the use of double walled incubator in reduction of hypothermia for premature infants. Partitional calorimetry was used to assess influence of a double-walled incubator on the body heat loss of eight premature infants. Found no difference in body temperatures and that double walled incubator reduced radiant heat loss, but increased convective heat loss, so that the total rate of body heat loss was unchanged.

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.

Impact Factor: 0.91
Quality of Evidence: Limited

Reviewed evidence related to thermo-regulation at birth in VLBW infants. Found that delivery room management that focuses on the adaptation of the infant, as well as early interventions

that improve long-term outcomes, may emphasize the "golden hour" of care and improve outcomes in this extremely vulnerable population.

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

Impact Factor: 1.52
Quality of Evidence: Acceptable

n=227 infants <30 weeks gestation. Article reports on an audit of the effect on admission temperatures of using occlusive polyethylene wrap, applied immediately after birth for extremely premature infants. For babies less than 27 weeks gestation, use of occlusive polyethylene wrap resulted in higher admission temperatures. No statistically significant improvement in admission temperatures for 27-29 weeks infants. Stated that removal of the wrap should be considered following admission to a closed care system in the NICU, as in the intervention group, hyperthermia in the first 12 hours was a potential side effect.

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.

Impact Factor: 1.59
Quality of Evidence: Acceptable

Systematic review (3 RCTS and 5 historical controlled trials included). Objective was to identify and synthesize investigations of the effectiveness of occlusive skin wrap for reducing heat loss in premature infants (<36 weeks). Found wrapped infants had significantly higher admission temperatures than unwrapped infants. States a significant difference in mortality was not found between wrapped and unwrapped infants.

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

Impact Factor: 1.42
Quality of Evidence: Limited

Studied 72 preterm infants and found massage therapy 3 times per day resulted in temperature increase of infants.

ANOVA and t-tests revealed massage therapy group temperature peaked during 15-minute massage period and remained elevated during post massage period. Used repeated measures for ANOVA and post hoc Bonferroni corrected t-tests.

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.

Impact Factor: 0.63
Quality of Evidence: Limited

n= 30 infants weighing <1500 grams. Study designed to determine effects of polyethylene occlusive skin wrapping on heat loss in VLBW infants admitted to NICU promptly after birth. Allocated to a wrap or non-wrap group, within an incubator after admission to the NICU. Temperatures taken on arrival at 1 hour and 2 hour. Found infants in the axillary group reached normal axillary temperature faster than non-wrap infants and required lower incubator temperatures.

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

Impact Factor: 5.65
Quality of Evidence: Acceptable

Assessed the effects of radiant warmers vs. incubators on neonatal fluid and electrolyte balance, morbidity and mortality. Used standard search strategy of Cochrane Neonatal Group. Eight studies included (six used crossover design) Radiant warmers result in increased water loss compared to incubators. Also determined that LBW babies have higher chance of survival if they are kept warm, but found insufficient evidence to show effects of radiant warmers vs. incubators for regulating body temperature in newborns.

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

Impact Factor: 5.65
Quality of Evidence: Acceptable

Cochrane review of five studies comparing cot nursing using a heated water filled mattress to incubator care. Cot nursed infants had no difference in mean body temperature, or weight gain compared to incubator care. Cot nursing with warming of the nursery resulted in smaller weight gain during week one compared to incubator group.

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

Impact Factor: 4.47

Quality of Evidence: Limited

Special Report on Neonatal Resuscitation: 2010 American Heart Associations' (AHA) Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Provides steps to resuscitation for babies needing resuscitation at birth (approximately 10% of babies). Initial step in resuscitation is to provide warmth by placing baby under radiant heat source. AAP also recommends pre-warming the delivery room to 20 degrees Celsius, covering the baby in plastic wrapping (food or medical grade, heat resistant plastic), monitor frequently and be aware of risk of hyperthermia (Class I). Other techniques have been used, but not studied specifically including pre-warming the linen, drying and swaddling and skin-to-skin contact covering both mom and baby with blanket (Class II)

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.

Impact Factor: 0.9
Quality of Evidence: Acceptable

n=156 infants (n=42 <28 weeks and n=114 28-31 weeks gestation).
Study conducted to determine if increasing ambient temperature in the operating theatre, and wrapping in polyethylene wrap at cesarean 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.

Retrospective review of NICU admission temperatures (over 3 periods) - First epoch (Jul 2000-2002): Operating temperature set at 20 degrees Celsius, infant placed under radiant warmer, dried and wrapped with warm blankets. Second epoch (Nov 2002-2003): Clinical change introduced increasing ambient operating theatre temperature to 26-28 degrees Celsius for deliveries <27 weeks gestation and to 25 degrees Celsius for deliveries 28-35 weeks gestation. Third epoch (Sep 2004-Dec 2005): Ambient theatre temperature increased along with wrapping infants in polyethylene.

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.

Impact Factor: 4.47
Quality of Evidence: Acceptable

n= 182 Retrospective review of ELBW (<1000 grams) babies born at Brigham and Women's between Jul 2002-Aug 2005. Objective was to identify changes in temperature, fluid and electrolyte management, growth and short-term outcome in ELBW infants nursed in humidified hybrid incubators compared with nonhumidified conventional incubators. Both groups were cared for in a radiant warmer pre-incubator.

Found use of humidified hybrid incubator improved care for ELBW infants by making it possible to decrease fluid intake, improve electrolyte balance and enhance growth velocity without disturbance of body temperature compared to conventional care.

Knobel, R., & Holditch-Davis, D. (2007). Thermo-regulation 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.

Impact Factor: 0.97
Quality of Evidence: Acceptable

Found that these interventions were effective ways to stabilize thermo-regulation and prevent heat loss in ELBW infants: Prewarming delivery room, use of plastic bag, hat wrap, warm blanket, warmer table, radiant heat on the infant during transport, when non-warmed supplies were put next to infant, recorded body temperature dropped.

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.

Impact Factor: 2.07
Quality of Evidence: Limited

n=1, case study of severely hypothermic newborn. Full-term infant accidentally exposed to temperature of minus 3 degrees Celsius for approximately 30 minutes. Slow re-warming was used and is advocated, as it replicates the normal physiological process in a neonate.

Infant was transported within 15 minutes to NICU and wrapped in aluminum foil. Core temperature at admission was 25 degrees Celsius. Over 24-hour period, core temperature rose from 25-44 degrees Celsius.

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.

Impact Factor: 5.65
Quality of Evidence: Acceptable

To assess effects of double versus single wall incubator on factors such as heat loss and rate of oxygen consumption. Found three studies, which met inclusion criteria. Results: Double wall incubators decreased heat loss, heat production and radiant heat loss when compared to single wall incubators. There is also the advantage of reduced oxygen consumption. A minimal increase in conductive heat loss was noted when compared to single wall incubators. All of

these effects are small and do not support the proposition that double wall incubators have a beneficial effect on long term outcomes including mortality or the duration of hospitalization.

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

Impact Factor: Not Available
Quality of Evidence: Acceptable

n=133 infants weighing <1500 grams. Evaluated the effect of three nursing interventions-occlusive wrap, chemical mattress, and regulation of delivery room temperature on thermo-regulation in six groups of LBW infants.
Outcome measured: NICU admission temperatures of infants weighing <1000 grams and those between 1000-1500 grams. For each of three interventions, the percentage having a normal NICU admission temperature exceeded control group percentage (but increase was not significant).

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

Impact Factor: 2.88
Quality of Evidence: Acceptable

Historical overview on studies dating back to 1950 with a focus on temperature control and neonatal mortality. Highlights how recent data again stress the importance of the thermal environment of the preterm infant. Suggest that a single measurement tells nothing about whether baby is using energy for thermal balance. Instead, preterm baby should be monitored with continuous recordings.

Lyon, A.J., & 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.

Impact Factor: 2.39
Quality of Evidence: Limited

n=20 Gestational Age <29 weeks studied during first five days of life. Comparing the effect of a computer program (HeatBalance) on temperature control of infants. Program recommends incubator temperature and humidity settings to keep babies in thermal balance. The study concluded that similar results were achieved in temperature stability with both methods. Highlighted the importance of continuous monitoring of central and peripheral temperatures.

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

Impact Factor: 2.07
Quality of Evidence: Limited

n=22 mean Gestational Age 25 weeks 4 days, mean weight 702 grams. Aim was to determine if clinically stable, extremely preterm infants can maintain their temperature during skin-to-skin contact and to screen for other negative effects.
Found no significant differences in mean skin temperature, heart rate, respiration rate, or oxygen saturation before, during, or after Skin-to-Skin Contact (SSC).

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 Database of Systematic Reviews*(1). doi:10.1002/14651858.CD004210.pub3.

Impact Factor: 5.65
Quality of Evidence: Acceptable

Cochrane Review assessing the safety and efficacy of interventions to prevent hypothermia in LBW infants within first 10 minutes of life. Concluded that plastic wraps or bags, plastic caps, skin-to-skin contact and transwarmer mattresses all keep preterm infants warmer, leading to higher temperatures upon admission to the NICU.

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.

Impact Factor: 5.65
Quality of Evidence: Acceptable

Barriers to heat loss, plastic wraps or bags were effective in reducing heat losses in infants < 28 weeks' gestation (4 studies, n=223; WMD 0.68 degrees Celsius; 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 <29 weeks' gestation (one study, n =4; MD 0.80 degrees Celsius; 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. An update of the 2008 search criteria.

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.

Impact Factor: 2.88
Quality of Evidence: Limited

n=25 VLBW infants (weighing <1500 grams), 16 weighed <1100 grams. Temperature changes associated with total care nursing procedures were studied. Found large drops in both central and peripheral temperature. Recovery often took 2 hours. Babies routinely nursed naked and covered by a single layer of bubble plastic in closed incubators.

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.

Impact Factor: 5.65
Quality of Evidence: Acceptable

n=4 studies. Cochrane Review to determine the effects of body weight in transferring preterm infants to unheated open cots. Concluded that 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. Two studies reported no difference between two groups in requiring an overhead heater for temperature maintenance.

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

Impact Factor: 1.7
Quality of Evidence: Acceptable

Updated guidelines on neonatal resuscitation. Provides indications for chest compressions and for the use of intravenous epinephrine, and recommends not using sodium bicarbonate or naloxone during resuscitation. Includes ventilation strategies for preterm infants. 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 place them under a radiant warmer. Hyperthermia should be avoided. Delivery room temperature should be set at least 78.8 degrees Fahrenheit (26 degrees Celsius) for infants less than 28 weeks' gestation.

Soll, R. F. (2008). Heat loss prevention in neonates. *Journal of Perinatology, 28 Suppl 1*, S57-59. doi: 10.1038/jp.2008.51

Impact Factor: 1.59
Quality of Evidence: Acceptable

Reviews interventions to prevent heat loss in neonates, from attention to the general environment (such as delivery room temperature) to specific individualized therapies, such as

the use of polyethylene occlusive skin wrap. Acknowledged that while an integral part of routine care of all newborns, these interventions have received little attention and study.

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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.

Impact Factor: 4.47
Quality of Evidence: Acceptable

n=112. Investigated effect of humidified and heated gas on admission temperature in preterm infants who require respiratory support at birth. 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.

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.

Impact Factor: Not Available
Quality of Evidence: Limited

n=14. Evaluated the safety of insulating heads of premature infants in servo controlled thermal environments. Measured body temperatures of premature infants (7 incubators, 7 radiant warmers) before, during, and after application of a head-wrap. Insulated head wrap increased scalp temperature of incubator infants, but not radiant warmer infants. Findings did not support routine use of head insulation.

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.

Impact Factor: 4.11
Quality of Evidence: Acceptable

n=53. Objective was to determine if polyethylene occlusive skin wrapping of very preterm infants, prevents heat loss after delivery better than conventional drying and to evaluate if any benefit is sustained after wrap removal. Plastic wraps of bags were effective in reducing heat losses in infants <29 weeks, but not infants between 28-31 weeks. Plastic caps were effective in reducing heat losses in infants <29 weeks. Insufficient evidence to suggest that either plastic wraps or caps reduce the risk of death within hospital stay.

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

Impact Factor: 1.54
Quality of Evidence: Acceptable

Summarizes recent report, increased mortality associated with hypothermia on admission to the NICU. Many conventional approaches are outmoded. Cites contradictory guidance re: thermo-regulation. For example, in 1994 WHO advised skin-to-skin contact to greatly reduce risk of hypothermia while the AAP Neonatal Resuscitation Textbook cites that the premature infant should be placed under radiant warmer and should not be covered to allow full visualization and to permit radiant heat to reach the baby.

Yeh, T. F., Voora, S., Lilien, L., Matwynshyn, J., Srinivasan, G., & Pildes, R. S. (1980). Oxygen consumption and insensible water loss in premature infants in single-versus double-walled incubators. *Journal of Pediatrics, 97*, 967-971.

Impact Factor: 4.12
Quality of Evidence: Acceptable

n=10. Mean birth weight 1444 grams. This study observed three hours of simultaneous measurement of insensible water loss and oxygen consumption under two conditions for the same infant: 1) inside single-walled incubator and 2) inside double-walled incubator. Double walled incubator had significantly lower insensible water loss, leading to a net caloric saving of 11.8 kilocalorie /kilogram/day. Saving of energy expenditure may be important in affecting the growth and outcome of LBW infants.

IV. Research Question 3
What are relevant issues regarding measurement, including: Techniques, Timing, and Comprehensiveness

Summary

Techniques associated with accurate measurement of temperature, include measuring temperature via differing locations and types of thermometry used. The literature review found skin thermometers, axillary thermometers, rectal thermometers, and core thermometers all acceptable locations for measuring temperature in this population. The literature review also supported infrared measurement, electronic sensory measurement and mercury sensitivity, as acceptable types of thermometry. Limitations were identified in the review indicating that each technique of assessment has significant limitations.

The technique of skin temperature measurement is found to be superior during the incubator and overhead heating scenarios. Use of skin temperature was accurate in assisting with control of heat, but studies found this technique was not an accurate method of assessment to reflect infant core temperature. Furthermore, it is noteworthy, that the literature review asserted that the assessment of core temperature does not reflect a true hypothermic state of the neonate, as the peripheries may continue to be sub-therapeutic in temperature.

This literature review concluded that when skin temperature is used, the recommended device is ThermoSpot. This device has been defined as a simple accurate device, allowing continuous thermal monitoring and could be advantageous for monitoring low birth weight infants, especially in resource poor settings.

Controversial information was found regarding the technique of temperature assessment when the rectal site was used. Rectal temperatures have been noted as a better measurement of core temperature; however, these measurements are invasive, uncomfortable and can come with risks for neonates. 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 literature review concluded that when the rectal site is chosen, Mercury-in-glass thermometry is considered the “gold-standard”. Unfortunately, accurate measurement with a Mercury-in-glass thermometer requires at least 3-5 minutes. Electronic thermometers sample temperature measurements over a shorter period.

Many studies reviewed the accuracy and relationship between axillary and rectal temperature measurements. In this search, most studies supported the axillary site for temperature assessment based on the rapid easy access in the newborn. Preterm infants’ axillary temperatures were demonstrated to be close in agreement with rectal measurements, which is contrary to the findings for full term babies. Axillary temperature measurement has also been recommended as the standard of care for neonates by the American Academy of Pediatrics and the National Association of Neonatal Nurses.

This literature review also included studies assessing infrared thermometers, and conflicting evidence was found. Some studies conclude that tympanic infrared thermometers are inappropriate for hospitalized neonates, while others recommend the use of infrared thermometers due to rapid result delivery, patient comfort and noninvasive procedure. There was no recommended tool of measurement for infrared thermometry. There were significant statistical differences identified between measurements using infrared tympanic thermometry, axillary glass mercury thermometer or digital axillary thermometer.
The use of an infrared temporal thermometer has been assessed as an advantageous device. The reason being that it yielded temperature measurement differences that were considered clinically insignificant and caused less discomfort for the neonates in comparison to the use of the axillary and rectal thermometers.

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

Repeated axillary temperatures were not shown to improve control of hypothermia. Nor was hypothermia controlled through 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 the outcome of babies care.

This literature review sought out recommendations for timing of temperature assessment. Mercury-in-glass thermometers yielded the most accurate result of measurement with a time between 3 to 5 minutes. However, delayed time for results can adversely affect the care provided to infants, thus, the tympanic infrared digital thermometers deliver rapid accurate results.

Finally, this literature review examined the comprehensiveness of temperature assessment in the premature neonatal population. It was determined that the majority of the population assessed in the research studies had their temperatures recorded. However, there were instances that did not yield a temperature measurement. Some reasons indicated by the literature included neonatal death, neonatal distress, abnormal otic or rectal structures, isolation for infectious diseases, and any circumstances that could negatively impact the care or health of the infant.

Bibliography

Bliss-Holtz, J. (1993). Determination of Thermoregulatory State in Full-Term Infants. *Nursing Research, 42*(4), 204-207.

Impact Factor: 1.40
Quality of Evidence: Limited

n=45, full-term infants within four hours of birth. Study purpose was to determine whether the relationship between axillary and tympanic core temperature readings could be used to detect and categorize thermal state and to determine if core and axillary temperature relationships would be useful in predicting core temperature decrease. Standard self-registering Mercury-in-glass thermometers were used for all axillary readings. Tympanic temperature readings represented core temperature and were taken with an infrared tympanic thermometer. The results support that three major categories of thermal state can be detected and classified through comparison of tympanic core and axillary temperature. The study demonstrated that if single site temperature readings were used to monitor each infant's response to the thermal environment, 53% would not have received appropriate thermal support.

Bliss-Holtz, J. (1995). Methods of Newborn Infant Temperature Monitoring: A Research Review. *Issues in Comprehensive Pediatric Nursing, 18*, 287-298.

Impact Factor: Not Available
Quality of Evidence: Limited

A review of relevant temperature monitoring in the newborn. In preterm infants (29 to 36 weeks) the difference between rectal and axillary readings after 5-minute placement is 0.05 degrees Celsius and is small and can be considered to be interchangeable. In preterm infants, skin-to-mattress readings yielded accurate results in less time than rectal readings. These results for full-term infants were different from the preterm results.

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.

Impact Factor: 1.59
Quality of Evidence: Limited

n= 9 (Gestational Age between 25-40 weeks). Objective was to test a new system designed for digital recording of skin and air temperature, which will allow analysis of cyclic changes in temperature in neonates in servo-controlled incubators. Established new system to study cyclic changes in skin and air temperature in neonates in servo-controlled incubators.

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.

Impact Factor: 2.34
Quality of Evidence: Limited

n=107. Tested reliability of measurement of body temperature using new infrared skin thermometer (instead of traditional mercury thermometer). Found it to be a comfortable and reliable way of measurement of body temperatures in newborns

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Dollberg, S., Lahav, S., & Mimouni, F. (2001). Precision of a New Thermometer for Rapid Rectal Temperature Measurement in Neonates. *American Journal of Perinatology, 18*(2), 103-105.

Impact Factor: 1.13
Quality of Evidence: Limited

n=224 (36-42 weeks) infants (admission from delivery room to Newborn-Nursery) (temperature was taken at age 2 hours +/- 30 minutes). Compared rectal temperature measurement in term and near-term infants using Mercury-in-glass and a Penguin thermometer. The study concluded that a Penguin thermometer is accurate and reproducible when measuring rectal temperatures in term and near-term infants, compared with a Mercury-in-glass thermometer.

Dollberg, S., Mincis, L., Mimouni, F., Ashbel, G., & Barak, M. (2003). Evaluation of a New Thermometer for Rapid Axillary Temperature Measurement in Preterm Infants. *American Journal of Perinatology, 20*(4), 201-204.

Impact Factor: 1.13
Quality of Evidence: Limited

n=50 thermally stable preterm infants (mean gestational age 30.1 weeks, mean birth weight 1258 grams). The study concluded that Penguin thermometers are less accurate and less reproducible than IVAC or Mercury-in-glass thermometers when compared with taking the axillary temperatures of incubated preterm infants. This finding is contrary to their observation in rectal temperatures in full -term infants. Overall the study shows that the IVAC thermometers are better for NICU settings because of its accuracy, reproducibility, and rapid measurement ability.

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

Impact Factor: 0.9
Quality of Evidence: Limited

n=34 VLBW babies (<1500 grams), conducted from day 7-14 of life.
Objective is to evaluate performance of non-invasive infrared thermometer applied to the mid forehead and temporal artery in comparison with axillary temperature recordings by Mercury- in-glass thermometer. Found infrared thermometer applied to the mid forehead is a useful and valid device for easy and less painful measurement of skin temp in VLBW infants.

Fallis, W., & Christiani, P. (1999). Neonatal Axillary Temperature Measurements: A Comparison of Electronic Thermometer Predictive and Monitor Modes. *JOGNN Clinical Studies, 28*, 389-394.

Impact Factor: 0.95
Quality of Evidence: Limited

n=72 healthy full-term newborns. The study focused on whether electronic predictive mode axillary temperature measurement was accurate for neonates. It was concluded that the difference between the axillary temperatures obtained in predictive and monitor mode are statistically significant, but not clinically significant.

Fleming, M., Hakansson, H., & Svenningsen, N. (1983). A disposable new electronic temperature probe for skin temperature measurements in the newborn infant nursery. *Int. J. Nurs. Stud., 20*(2), 89-96.

Impact Factor: 1.91
Quality of Evidence: Limited

n=18 newborn babies, birth weights between 850 and 3000 grams; treated in NICU
The study concluded that axillary temperature is as accurate a measure of the body temperature as the rectum temperature measurement for both preterm and full-term babies. The new electronic disposable temperature probe was more attractive than non-disposable methods due to convenience and reduction of possible hygienic problems. The mean value of differences between the rectal and axillary temperatures was 0.40 degrees Celsius.

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.

Impact Factor: 0.52
Quality of Evidence: Limited

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

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

Impact Factor: 2.66
Quality of Evidence: Acceptable

n=33 (Gestational Age 25-42 weeks). Aim was to evaluate the agreement between axillary temperature measurement and rectal temperature measurements in neonates. Found wide variation between mean difference of axillary and rectal temperature, suggesting that the two cannot be used interchangeably.

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.

Impact Factor: 1.03
Quality of Evidence: Acceptable

n=36, studied for 96 hours postpartum. Objective was to determine if different temperature monitoring devices routinely used in postpartum mothers and newborns provide similar temperatures and to compare rectal and axillary routes for temperature monitoring in newborns. Found statistically significant differences between rectal and axillary temperatures. Demonstrates need to use a consistent device when monitoring temperature.

Johnston, A., & Shorten, D. (1991). Optimal Axillary Thermometer Placement Time for Recording Neonatal Temperature. *Australian College of Midwives Journal*, 25-27.

Impact Factor: Not Available
Quality of Evidence: Limited

n=100 healthy term infants. The purpose of the study was to determine the optimal thermometer placement time to record the maximum axillary temperature in a healthy term neonate. The data results indicated that the optimal thermometer placement time for recording an accurate neonatal axillary temperature is 6 minutes.

Kennedy, N., Gondwe, L., & Morley, D. C. (2000). Temperature monitoring with ThermoSpots in Malawi. *The Lancet, 355*(9212), 1364. doi: 10.1016/s0140-6736(05)72592-7

Impact Factor: 38.28
Quality of Evidence: Limited

n=10 newborns; birth weight under 2000 grams. Assessed the use of Thermospots in a rural hospital in Northern Malawi. The Thermospot device is an accurate way to continuously monitor infants with a LBW in resource poor settings. The Thermospot device identified all cases of hypothermia.

Khan, M., Ahmad, S. H., & Fakhir, S. (1990). Comparison of Temperatures at Different Sites in Term and Pre-Term Neonates. *Indian Pediatrics, 27*, 807-809.

Impact Factor: 0.75
Quality of Evidence: Accepted

n=30 term and 20 preterm neonates. The study assessed the differences in temperature at different sites in term and pre-term neonates using a glass/mercury thermometer. There is a significant difference between aural and rectal temperatures in both preterm and full-term neonates. The rectal temperature was found to be higher in both groups as well. Also there was less variation in the different sites in the preterm infants.

Lee, G., Flannery-Bergey, D., Randall-Rollins, K., Curry, D., Rowe, S., Teague, M., . . . Schroeder, S. (2011). Accuracy of temporal artery thermometry in neonatal intensive care infants. *Adv Neonatal Care, 11*(1), 62-70. doi: 10.1097/ANC.0b013e3182087d2b

Impact Factor: 0.91
Quality of Evidence: Accepted

n=33 neonates in the NICU with the gestational age between 32 and 40 weeks at birth. The study focused on the accuracy of the temporal artery thermometer in neonates. The temperatures measured by a temporal artery thermometer were statistically different from the rectal probe temperatures. However, the difference was seen to be clinically insignificant. The use of the temporal thermometer yielded less discomfort for the neonates in comparison to the use of the axillary thermometers. The study concluded that the temporal thermometer was an attractive alternative from rectal temperature and axillary temperature taking methods due to its accuracy and low discomfort for stable, normothermic neonates.

Leick-Rude, M. K., & Bloom, L. F. (1998). A Comparison of Temperature-Taking Methods in Neonates. *Neonatal Network, 17*(5), 21-37.

Impact Factor: Not Available
Quality of Evidence: Limited

n=220 infants weighing greater than 1,500gm (Level III NICU), term and preterm infants Glass/mercury thermometers; B-D digital fever thermometers; Tempa DOT single-use clinical thermometers; IVAC CORE CHECK tympanic thermometer system; Mon-a-therm Infant Temperature Model 1000 monitor and temperature probe; IncuTemp 3 temperature sensor probes.

This study concluded that tympanic thermometry is inappropriate for hospitalized neonates.

Lyon, A.J., & 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.

Impact Factor: 2.39

Quality of Evidence: Limited

n=20 Gestational Age <29 weeks studied during first 5 days of life. Comparing the effect of a computer program (HeatBalance) on temperature control of infants. Program recommends incubator temperature and humidity settings to keep babies in thermal balance. Concluded that similar results were achieved in temperature stability with both methods. Highlighted the importance of continuous monitoring of central and peripheral temperatures.

Mayfield, S., Bhatia, J., Nakamura, K., Rios, G., & Bell, E. (1984). Temperature measurement in term and preterm neonates. *Journal of Pediatrics, 104*(2), 271-275.

Impact Factor: 4.47
Quality of Evidence: Accepted

n=99 term infants, n=44 preterm infants. Four sites were measured: core (5 centimeter beyond anus, electronic telethermometer), rectum (2 centimeter, Mercury-in-glass thermometer, axillary, and between the skin and mattress.
Preterm infants' temperatures varied less with the site of measurement and were lower, indicating a smaller core-surface temperature gradient because of their relative lack of thermal insulation by body fat. Axillary temperature was demonstrated to be close in agreement with rectal measurements. Preterm infants showed closer agreement in axillary and rectal temperatures at different sites than the full term babies did. Axillary temperature measure with glass mercury thermometer was as good as rectal temperature measured with a Mercury-in-glass thermometer.

McKenzie, N. (2003). Evaluation of a New, Wearable, Precision Phase-Change Thermometer in Neonates. *Pediatric Nursing, 29*(2), 117-125.

Impact Factor: Not Available
Quality of Evidence: Limited

n=29 neonates. Assesses the quantitative relationship between a new, wearable, continuous-read, precision phase-change thermometer (WCPPT) and a glass mercury thermometer used in the axilla in neonates. The results indicated the TraxIt measurements with placement of at least one hour were reflective of true body temperature because of the elimination of drawdown. In addition, the difference in measurement outcomes between the TraxIt and the glass mercury thermometers were clinically and statistically insignificant. The NexTemp precision phase change thermometers used between the skin and the mattress of neonates resulted in measurements that were 0.2 degrees Celsius lower than the axillary GMA measurements, which were clinically significant. The study suggested this difference was more likely due to the temperature differences in measurement sites than the actual thermometer.

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.

Impact Factor: 2.88
Quality of Evidence: Limited

n=25 VLBW infants (weighing <1500 grams), 16 weighed less than 1100 grams. Temperature changes associated with total care nursing procedures were studied. Found large drops in both central and peripheral temperature. Recovery of temperature took 2 hours. Babies routinely nursed naked and covered by a single layer of bubble plastic in closed incubators.

Pejaver, R. K., Nisarga, R., & Gowda, B. (2004). Temperature Monitoring in Newborns Using Thermospot. *Indian J Pediatr, 71*(9), 795-796.

Impact Factor: 0.52
Quality of Evidence: Acceptable

A simple liquid crystal temperature monitoring device was used in 20 infants on a continuous basis to monitor for hypothermia. This was compared with the measurement of rectal temperature using a rectal thermometer. ThermoSpot device is a simple accurate device allowing continuous thermal monitoring of low birth weight infants, especially in resource poor setting. It underestimated the temperature of three infants, falsely indicating hypothermia in a normothermic child with normal body temperature. It correctly identified hypothermia in every case.

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.

Impact Factor: 2.41
Quality of Evidence: Limited

Study to address whether both the infants 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.

Roy, A. S., Chowdhury, T., Bandhopadhya, D., & Ghosh, G. (2009). Time Required to Document Temperature by Electronic Skin Thermometer in a Healthy Neonate. *Indian Pediatrics, 46*, 1103-1104.

Impact Factor: 0.75
Quality of Evidence: Limited

n = 100, all neonates of any gestational age or mode of delivery after initial stabilization (preferably within 1 hour of birth) without congenital anomalies or any sickness or distress. The study was conducted to address actual time taken to document temperature by an electronic digital skin thermometer. The mean time required for documenting the temperature by an

electronic thermometer in axilla was 56.34±1.54 seconds for term neonates (>2500 grams) and 54.87±1.23 seconds for low birth weight (<2500 grams). The time required for documenting temperature did not change significantly (P<0.01) with environmental temperature. The skin temperature measured by the ordinary mercury thermometer did not differ significantly from that noted by using the electronic digital skin thermometer (P< 0.01).

Sganga, A., Wallace, R., Kiehl, E., Irving, T., & Witter, L. (2000). A Comparison of Four Methods of Normal Newborn Temperature Measurement. *MCN, 25*(2), 76-79.

Impact Factor: 0.79
Quality of Evidence: Limited

n=184 normal newborns between 1 and 168 hours of age. Aim was to compare newborn temperatures measured by glass, digital disposable, electronic, and tympanic thermometers. Glass mercury thermometers, electronic thermometers, and digital thermometer temperature measurements were highly correlated, while the tympanic temperature assessment correlated poorly with the glass thermometer assessment. Concluded that the digital thermometer was the best instrument to use for measurement with newborns.

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.

Impact Factor: 0.74
Quality of Evidence: Limited

Medical records of 203 healthy full-term infants were reviewed to determine the range of axillary temperatures for newborns, factors that affect temperature and nursery management of infants with temperature outside published normal ranges. Mean axillary temperature was 36.5 degrees Celsius. Maternal fever, birth weight, race/ethnicity were significant predictors of birth temperature. Found newborn axillary temperatures to be considerably lower than what has previously been described as "normal". Given the frequency of "hypothermia" recommends expanding newborn temperatures to include lower temperatures.

Uslu, S., Ozdemir, H., Bulbul, A., Comert, S., Bolat, F., Can, E., & Nuhoglu, A. (2011). A comparison of different methods of temperature measurements in sick newborns. [Clinical Trial, Comparative Study]. *J Trop Pediatr, 57*(6), 418-423. doi: 10.1093/tropej/fmq120

Impact Factor: 1.22
Quality of Evidence: Limited

n=633 newborns, n=305 preterm, n=319 LBW (less 2500 grams). This study compared the accuracy of digital axillary thermometer (DAT), rectal glass mercury thermometer (RGMT), infrared tympanic thermometer (ITT) and infrared forehead skin thermometer (IFST)

measurements with traditional axillary glass mercury thermometer (AGMT) for intermittent temperature measurement in sick newborns. There were significant statistical differences between measurements; however, the differences between the axillary glass mercury thermometer and digital axillary thermometer or infrared tympanic thermometer were not clinically significant. This study recommends the use of a tympanic thermometer due to rapid result delivery, patient comfort, and noninvasive procedure.

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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.

Impact Factor: 2.07
Quality of Evidence: Acceptable

n=26 (birth weight between 520 grams-1250 grams). Hypothesize that for monitoring body temperature in VLBW infants, central measurement of temperature with continuous skin probe (zero heat flow) is just as reliable as rectal temperature. Both measurements registered every hour over period of 48 hours. Analysis of 1205 (out of 1248) measurements demonstrated that the zero heat flow method was as reliable as the rectal method with less complications and no discomfort.

Weiss, M. (1991). Tympanic Infrared Thermometry for Full term and Preterm Neonates. *Clinical Pediatrics, Supplement*, 42-45.

Impact Factor: 0.74
Quality of Evidence: Limited

n=22 full-term neonates, n=12 preterm neonates. Assessed the accuracy and precision of tympanic temperatures taken in full-term and preterm neonates. No significant differences were found between left tympanic and axillary temperatures. The opposite was found for the right tympanic measurement, which was slightly higher than the axillary temperatures, the differences are statistically significant however they are small differences may not be that clinically significant. Overall the results suggested that tympanic temperature is as accurate an estimation of body temperature in the neonates as axillary temperature.

Weiss, M., Poeltler, D., & Gocka, I. (1994). Infrared Tympanic Thermometry for Neonatal Temperature Assessment. *JOGNN Clinical Studies, 23*(9), 798-804.

Impact Factor: 0.95
Quality of Evidence: Limited

n=34 full-term newborns. The study investigated the accuracy and precision of infrared tympanic thermometer use with neonates, by comparing with axillary and rectal measurements. Tympanic measures were very consistent in repeated measurements in the same and opposite

ear. However, there was variation between tympanic and both the axillary and rectal measurements and the axillary and rectal measurements had less variation.

Yetman, R., Coody, D., West, M., Montgomery, D., & Brown, M. (1993). Comparison of temperature measurements by an aural infrared thermometer with measurements by traditional rectal and axillary techniques. *The Journal of Pediatrics, 122*(5), 769-773.

Impact Factor: 5.437
Quality of Evidence: Limited

n=200 term newborn infants. Evaluated temperatures obtained with glass-mercury axillary (GMA) and aural infrared thermometers with temperatures obtained with glass-mercury rectal (GMR) thermometers. The results indicated that the glass-mercury axillary and rectal temperatures had reasonable correlation but temperatures are not interchangeable. (GMA were more than 0.3 degrees Celsius higher or lower than the GMR) The FirstTemp tympanic membrane thermometer in either the rectal- or oral- equivalent mode cannot be substituted for GMA or GMR to obtain temperatures in normal neonates. Therefore, the use of this device is not recommended in nurseries.

V. Research Question 4
Is there evidence of systematic variation that disadvantage any specific race or ethnic group, insurance type, or maternal demographic characteristic?

Summary

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

Infant variations that affect thermoregulation of a newborn are those characteristics such as birth weight, age, gender, ethnic diversity, delivery room setting, acuity of infant and need for resuscitation.

Variations of the organizations also effects disadvantaged populations, specifically low resource areas serving this population. Infant exposure to hypothermia in low resource organizations was related to electricity cuts or malfunctioning of the incubators. In situations of malfunctioning or unavailability of conventional thermoregulatory equipment, the use of Kangaroo Method Care was used to maintain adequate temperatures in preterm low birth weight infants.

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

Beeram, M., Solarin, K., Young, M., & Abedin, M. (1995). Morbidity and Mortality of Infants Born Before Arrival at the Hospital. Clinical Pediatrics, 313-316.

Impact Factor: 0.74
Quality of Evidence: Limited

This retrospective study focused on morbidity and mortality of infants that were born at home, in a car or ambulance, on the street, or right outside the emergency department. All infants were admitted directly to the NICU. This study took place in the District of Columbia and noted that there is a sufficient amount of accessible hospitals with adequate delivery services, and ambulance services available to its residents. It is suggested that under utilization of these services could be due to low socioeconomic status, poor prenatal care, poor education about health and pregnancy, and poor nutrition.

Ibe, O. E., Austin, T., Sullivan, K., Fabanwo, O., Disu, E., & Costello, A. M. (2004). A comparison of kangaroo mother care and conventional incubator care for thermal regulation of infants < 2000 g in Nigeria using continuous ambulatory temperature monitoring. [Comparative Study, Multicenter Study]. Annals of Tropical Paediatric, 24(3), 245-251. doi: 10.1179/027249304225019082

Impact Factor: 0.9
Quality of Evidence: Limited

n=13 (aged from 24 hours to 30 days were recruited by incident density sampling; birth weight of 1200-1999 grams. Kangaroo Mother Care (KMC) is a feasible, low-cost, and preferable alternative for maintaining warmth in situations where equipment for thermal regulation is unreliable. The LBW infants were observed to have fewer episodes of hypothermia in KMC than in conventional care (CC); However, the instances of hypothermia recorded during CC occurred when there were electricity cuts or malfunctioning of the incubators. In situations of malfunctioning or unavailability of conventional thermoregulatory equipment, the use of KMC to maintain adequate temperatures in preterm/LBW infants is a safe alternative.

Kadam, S., Binoy, S., Kanbur, W., Mondkar, J. A., & Fernandez, A. (2005). Feasibility of Kangaroo Mother Care in Mumbai. Inidan J Pediatr, 72(1), 35-38. Infants with birth weight less than 1800 grams.

Impact Factor: 0.52
Quality of Evidence: Limited

A randomized-controlled trial was performed to investigate the feasibility and acceptability of kangaroo care in a tertiary NICU in a hospital in Mumbai, India. The study indicated that Kangaroo Mother Care (KMC) is a feasible method to regulate the temperature of LBW neonates in a NICU where resources could be limited. The study did report that the infants in the KMC group had statistically significant less episodes of hypothermia when compared to the babies in the conventional method of care group.

Kumar, V., Shearer, J. C., Kumar, A., & Darmstadt, G. L. (2009). Neonatal hypothermia in low resource settings: a review. [Research Support, Non-U.S. Gov't Research Support, U.S. Gov't, Non-P.H.S.Review]. J Perinatol, 29(6), 401-412. doi: 10.1038/jp.2008.233

Impact Factor: 1.59
Quality of Evidence: Limited

A review of that describes the patho-physio-epidemiology of neonatal hypothermia in low resource settings. The literature also focuses on risks associated with neonatal hypothermia, as well as the prevention and management of neonatal hypothermia. There are studies that have addressed the knowledge and practice of health professionals in low resource settings and have revealed many high risk practices, such as inadequate warmth in delivery rooms, improper or

delayed drying and wrapping of the newborn, bathing immediately after birth, reduced and delayed contact with the mother and delayed initiation of breastfeeding.

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

Impact Factor: 1.59
Quality of Evidence: Acceptable

n=11664 VLBW infants (Birth Weight <1500 grams). Study conducted to evaluate the epidemiology of neonatal hypothermia (using WHO temperature criteria) and found that moderate and severe hypothermic conditions were associated with higher risk of intraventricular hemorrhage and higher risk of death. Use of WHO criteria can guide need for quality improvement initiatives targeted towards most vulnerable infants. In bivariate analysis, blacks and Hispanics associated with hypothermia and maternal hypertension.

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

Impact Factor: 0.63
Quality of Evidence: Limited

n=487 (23 studies). Meta-analysis to investigate whether skin-to-skin contact for newborn babies and their mothers affects body temperature. Found evidence of an increase in body temperature and found to be more evident in low- income settings, but no clear explanation was found. The study concluded that skin-to-skin contact is effective in increasing body temperature of babies, particularly in resource-limited environments.

Mullany, L. C. (2010). Neonatal hypothermia in low-resource settings. [Research Support, N.I.H., Extramural Review]. Semin Perinatol, 34(6), 426-433. doi: 10.1053/j.semperi.2010.09.007

Impact Factor: 2.33
Quality of Evidence: Limited

Summarizes recent report, increased mortality associated with hypothermia on admission to the NICU. Many conventional approaches are outmoded. Cites contradictory guidance: thermoregulation. For example, in 1994 WHO advised skin-to-skin contact to greatly reduce risk of hypothermia. Displays studies showing association between hypothermia and mortality risk in hospital and communities of low resource settings.

Zayeri, F., Kazemnejad, A., Ganjali, M., Babaei, G., & Nayeri, F. (2007). Incidence and risk factors of neonatal hypothermia at referral hospitals in Tehran, Islamic Republic of Iran. La Revue de Sante de la Mediterranee orientale, 13(6), 1308-1318.

Impact Factor: Not Available
Quality of Evidence: Limited

n=900. More than 50% became hypothermic soon after birth. Multiple regression analysis showed that low birth weight, low gestational age, low environmental temperature, low Agar score, multiple pregnancies and receiving cardiopulmonary resuscitation were significantly associated with hypothermia. These findings suggested that there is an urgent need to sensitize and educate all levels of staff dealing with neonates in the country of Iran.
"Kangaroo" mother care is the only effective, affordable and available method in most developing countries, especially in rural areas. Therefore, there is an urgent need to increase awareness about the consequences of hypothermia and train mothers and all levels of neonatal care staff to control this health problem in developing countries.

VI. Grey Literature: Identified guidelines, proposed or endorsed measures regarding the importance of temperatures outcomes in infants.

Summary

At the Global level, summaries were dismissed when information occurred outside of an organized hospital. Review of the NICE summaries included information directing care takers to immediately dry infants and encouraged Skin to Skin Contact to reduce hypothermia.
On the National level, review of the Vermont Oxford Network measures that have been developed including care regarding the first temperature measured within one hour of admission to the NICU, as well as the incidence of a temperature below 36 degrees Celsius. These measures did not receive endorsement from the National Quality Forum.

The California Maternal Quality Care Collaborative (CMQCC) works in conjunction with the National Quality Forum (NQF) to create the National Quality Form Perinatal Care and Reproductive Health Project 2011. This group reviews and endorses quality measures that are then used by government agencies such as Centers for Medicare and Medicaid Services and by non-government quality review agencies such as The Joint Commission and the LeapFrog Group.

The Health and Human Services on Women's' Health encourages the use of incubators in this vulnerable population to reduce heat loss, evaporative water loss, and decrease environmental exposures to infectious bacteria. The Association of Maternal & Child Health Programs (AMCHP) - has a multitude of federally funded programs improving birth outcomes and eliminating morbidity and mortality.

The California Perinatal Quality Care Collaborative confirms the responsibility to ensure protection from hypothermia to significantly decrease mortality and morbidity. They encourage care takers to avoid thermal stress by using skin-to-skin (e.g. kangaroo) care or by double wrapping if necessary and by dressing the baby in a shirt and hat. They encourage that all providers consider intermittent use of an incubator to maintain temperature. They address the cultural acceptability of allowing and facilitating mothers to sleep with the baby to provide warmth. The New York State Health Department has the State Health Plan FY 2004 Prenatal Care in which temperature is not noted as important in the care of the newborn. However, the Texas Department of Health and Services measures the incidence of hypothermia prior to transport in the Healthy Texas Babies Provider Subgroup #2.

On the professional organizational and societal level, there is contradicting recommendations to warm prior to resuscitation, as the ACOG/AAP- recommends the first step to resuscitation includes warmth protection from hypothermia and exposure, contradicting the AWON recommendation, who directs care takers to measure temperature during resuscitative process. Both recommend warming of the delivery rooms as well as warming all the supplies needed including blankets, mattresses and overhead heaters. As the above literature review notes, there is differing discussion regarding plastic wrap use and humidified heat application and prevention of loss.

Bibliography

American Congress of Obstetricians and Gynecologists (ACOG)/American Academy of Pediatrics (AAP)

Quality of Evidence: Acceptable

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 degrees Celsius, 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).

Association of Maternal & Child Health Programs

Quality of Evidence: Limited

Policy and evolution of the Title V Federal Children's Bureau

*Newborn Care Project areas- all outside of hospitals.
Infant Mortality: AMCHP Resources for reducing Infant Mortality:
*Improving Birth Outcomes in the US
*Emerging, Promising, and Best Practices on Infant Mortality and improving birth outcomes
*Partnership on eliminating disparities in infant mortality
*State Infant Mortality Collaborative 2004-2006
*Partner Resources for reducing infant mortality- Association of State and Territorial Health Officials (ASTHO) 2011-2012 Presidential Challenge, The Health Babies Project
* Health Resources and Services Administration (HRSA) Region IV and VI Infant Mortality.

Association of Women's Health, Obstetric and Neonatal Nurses (AWON)

Quality of Evidence: Acceptable

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 Transepidermal Water Loss (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.

California Department of Public Health

Quality of Evidence: Limited

Birth and Beyond: Bibliography of Premature infant transfer from the NICU to home,: As well as Birth and Beyond California Annotated Bibliography mentions care from hypothermia-Annotative Bibliography citations of importance of normothermia. All citations present in Joint Commission bibliography.

California Maternal Quality Care Collaborative (CMQCC)

Quality of Evidence: Limited

CMQCC is devoted to eliminating preventable maternal death and injury and promoting equitable maternity care in California by bringing resources, tools, measures, and quality improvement techniques to providers, administrators, and public health leaders.
National Quality Forum (NQF) Perinatal Care and Reproductive Health Project 2011

NQF reviews and endorses quality measures that are then used by government agencies such as CMS and by non-government quality review agencies such as The Joint Commission and the LeapFrog Group. The last comprehensive NQF review of Perinatal Measures was in 2008, with a few additional relevant measures added during other reviews (e.g. Healthy Term Newborn was added as part of the Pediatric Population Review Process in 2009). There is a current process underway (2011-2012) for measure maintenance and consideration of new measures. Information on this process can be found at NQF Perinatal Care and Reproductive Health Project web page.

17 NQF Perinatal Measures were endorsed in the 2008 process and can be found here. Note that CMQCC was the developer (and the Intellectual Property Owner) of 3 of these measures. In addition, CMQCC was the developer of the measure, Healthy Term Newborn.

California Perinatal Quality Care Collaborative

Quality of Evidence: Limited

Potentially Better Practices:
Best Practices related to ALL deliveries

We believe that the smallest and most immature of infants have unique requirements to ensure an effective transition from fetal to extra-uterine life. These infants have immature organ systems, and without appropriate preparation and intervention can develop severe degrees of hypothermia, and respiratory failure that can significantly increase mortality and morbidity.

Academy of Breastfeeding Medicine:
In the "Near Term Infant (35-37 weeks).
Avoid thermal stress by using skin-to-skin (e.g. kangaroo) care or by double wrapping if necessary and by dressing the baby in a shirt and hat. Consider intermittent use of an incubator to maintain temperature. Where it is culturally acceptable, mothers can sleep with the baby to provide warmth.

Health and Human Services/Health Resources and Services Administration

Quality of Evidence: Limited

Maternal Child Health Bureau: Title V Partnership with State Maternal Child Health in developing programs, public information regarding children and newborn care.
Neonatal Outcome Project: Intervention #4 Focus on facilities without tertiary care NICU, optimal resuscitation and stabilization of the baby before transfer.

Health and Human Services Office on Women's Health

Quality of Evidence: Limited

A Preemie's Basic Needs Warmth.

Premature babies lack the body fat necessary to maintain their body temperature, even when swaddled with blankets. So incubators or radiant warmers are used to keep them warm in the NICU. Keeping babies' temperatures within a normal range will help them grow faster. Incubators are made of transparent plastic, and completely surround babies to keep them warm, decrease the chance of infection, and limit water loss. Radiant warmers are electrically warmed beds open to the air. These are used when the medical staff needs frequent access to the baby for care. A tiny thermometer taped to the baby's skin senses his/her body temperature and regulates the heat.

National Collaborating Centre for Women's and Children Health

Quality of Evidence: Acceptable

Summary from previous Joint Commission Literature Review (March 2012): 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.

National Quality Forum

Quality of Evidence: Limited

California Maternal Quality Collaborative - Measure for delivery of <1500 grams institution.
Perinatal and Reproductive Healthcare Endorsement Maintenance Workgroup
National Voluntary Consensus Standards for Prenatal Care (2008)
VON Measure NQF#0481
2a1.1 Numerator Statement: Infants 501 to 1500 grams with first temperature taken within 1 hour of NICU admission
2a1.4 Denominator Statement: Infants whose birth weight is between 501 and 1500 grams who are admitted to a NICU in the reporting hospital.
VON NQF#0482
2a1.1 Numerator Statement: Infants whose birth weight is between 501-1500 grams and whose temperature first measured within one hour of admission to the NICU and is less than 36 degrees Celsius.
2a1.4 Denominator Statement: Number of infants with birth weights between 501 and 1500 grams whose temperature was measured within one hour of admission to the NICU.

New York State Department of Health

Quality of Evidence: Acceptable

Neonatology special considerations:
Temperature is last in algorithm for neonate care
defines hypothermia as <35 C and source of infant morbidity/mortality
State Health Plan FY 2004 Prenatal Care does not note temperature importance in newborn

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Texas Department of State Health Services

Quality of Evidence: Acceptable

Measured incidence of hypothermia prior to transport in Healthy Texas Babies Provider Subgroup #2 (Perinatal regionalization) Intervention Action Plan in July 19, 2011
Multiple publications on NICU Care.

Vermont Oxford Network

Quality of Evidence: Acceptable

There were documents describing two proposed measures (neither of which was endorsed by the National Quality Forum):
1. NQF#0481 First Temperature Measured Within One Hour of Admission to the NICU

2. NQF#0482 First NICU Temperature <36 degrees Centigrade
The documents did NOT include the literature references, but did give a VON Contact person, whom we could potentially reach out to for more information
Found information on the Heat Loss Prevention (HeLP) Trial, which was also included in March 2012 Joint Commission Literature Review: Heat Loss Prevention (HeLP) Trial. (Retrieved March 15, 2011)

Appendix C

Powerpoint Presentation Orienting EP to the Process

CAPQuaM

COLLABORATION FOR ADVANCING PEDIATRIC QUALITY MEASURES

CAPQuaM Expert Panel Orientation Presentation

Dr. Larry Kleinman, CAPQuaM PI

Children Are Not Young Adults

- 4 D's Model (Forrest & Dougherty)
  - Changing **D**evelopmental Status of Children
  - **D**ifferences in epidemiological patterns of disease
  - Differing **D**emography of children compared to adults
  - **D**ependent upon their parents / caregivers
- More D's
  - Lack of a **D**ata Infrastructure equivalent to Medicare
  - Lack of strong financial **D**rivers for research

Medicaid and the SCHIP Program

- Federal State partnership
- Major public insurance program for children
- Supplemented in late 1990's by State Child Health Insurance Program (CHIP or SCHIP)
  - For working poor who did not qualify for Medicaid
  - Benefits and eligibility vary by state
  - Could be Medicaid expansion or separate program

Children's Health Insurance Program Reauthorization Act (CHIPRA), 2009

- CHIP = Children's Health Insurance Program
  - administered at the state level
  - insures low-income children whose parents do not qualify for Medicaid
  - reauthorizes CHIP through 2013
- Creates the Pediatric Quality Measures Program

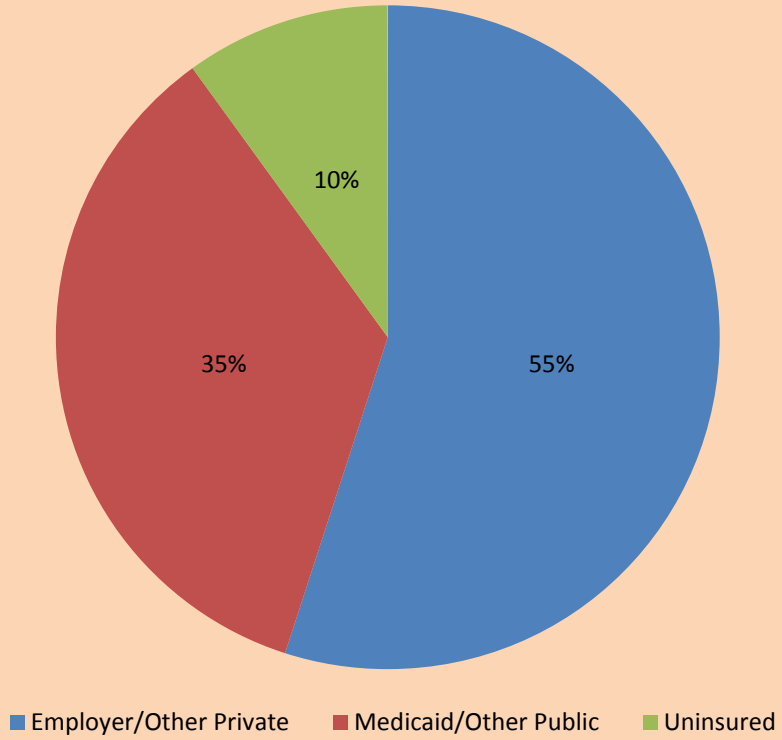
Background and Context

- CHIPRA's Title IV signals a new day for children's healthcare quality measurement in the U.S.
- AHRQ is partnering with CMS on identification and development of children's healthcare quality measures
  - Phase I-- Identification of an initial core measurement set for voluntary use by Medicaid and CHIP programs-- is completed
  - Phase II – the Pediatric Quality Measures Program (Sec. 1139A(b) of Title XI (42 USC 1301 et seq.) began in January 2011 (PQMP).
    - Improved core measures are to be published annually beginning January 1, 2013.

www.ahrq.gov/CHIPRA

Slide courtesy of Denise Dougherty, AHRQ

Health Insurance for Children, 2009



Source: Kaiser Commission for Medicaid and Uninsured

PQMP Goals

CHIPRA Title IV Sec. 401 which amended Title XI (42 USC 1301 et seq.) by adding the following new section: Sec. 1139A (b).

- The Secretary shall establish a pediatric quality measures program to:
  - **Improve and strengthen …**children's health care quality measures;
  - **Expand on existing pediatric quality measures** .. and advance [their] development; and
  - **Increase the portfolio** of evidence-based, consensus pediatric quality measures available to public and private purchasers of children's health care services, providers, and consumers.

Courtesy of Denise Dougherty, AHRQ

Definitions of Quality

- IOM – The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge.
- Doing the right thing, well, for the right person, at the right time

The Constituents of Quality

- Donabedian
  - Structure / System
  - Process
  - Outcomes
- Coordination of care
- Patient experience of care

Attributes of Quality (IOM)

Health care should be:

- Safe
- Effective
- Patient-centered
- Timely
- Efficient
- Equitable

Desirable Attributes of Quality Measures

- Individual Measures
  - Reliable
  - Valid
  - Well-specified
  - Usable/feasible
  - Useful/actionable
- Portfolio of Measures
  - enhance innovation
  - expose new clinical areas to measurement
  - Improve health and health care

Purposes of Quality Measurement

- Accountability
- Quality Improvement
- Monitoring
- Learning

Simple Model

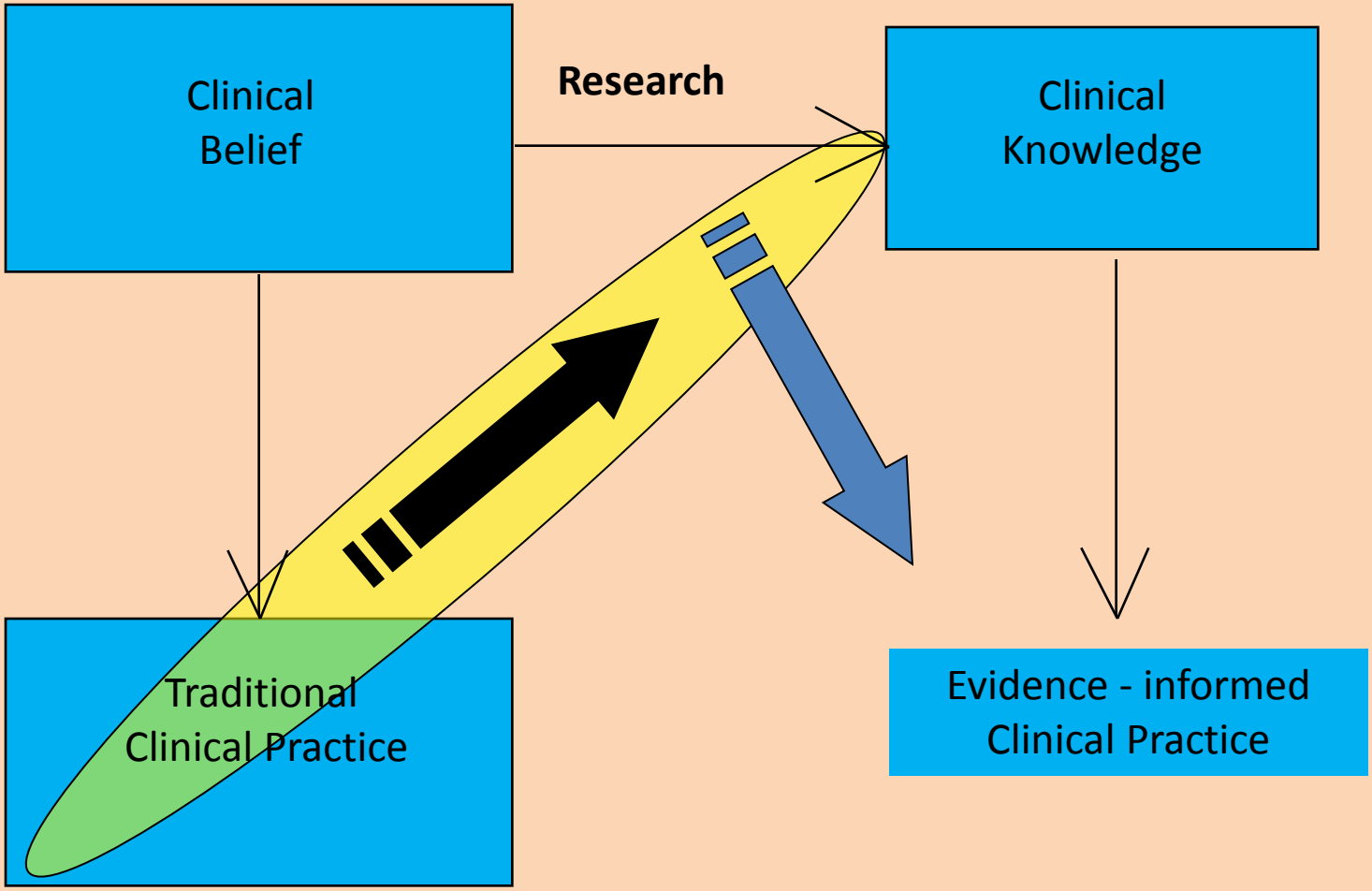
Research Corroborated ?		Believed useful ? Yes	No
	Yes	a	b
	No	c	d

Evidenced based = a + b
Traditional practice = a + c

Popper: Confirming evidence should not count *except when it is the result of a genuine test of the theory*; [by] a serious but unsuccessful attempt to falsify the theory. ("I now speak in such cases of 'corroborating evidence.'")

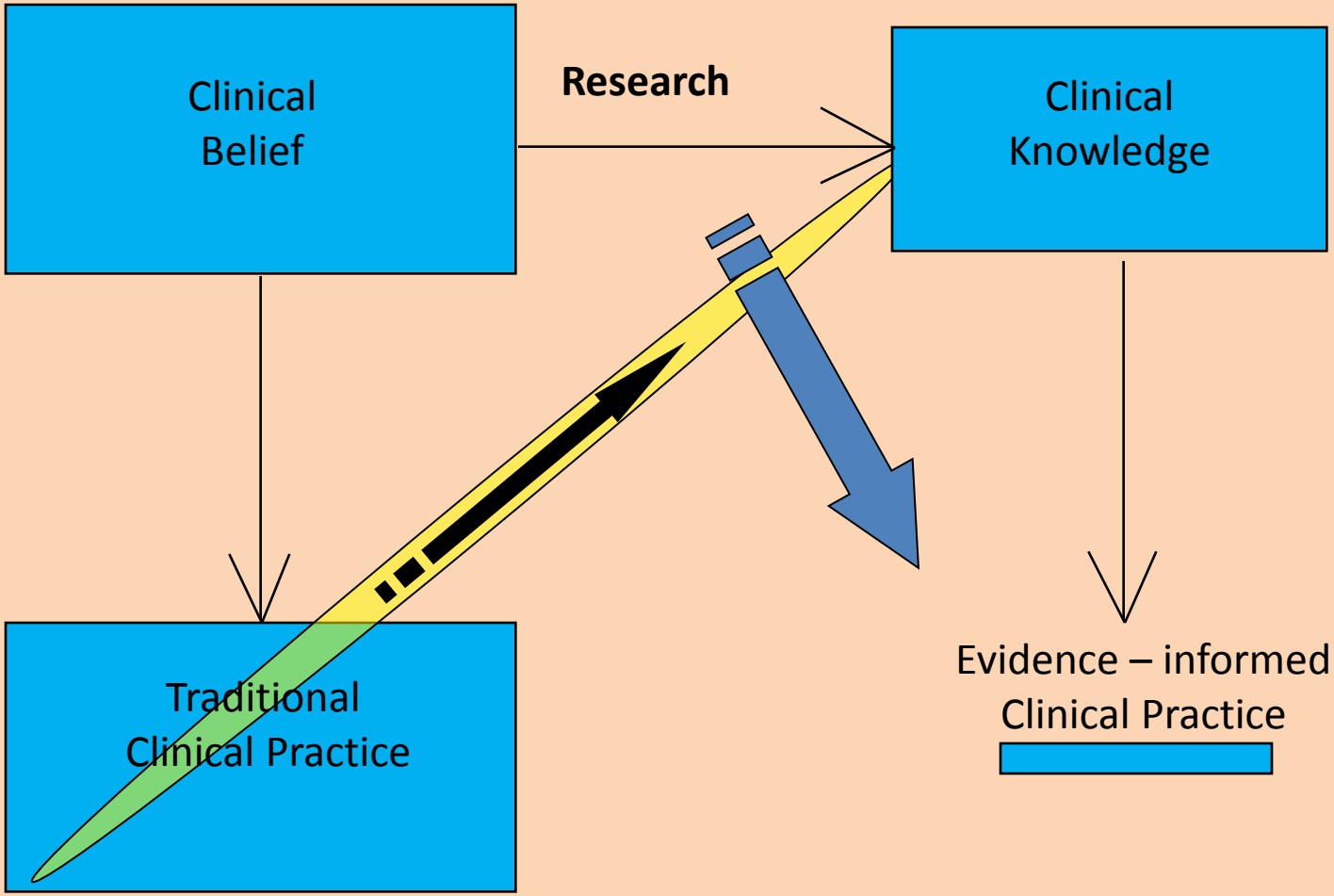
Kleinman, AJPM 1998

Adult Medicine



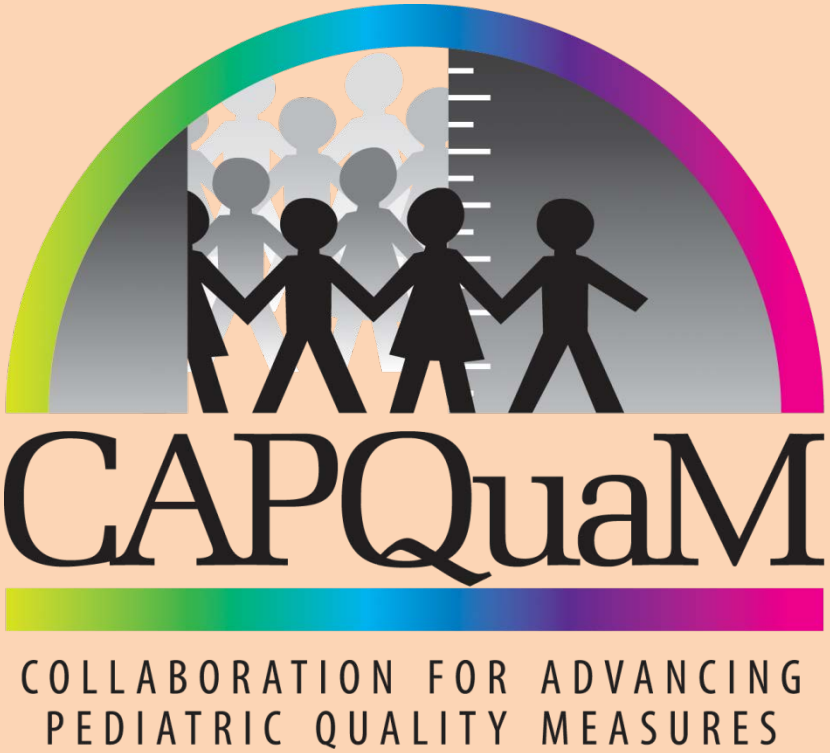
Kleinman LC, Am J Prev Med, 1998

Evidence is particularly limited when it comes to pediatric care



CAPQuaM
COLLABORATION FOR ADVANCING PEDIATRIC QUALITY MEASURES

The Mount Sinai Collaboration for Advancing Pediatric Quality Measures (CAPQuaM)



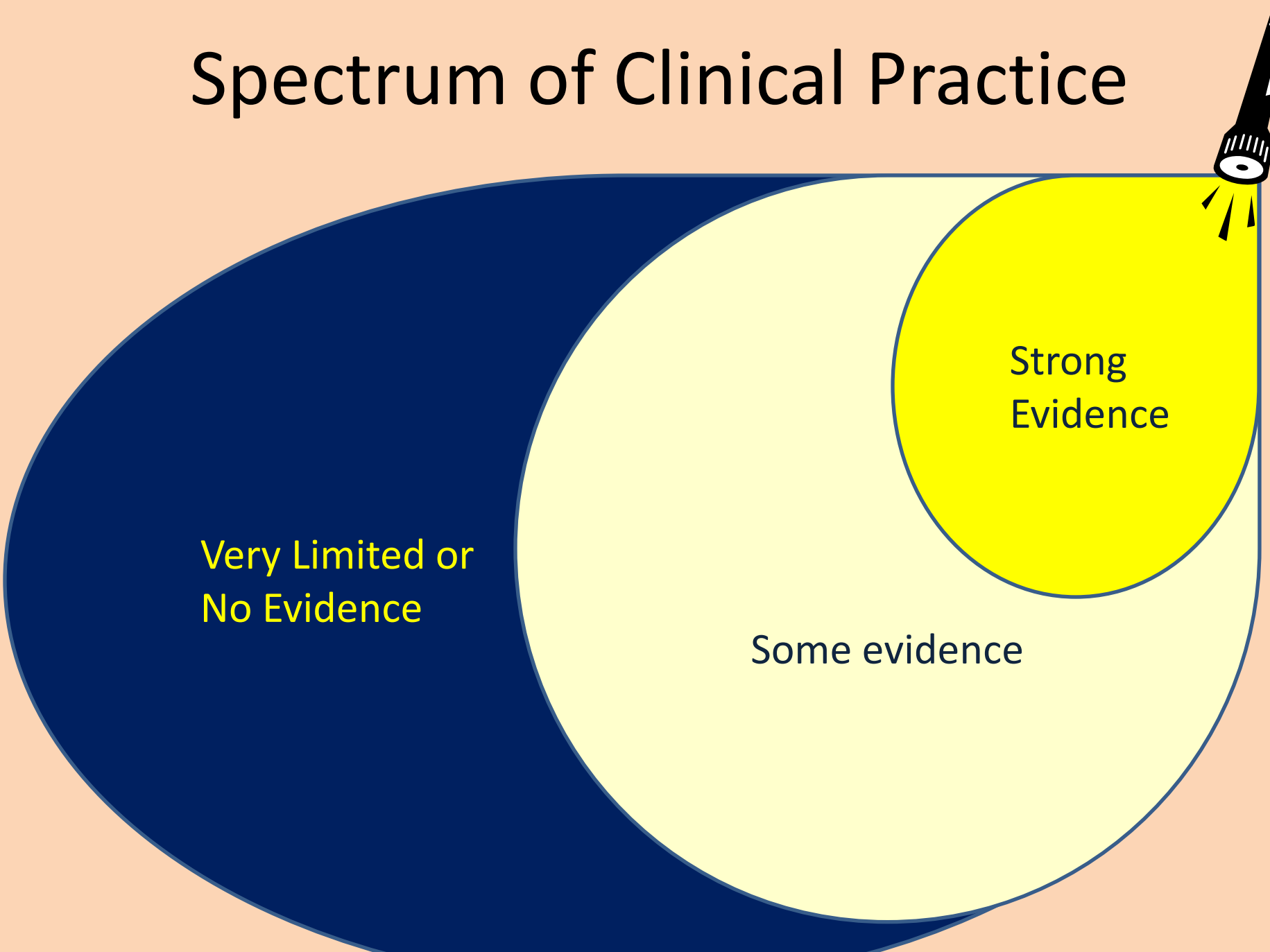
CAPQuaM Principles

- It is possible to develop excellent quality measures even when there is meaningful uncertainty about clinical practice
- Medicine is a clinical practice for which the evidence is rarely dispositive for a specific patient
- There exist overuse, underuse, and misuse and all should be open to measurement

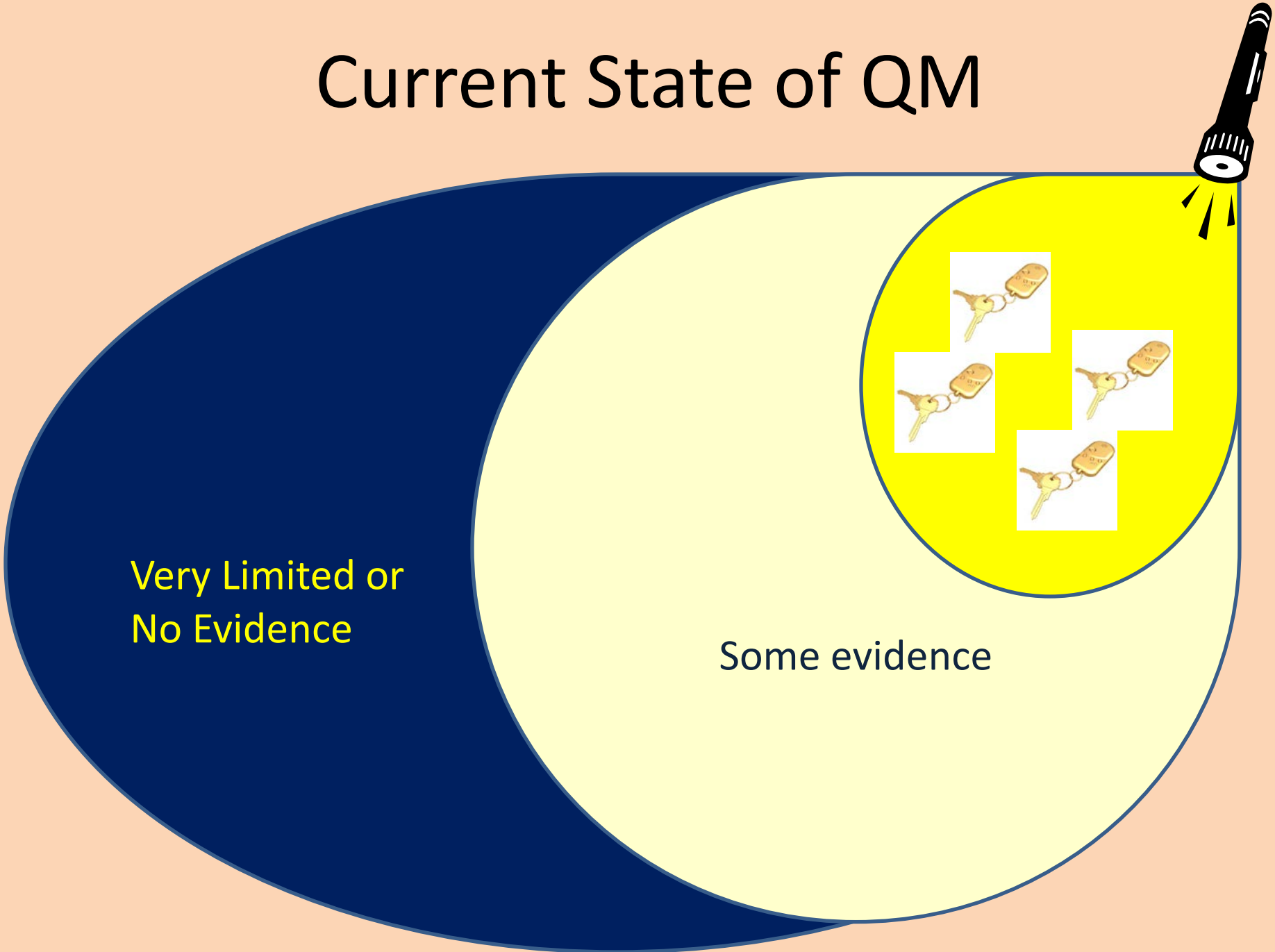
Better Quality Measures are one of the keys to better health and health care

CAPQuaM
COLLABORATION FOR ADVANCING PEDIATRIC QUALITY MEASURES

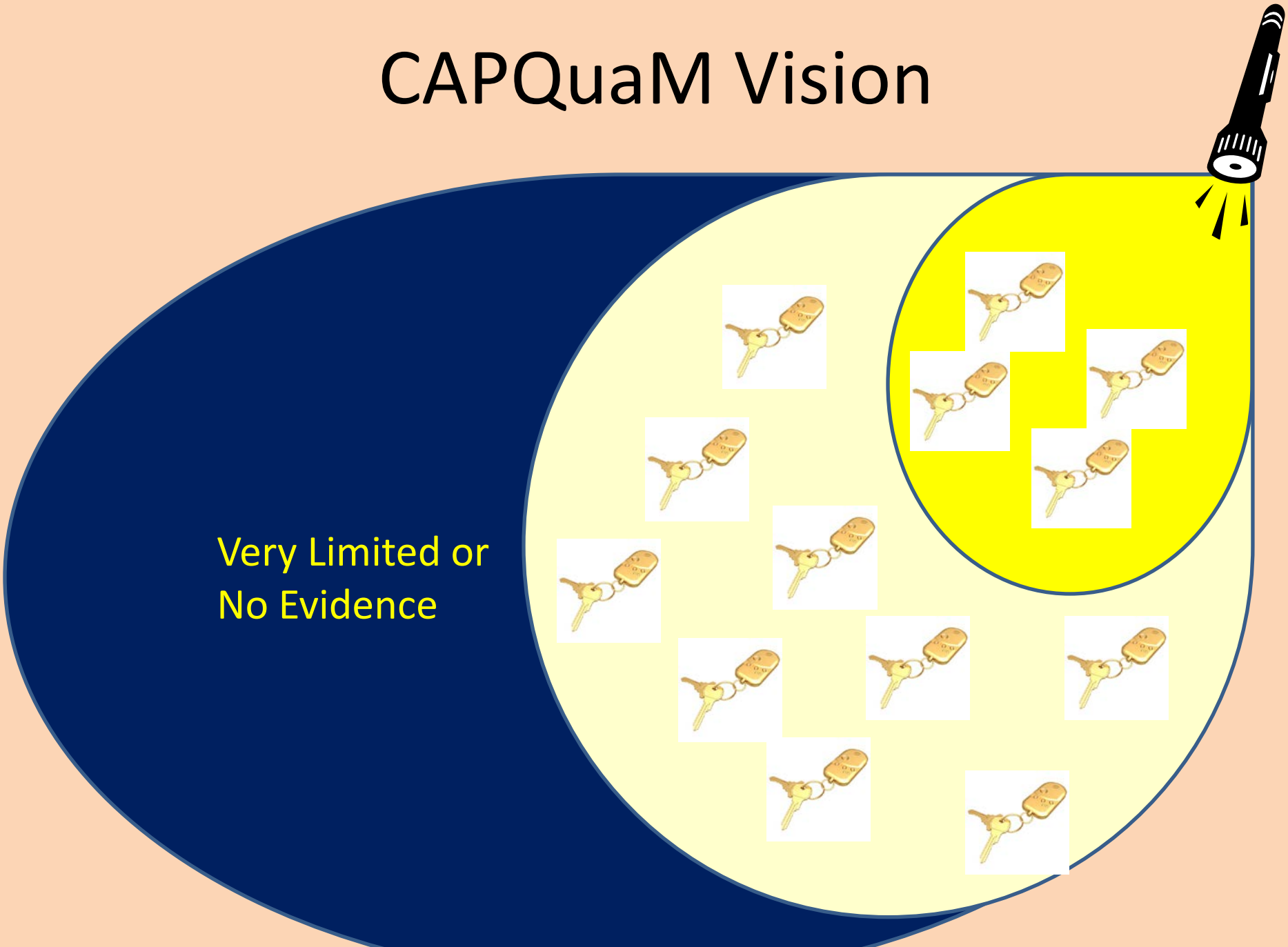
Spectrum of Clinical Practice



Current State of QM



CAPQuaM Vision



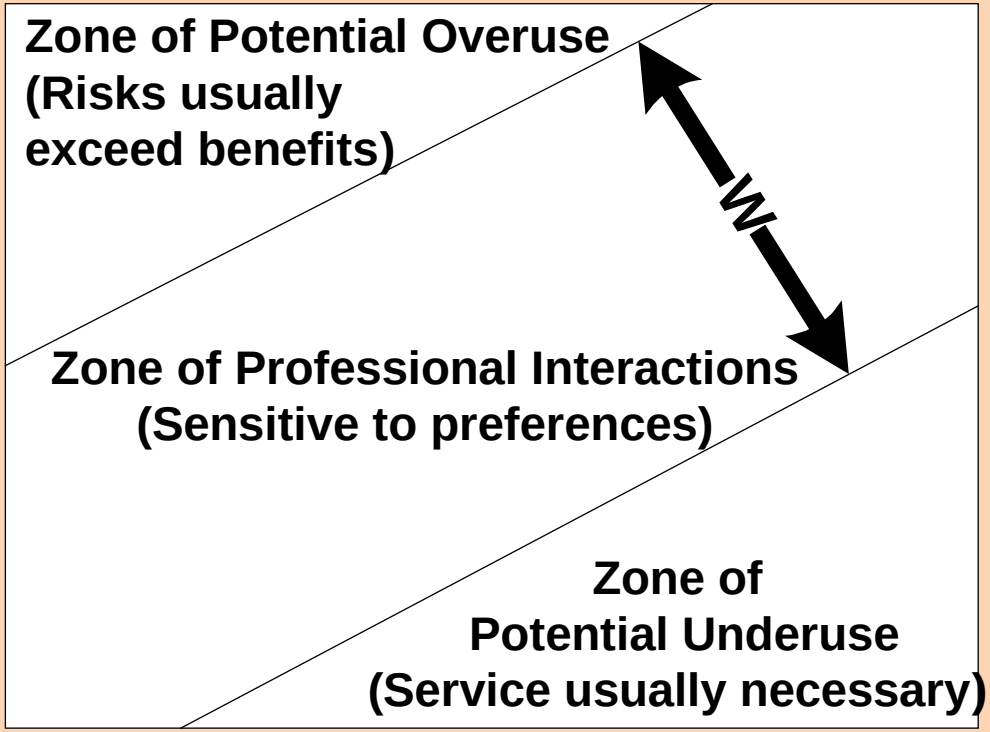
Our Approach

- Build Coalition of Strong Institutional Partners
  - Accreditors (TJC, NCQA)
  - Clinicians (AAP, AAFP, ACOG)
  - Consumers (Consumer Reports, IPFCC, NAMI)
  - Insurers
- Offered things of opposing value(s)
  - Overuse on the one hand
  - Validation of clinical process on the other

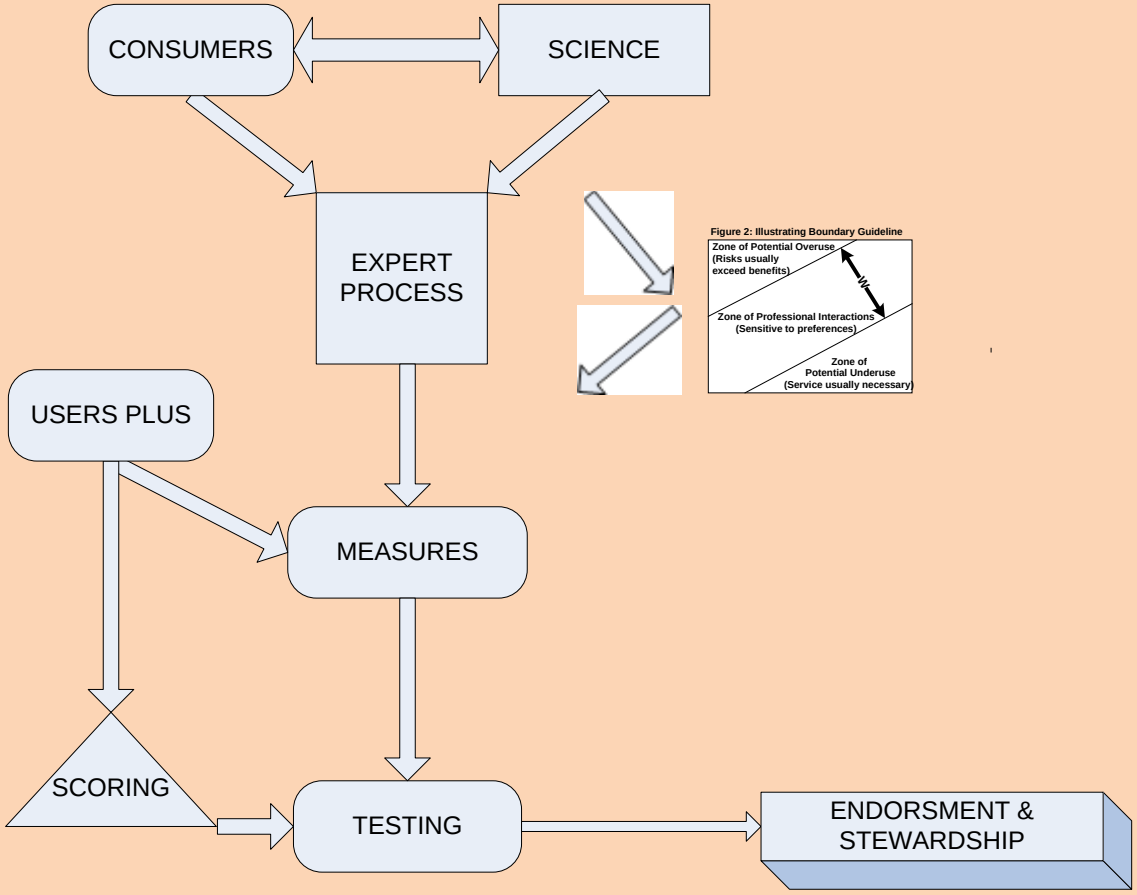
Explicitly incorporate uncertainty

- Boundary Guideline
  - Incorporates evidence and uncertainty

Figure 2: Illustrating Boundary Guideline



Develop Consensus around the Process, not the Measure



Mount Sinai Collaboration for Advancing Pediatric Quality Measures (CAPQuaM)

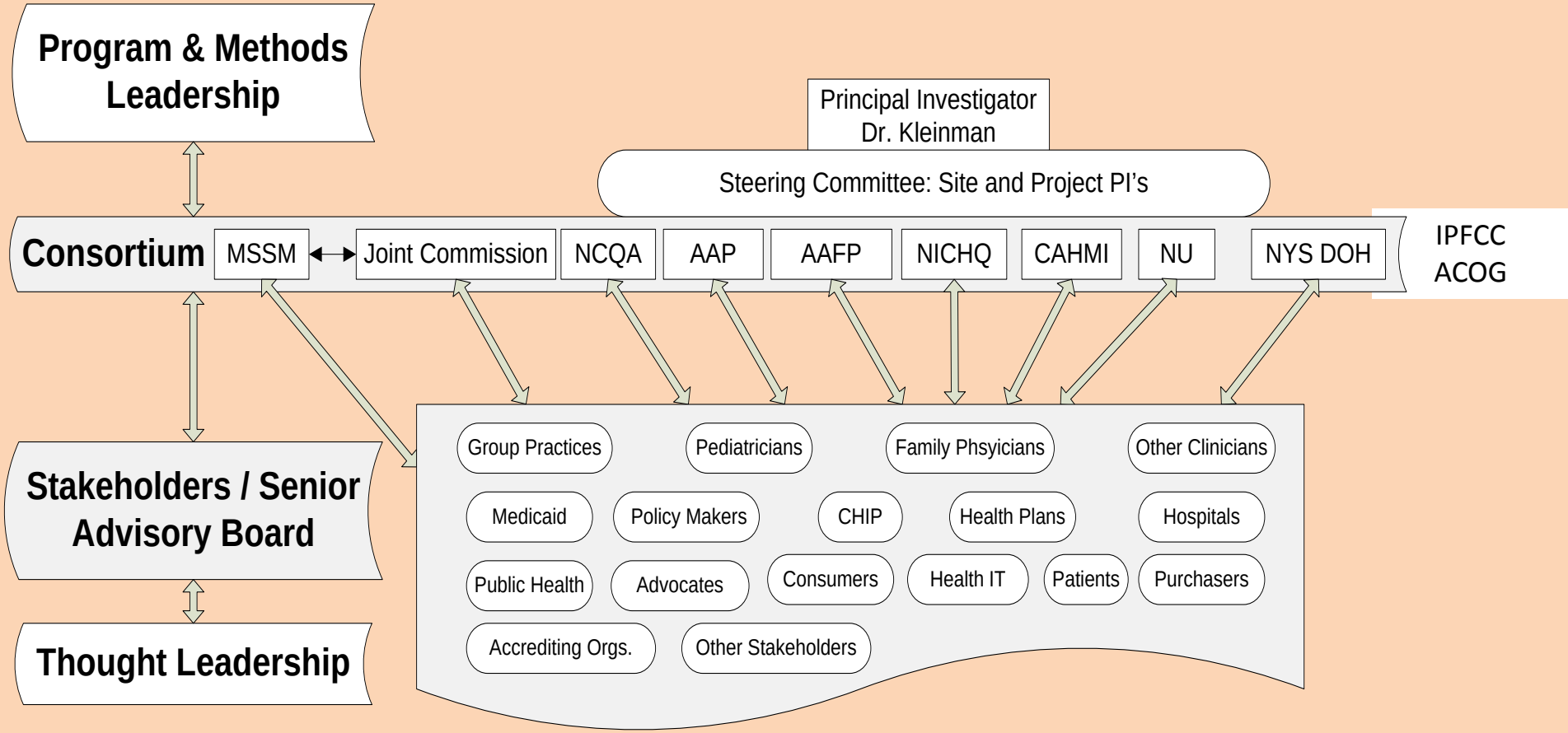


Table 2. MSSM CAPQuaM Steering Committee and Senior Advisors			
Steering Committee	**Organization**	**Senior Advisors**	**Organization**
Christina Bethell, PhD, MBA, MPH	CAHMI, OHSU	Mark Chassin, MD, MPH, MPP	TJC
Marla Clayman, PhD	Northwestern	John Clarke, MD	ECRI, PA Patient Safety Authority
Foster C. Gesten, MD	OHIP, NYS DOH	Martin Hatlie, JD	Partnership 4 Pt. Safety, Consumers Advancing Pt Safety
Charles J. Homer, MD, MPH	NICHQ	Tony Hope, BM BCh, PhD	Oxford U.
Jerod M. Loeb, PhD	TJC	Beverly K. Johnson	Institute for Family Centered Care
Lynn Olson, PhD	AAP	Marilyn Kacica, MD	NYS DOH DFH
Wilson Pace, MD	AAFP	Steve Kairys, MD	AAP/QuIIN
Mary Barton, MD	NCQA	Barbara Kupferman	UHC/Americhoice
Elizabeth Howell, MD	MSSM	Marc Lashley, MD,	Allied Pediatrics
Harold Kaplan, MD	MSSM	Gregory Pawlson, MD	BC/BS Association
Lawrence Kleinman, MD, MPH	MSSM	Laurel Pickering	Northeast BGH
Ira Nash, MD	MSSM	Harold Pincus, MD	Columbia U, NYPI
Eyal Shemesh, MD	MSSM	Eric A. Rose, MD	MSSM
Senior Advisors	**Organization**	Robert St. Peter, MD, MPH	Kansas Health Institute
Arthur Aufses, MD	MSSM	John Santa, MD	Consumers Union
Anne C. Beal, MD, MPH	Aetna Foundation	Shoshanna Sofaer, Dr PH	CUNY Baruch
David Baker, MD, MPH	Northwestern	Ruth Stein, MD	CH @ Montefiore
Scott Breidbart, MD	Empire BCBS	Jeff Terry	GE Healthcare
Wendy Brennan, MS	NAMI- NYC Metro	Paul Wise, MD	Stanford University

Assigned Measures, Phase 1

- Availability of High Risk Ob Care
- Inpatient Perinatal
  - Temperature on admission to NICU
- ER Visits for Asthma
  - As an indicator of chronic asthma care
  - As an indicator of adequacy of primary care

Stakeholder Engagement

- Consumer Stakeholders
  - Share their beliefs, priorities, values based upon relevant experiences (CFLR is novel)
- Clinician Stakeholders
  - Share their beliefs priorities, values and relevant experiences
  - Staff expert panels to develop criteria to support boundary guideline
- Organizational Stakeholders
  - Assist with specification of measures
  - Plan for interpretation of measures

Institutional Stakeholder Contributions

- Advise & engage
- Assist with translating boundary guideline to measure specifications
- Inform the scoring process
- Prioritize data elements for collection and feasibility

Expert Panel (EP) Contribution

- Integrates the input from the literature and stakeholders with their own expertise to
  - Define clinical standards / criteria
  - Assess the validity / importance of specific constructs within the clinical framework
  - Assess the value of specific items, measures. specifications, etc as appropriate
- The final arbiter on clinical decisions

EP Composition

- Multidisciplinary
- Academic and Community Settings
- Geographically Diverse

EP Method

- Adopted from the RAND UCLA Appropriateness Method (RUAM)
- RAND 2-round Modified Delphi Process
  - Round 1 Telephone
  - Round 2 Face-to-face
- CAPQuaM adds:
  - Input from clinician and consumer stakeholders
  - Post processing and potential third round (only if needed)

EP Process

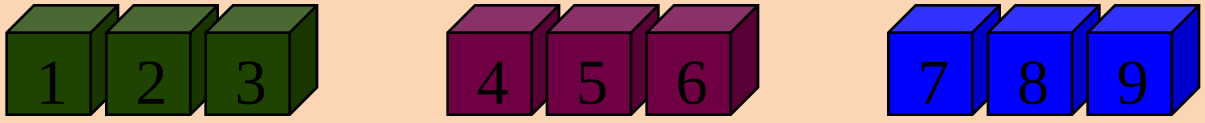
- Scientific Team organizes questions for discussion in the form of “scenarios”
- Scenarios may be true clinical circumstances, constructs or survey questions for rating importance, or other formulations that allow panel to assess validity, importance, or clinical judgment
- Scenarios may be organized into “chapters” and “verse” to help to promote efficient rating process

EP Role in 360° Method

- EP owns the clinical importance of specific constructs
  - Provides expert judgment as a path to validity
  - Advise regarding editing/revising scenarios
  - May advise regarding specifications
- Stakeholders (Senior Advisors) own the final specifications and scoring strategies
- Scientific Team frames, interprets, organizes, provides feedback and organizes testing

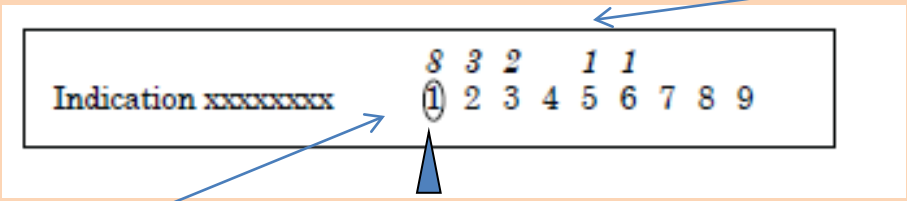
EP Member Role in the Process

- Examine Literature Review
- Review Summary of Stakeholder Input
- Work with team to revise scenarios
- Incorporate your judgment
  - 2 stage rating: Telephone & In-Person
- Scenarios rated on 9 point scale



EP Voting Method

	C	D	E	J	K	L	M	N	O
1	CHAPTER TITLE	Heading 1	Heading 2						
2									0
3	First example indicator.	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	(	1	-	2	)	2
4									2
5	Second example indicator.	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	(	3	-	4	)	4
6									4
7	Third example indicator.	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	(	5	-	6	)	6
8									6
	Fourth example indicator. This one will be longer so we can see an example of								8



Ratings 1-9

Panelist vote is circled

Summary of votes:

- Eight votes for 1
- Three votes for 2
- Two votes for 3
- One vote for 5
- One vote for 6

CAPQuaM

COLLABORATION FOR ADVANCING PEDIATRIC QUALITY MEASURES

Thank you for participating with the CAPQuaM on this important project

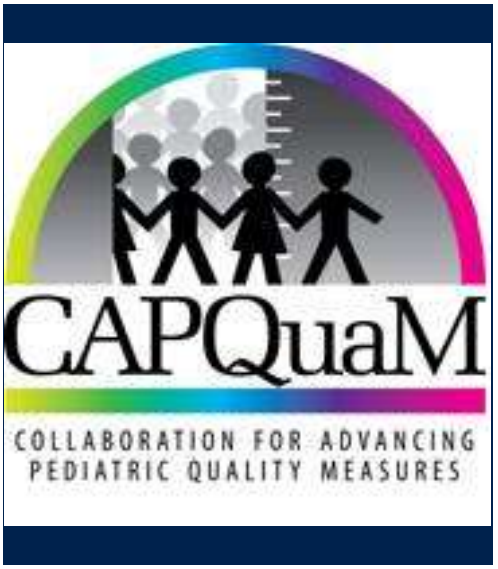
We will be in touch soon about the next call and in-person meeting details.

Any questions?

Please contact: capquam@mountsinai.org
Barbara Rabin 212-659-8396
Larry Kleinman Lawrence.Kleinman@mssm.edu

Appendix D

2nd Round EP Ratings Summary



Perinatal Panel

Dr. Thomas Bartman
Dr. George Hoehn
Dr. Jodi Jackson
Dr. Jennifer L. Kloesz
Dr. Robin B. Knobel
Dr. Chris Lupold
Dr. Girija Natarajan
Dr. Jeanmarie Schied
Dr. Jennifer Ustianov

Chapter 1

#	Scenario	Weight	Frequency									Median	Variation
			1	2	3	4	5	6	7	8	9		
1.01	All admission temperatures should be measured as rectal temperatures.	Any Weight	2	0	2	0	1	1	2	1	0	5	2.2
			1	2	3	4	5	6	7	8	9		
1.02	All admission temperatures should be measured as axillary temperatures	Any Weight	3	1	3	0	1	0	0	1	0	3	1.6
			1	2	3	4	5	6	7	8	9		
1.03	Infants should be delivered to NICU with admission temp of >= 35.5	Lower Weight	0	0	0	0	0	0	0	0	9	9	0.0
			1	2	3	4	5	6	7	8	9		
1.03	Infants should be delivered to NICU with admission temp of >= 35.5	Higher Weight	0	0	0	0	0	0	0	0	9	9	0.0
			1	2	3	4	5	6	7	8	9		
1.04	Infants should be delivered to NICU with admission temp of >= 36.0	Lower Weight	0	0	0	0	0	0	0	0	9	9	0.0
			1	2	3	4	5	6	7	8	9		
1.04	Infants should be delivered to NICU with admission temp of >= 36.0	Higher Weight	0	0	0	0	1	0	0	0	8	9	0.4
			1	2	3	4	5	6	7	8	9		
1.05	Infants should be delivered to NICU with admission temp of >= 36.5	Lower Weight	0	0	0	0	1	0	0	0	8	9	0.4
			1	2	3	4	5	6	7	8	9		
1.05	Infants should be delivered to NICU with admission temp of >= 36.5	Higher Weight	0	0	0	0	0	1	0	0	8	9	0.3
			1	2	3	4	5	6	7	8	9		
1.06	Infants should be delivered to NICU with admission temp of >= 36.6	Lower Weight	0	0	0	0	0	2	0	3	4	8	0.9
			1	2	3	4	5	6	7	8	9		
1.06	Infants should be delivered to NICU with admission temp of >= 36.6	Higher Weight	0	0	0	0	0	2	0	3	4	8	0.9
			1	2	3	4	5	6	7	8	9		
1.07	Infants should be delivered to NICU with admission temp of >= 36.7	Lower Weight	0	0	0	1	0	1	1	3	3	8	1.1
			1	2	3	4	5	6	7	8	9		
1.07	Infants should be delivered to NICU with admission temp of >= 36.7	Higher Weight	0	0	0	1	0	1	2	3	2	8	1.1

			1	2	3	4	5	6	7	8	9		
1.08	Infants should be delivered to NICU with admission temp of >= 36.75	Lower Weight	0	1	0	0	1	1	1	3	2	8	1.6
			1	2	3	4	5	6	7	8	9		
1.08	Infants should be delivered to NICU with admission temp of >= 36.75	Higher Weight	0	1	0	0	1	1	2	2	2	7	1.6
			1	2	3	4	5	6	7	8	9		
1.09	Infants should be delivered to NICU with admission temp of >= 36.8	Lower Weight	1	0	0	1	0	0	1	4	2	8	1.6
			1	2	3	4	5	6	7	8	9		
1.09	Infants should be delivered to NICU with admission temp of >= 36.8	Higher Weight	1	0	0	1	0	0	2	2	3	8	1.8
			1	2	3	4	5	6	7	8	9		
1.10	Infants should be delivered to NICU with admission temp of >= 36.9	Lower Weight	1	0	0	1	0	1	1	2	3	8	1.9
			1	2	3	4	5	6	7	8	9		
1.10	Infants should be delivered to NICU with admission temp of >= 36.9	Higher Weight	1	0	0	1	0	1	2	1	3	7	1.9
			1	2	3	4	5	6	7	8	9		
1.11	Infants should be delivered to NICU with admission temp of >= 37.0	Lower Weight	1	0	0	1	0	2	0	3	2	8	1.9
			1	2	3	4	5	6	7	8	9		
1.11	Infants should be delivered to NICU with admission temp of >= 37.0	Higher Weight	1	0	0	1	0	3	0	1	3	6	2.0
			1	2	3	4	5	6	7	8	9		
1.12	Infants should be delivered to NICU with admission temp of >= 37.5	Lower Weight	6	2	0	0	1	0	0	0	0	1	0.7
			1	2	3	4	5	6	7	8	9		
1.12	Infants should be delivered to NICU with admission temp of >= 37.5	Higher Weight	6	2	0	0	1	0	0	0	0	1	0.7
			1	2	3	4	5	6	7	8	9		
1.13	NICUs should measure the proportion of infants admitted with	Lower Weight	0	0	0	0	0	1	1	0	7	9	0.6
			1	2	3	4	5	6	7	8	9		
1.13	NICUs should measure the proportion of infants admitted with	Higher Weight	0	0	0	0	0	1	1	0	7	9	0.6
			1	2	3	4	5	6	7	8	9		
1.14	NICUs should measure the proportion of infants admitted with	Higher Weight	0	1	0	0	0	0	0	1	7	9	0.9

			1	2	3	4	5	6	7	8	9		
1.14	NICUs should measure the proportion of infants admitted with	Lower Weight	0	1	0	0	0	0	0	1	7	9	0.9
			1	2	3	4	5	6	7	8	9		
1.15	NICUs should measure the proportion of infants admitted with	Lower Weight	0	0	0	0	0	1	1	1	6	9	0.7
			1	2	3	4	5	6	7	8	9		
1.15	NICUs should measure the proportion of infants admitted with	Higher Weight	0	0	0	0	0	0	1	1	7	9	0.3
			1	2	3	4	5	6	7	8	9		
1.16	NICUs should measure the proportion of infants admitted with	Lower Weight	0	1	0	1	1	0	0	2	4	8	1.9
			1	2	3	4	5	6	7	8	9		
1.16	NICUs should measure the proportion of infants admitted with	Higher Weight	0	1	0	1	1	1	0	2	3	8	2.0
			1	2	3	4	5	6	7	8	9		
1.17	NICUs should measure the proportion of infants admitted with	Lower Weight	3	2	0	0	3	0	0	1	0	2	2.0
			1	2	3	4	5	6	7	8	9		
1.17	NICUs should measure the proportion of infants admitted with	Higher Weight	4	2	0	0	2	0	0	1	0	2	1.8
			1	2	3	4	5	6	7	8	9		
1.18	NICUs should assess the 5th percentile of the admission	Lower Weight	0	0	0	0	2	0	0	0	7	9	0.9
			1	2	3	4	5	6	7	8	9		
1.18	NICUs should assess the 5th percentile of the admission	Higher Weight	0	0	0	0	2	0	0	0	7	9	0.9
			1	2	3	4	5	6	7	8	9		
1.19	NICUs should assess the 10th percentile of the admission	Lower Weight	0	0	0	0	0	0	0	0	9	9	0.0
			1	2	3	4	5	6	7	8	9		
1.19	NICUs should assess the 10th percentile of the admission	Higher Weight	0	0	0	0	0	0	0	0	9	9	0.0
			1	2	3	4	5	6	7	8	9		
1.20	NICUs should assess the 15th percentile of the admission	Lower Weight	1	1	1	0	1	0	1	1	3	7	2.7
			1	2	3	4	5	6	7	8	9		
1.20	NICUs should assess the 15th percentile of the admission	Higher Weight	1	1	1	0	1	0	1	1	3	7	2.7

			1	2	3	4	5	6	7	8	9		
1.21	NICUs should assess the 20th percentile of the admission	Lower Weight	1	1	2	0	1	0	1	1	2	5	2.7
			1	2	3	4	5	6	7	8	9		
1.21	NICUs should assess the 20th percentile of the admission	Higher Weight	1	1	2	0	1	0	1	1	2	5	2.7
			1	2	3	4	5	6	7	8	9		
1.22	NICUs should assess the 25th percentile of the admission	Lower Weight	0	0	0	0	0	0	0	1	8	9	0.1
			1	2	3	4	5	6	7	8	9		
1.22	NICUs should assess the 25th percentile of the admission	Higher Weight	0	0	0	0	0	0	0	1	8	9	0.1
			1	2	3	4	5	6	7	8	9		
1.23	NICUs should assess the 30th percentile of the admission	Lower Weight	1	1	1	0	1	0	1	1	3	7	2.7
			1	2	3	4	5	6	7	8	9		
1.23	NICUs should assess the 30th percentile of the admission	Higher Weight	1	1	1	0	1	0	1	1	3	7	2.7
			1	2	3	4	5	6	7	8	9		
1.24	NICUs should assess the 35th percentile of the admission	Higher Weight	1	3	2	0	1	0	2	0	0	3	1.7
			1	2	3	4	5	6	7	8	9		
1.24	NICUs should assess the 35th percentile of the admission	Lower Weight	1	3	2	0	1	0	2	0	0	3	1.7
			1	2	3	4	5	6	7	8	9		
1.25	NICUs should assess the 40th percentile of the admission	Higher Weight	1	2	2	0	1	1	1	0	1	3	2.1
			1	2	3	4	5	6	7	8	9		
1.25	NICUs should assess the 40th percentile of the admission	Lower Weight	1	2	2	0	1	1	1	0	1	3	2.1
			1	2	3	4	5	6	7	8	9		
1.26	NICUs should assess the 45th percentile of the admission	Lower Weight	1	3	2	0	1	1	1	0	0	3	1.6
			1	2	3	4	5	6	7	8	9		
1.26	NICUs should assess the 45th percentile of the admission	Higher Weight	1	3	2	0	1	1	1	0	0	3	1.6
			1	2	3	4	5	6	7	8	9		
1.27	NICUs should assess the 50th percentile (median) of the admission	Lower Weight	0	0	0	0	0	0	1	0	8	9	0.2

			1	2	3	4	5	6	7	8	9		
1.27	NICUs should assess the 50th percentile (median) of the admission	Higher Weight	0	0	0	0	0	0	1	0	8	9	0.2
1.28	NICUs should assess the 75th percentile of the admission	Higher Weight	0	1	0	0	0	0	1	1	6	9	1.1
1.28	NICUs should assess the 75th percentile of the admission	Lower Weight	0	1	0	0	0	0	1	1	6	9	1.1
1.29	NICUs should assess the 90th percentile of the admission	Lower Weight	0	1	0	0	0	0	1	0	7	9	1.0
1.29	NICUs should assess the 90th percentile of the admission	Higher Weight	0	1	0	0	0	0	1	0	7	9	1.0
1.30	NICUs should report the admission temperatures of all infants	Lower Weight	0	0	0	0	0	1	0	0	8	9	0.3
1.30	NICUs should report the admission temperatures of all infants	Higher Weight	0	0	0	0	0	1	0	0	8	9	0.3
1.31	NICUs should report the average (mean) temperature of infants	Lower Weight	0	0	1	0	0	0	3	0	5	9	1.3
1.31	NICUs should report the average (mean) temperature of infants	Higher Weight	0	0	1	0	0	0	3	0	5	9	1.3
1.32	NICUs should report the standard deviation of the temperature of	Higher Weight	0	0	1	0	0	0	1	0	7	9	0.9
1.32	NICUs should report the standard deviation of the temperature of	Lower Weight	0	0	1	0	0	0	1	0	7	9	0.9
1.33	NICUs should measure the proportion of infants admitted with	Lower Weight	0	0	3	0	0	2	0	2	2	6	2.1
1.33	NICUs should measure the proportion of infants admitted with	Higher Weight	0	0	3	0	0	1	0	2	3	8	2.2

			1	2	3	4	5	6	7	8	9		
1.34	NICUs should measure the proportion of infants admitted with	Lower Weight	1	1	3	0	0	2	0	0	2	3	2.3
			1	2	3	4	5	6	7	8	9		
1.34	NICUs should measure the proportion of infants admitted with	Higher Weight	1	1	3	0	0	2	0	0	2	3	2.3
			1	2	3	4	5	6	7	8	9		
1.35	NICUs should measure the proportion of infants admitted with	Lower Weight	1	1	3	1	0	1	0	0	2	3	2.1
			1	2	3	4	5	6	7	8	9		
1.35	NICUs should measure the proportion of infants admitted with	Higher Weight	1	1	3	1	0	1	0	0	2	3	2.1
			1	2	3	4	5	6	7	8	9		
1.36	NICUs should measure the proportion of infants admitted with	Lower Weight	1	1	2	1	1	1	1	0	1	4	2.0
			1	2	3	4	5	6	7	8	9		
1.36	NICUs should measure the proportion of infants admitted with	Higher Weight	1	1	2	1	1	1	1	0	1	4	2.0
			1	2	3	4	5	6	7	8	9		
1.37	NICUs should measure the proportion of infants admitted with	Lower Weight	1	1	2	1	0	1	2	0	1	4	2.2
			1	2	3	4	5	6	7	8	9		
1.37	NICUs should measure the proportion of infants admitted with	Higher Weight	1	1	2	1	0	1	2	0	1	4	2.2
			1	2	3	4	5	6	7	8	9		
1.38	NICUs should measure the proportion of infants admitted with	Lower Weight	0	1	1	0	1	0	1	0	5	9	2.1
			1	2	3	4	5	6	7	8	9		
1.38	NICUs should measure the proportion of infants admitted with	Higher Weight	0	1	1	0	1	0	1	0	5	9	2.1
			1	2	3	4	5	6	7	8	9		
1.39	NICUs should measure the proportion of infants admitted with	Lower Weight	0	1	1	0	1	0	1	0	5	9	2.1
			1	2	3	4	5	6	7	8	9		
1.39	NICUs should measure the proportion of infants admitted with	Higher Weight	0	1	1	0	1	0	1	0	5	9	2.1
			1	2	3	4	5	6	7	8	9		
1.40	NICUs should measure the proportion of infants admitted with	Lower Weight	0	0	1	1	0	1	0	0	6	9	1.6

			1	2	3	4	5	6	7	8	9		
1.40	NICUs should measure the proportion of infants admitted with	Higher Weight	0	0	1	1	0	1	0	0	6	9	1.6
1.41	The interguartile range should be reported	Lower Weight	0	0	1	0	0	0	0	2	6	9	0.9
1.41	The interguartile range should be reported	Higher Weight	0	0	1	0	0	0	0	2	6	9	0.9
1.42	A measure of variation should be reported (potentially the skew).	Lower Weight	0	0	0	0	0	0	1	2	6	9	0.4
1.42	A measure of variation should be reported (potentially the skew).	Higher Weight	0	0	0	0	0	0	1	2	6	9	0.4
1.43	NICUs should assess the 95th percentile of the admission	Lower Weight	0	1	0	0	1	0	1	0	6	9	1.4
1.43	NICUs should assess the 95th percentile of the admission	Higher Weight	0	1	0	0	1	0	1	0	6	9	1.4
1.44	The lowest 5 temperatures should be reported.	Lower Weight	0	2	1	0	0	0	0	0	6	9	2.2
1.44	The lowest 5 temperatures should be reported.	Higher Weight	0	2	1	0	0	0	0	0	6	9	2.2
1.45	The highest 5 temperatures of non-febirle mothers should be reported	Higher Weight	0	2	1	0	0	0	0	0	6	9	2.2
1.45	The highest 5 temperatures of non-febirle mothers should be reported	Lower Weight	0	2	1	0	0	0	0	0	6	9	2.2
1.46	A temperature must be documented between 15 and 30 minutes of age	Lower Weight	1	0	0	0	0	0	4	1	3	7	1.4
1.46	A temperature must be documented between 15 and 30 minutes of age	Higher Weight	1	0	0	1	0	0	3	1	3	7	1.8

Chapter 2

#	Scenario	Frequency									Median	Variation
		1	2	3	4	5	6	7	8	9		
2.01	LBW infants born with open cavity congenital anomalies (omphalocele,	4	2	1	1	0	0	0	0	1	2	1.6
		1	2	3	4	5	6	7	8	9		
2.02	LBW infants born with open cavity congenital anomalies (omphalocele,	0	1	0	0	1	0	1	1	5	9	1.6
		1	2	3	4	5	6	7	8	9		
2.03	LBW infants with anencephaly should be EXCLUDED from this	1	0	0	0	0	0	0	0	8	9	0.9
		1	2	3	4	5	6	7	8	9		
2.04	LBW infants born outside of the admitting nursery's hospital and not	2	1	1	0	0	0	2	2	1	7	2.8
		1	2	3	4	5	6	7	8	9		
2.05	LBW infants born outside of the admitting nursery's network should	2	2	1	0	0	0	1	1	2	3	3.0
		1	2	3	4	5	6	7	8	9		
2.06	LBW infants admitted to a NICU at a children's hospital inside a hospital	6	2	0	0	0	0	0	0	1	1	1.1
		1	2	3	4	5	6	7	8	9		
2.07	LBW infants admitted to a NICU at a hospital after being born at another	0	0	0	0	0	0	0	1	8	9	0.1
		1	2	3	4	5	6	7	8	9		
2.08	LBW infants born at an outside hospital and transported by a team	0	0	0	0	1	0	0	1	7	9	0.6
		1	2	3	4	5	6	7	8	9		
2.09	LBW infants who are managed for comfort care only should be	0	0	0	0	0	0	0	0	9	9	0.0
		1	2	3	4	5	6	7	8	9		
2.10	A child receiving respiratory support (beyond oxygen) after they are	0	0	0	0	0	0	1	0	8	9	0.2
		1	2	3	4	5	6	7	8	9		
2.11	Children with low Apgars and prolonged resuscitation should be	6	3	0	0	0	0	0	0	0	1	0.3
		1	2	3	4	5	6	7	8	9		
2.12	LBW infants undergoing EXIT or fetal surgeries should be excluded from	4	1	2	0	1	0	0	1	0	2	1.7

		1	2	3	4	5	6	7	8	9		
2.13	Deliveries that occur in the a hospital but prior to admission to the delivery	4	2	1	1	0	0	0	1	0	2	1.4
		1	2	3	4	5	6	7	8	9		
2.14	There should be no lower weight limit for inclusion in this measure.	0	0	0	0	0	0	0	0	9	9	0.0
		1	2	3	4	5	6	7	8	9		
2.15	Deliveries that occur prior to arrival at a hospital should be excluded	0	0	0	0	0	1	1	2	5	9	0.8
		1	2	3	4	5	6	7	8	9		
2.16	Infants who meet the institutions inclusion criteria for therapeutic	0	0	0	0	0	0	0	1	8	9	0.1

Chapter 3

#	Scenario	Frequency									Median	Variation
		1	2	3	4	5	6	7	8	9		
3.01	There should be a functioning, appropriate external radiant heat	0	0	0	0	0	1	0	2	6	9	0.6
		1	2	3	4	5	6	7	8	9		
3.02	All LBW infants should have a temperature taken before 1 minute	7	2	0	0	0	0	0	0	0	1	0.2
		1	2	3	4	5	6	7	8	9		
3.03	All LBW infants should have a temperature taken before 5 minutes	6	2	1	0	0	0	0	0	0	1	0.4
		1	2	3	4	5	6	7	8	9		
3.04	All hospitals should have electronic or paper checklists to document the	0	1	0	0	0	0	0	2	6	9	1.0
		1	2	3	4	5	6	7	8	9		
3.05	When reporting quality of care, temperature of all LBW infants at	0	0	0	0	0	0	1	3	5	9	0.6
		1	2	3	4	5	6	7	8	9		
3.06	When reporting quality of care, temperature of all LBW infants at	0	1	0	2	0	0	1	2	3	8	2.0
		1	2	3	4	5	6	7	8	9		
3.07	When reporting quality of care, temperature of all LBW infants at	0	0	0	0	1	3	1	2	2	7	1.2
		1	2	3	4	5	6	7	8	9		
3.08	When reporting quality of care, temperature of all LBW infants at	0	1	0	0	1	1	2	2	2	7	1.6
		1	2	3	4	5	6	7	8	9		
3.09	When reporting quality of care, temperature of all LBW infants at	0	3	1	2	2	0	0	1	0	4	1.4
		1	2	3	4	5	6	7	8	9		
3.10	When reporting quality of care, temperature of all LBW infants at	0	0	0	0	0	0	0	3	6	9	0.3
		1	2	3	4	5	6	7	8	9		
3.11	When reporting quality of care, temperature of all LBW infants at	0	1	1	0	0	0	0	3	4	8	1.7
		1	2	3	4	5	6	7	8	9		
3.12	When reporting quality of care, temperature of all LBW infants at	2	2	1	0	2	1	0	0	1	3	2.1

		1	2	3	4	5	6	7	8	9		
3.13	Temperature of LBW infants with major congenital anomalies or	0	0	0	0	0	0	1	5	3	8	0.4
3.14	Temperature of LBW infants transferred from the off campus	0	0	0	0	0	0	1	3	5	9	0.6
3.15	The optimal weight categories for reporting temperature are: <1000g,	0	0	0	0	0	0	1	2	6	9	0.4
3.16	Temperature of all LBW infants should be taken and documented	0	1	0	0	0	0	0	0	8	9	0.8
3.17	Temperature of all LBW infants should be taken and documented	0	0	0	0	0	0	1	0	8	9	0.2
3.18	Temperature of all LBW infants should be taken and documented	0	1	0	1	0	1	1	1	4	8	1.9
3.19	Nurseries should have care guidelines in place to support the	0	0	0	0	0	0	0	1	8	9	0.1

Appendix E

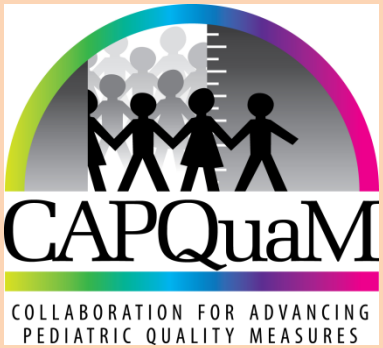
Pediatric Academic Society

State of the Science Presentation

May 2012 (given by Dr. Larry Kleinman)

Applying Evidence Standards in an Uncertain World

Considering uncertainty when developing measures in the PQMP



Lawrence C. Kleinman, MD, MPH, FAAP
PI, Mount Sinai CAPQuaM
PAS State of the Science
May, 2012

AHRQ-CMS CHIPRA C o E, Funded by AHRQ 1 U18 HS020518-01

Rock n Roll

http://www.youtube.com/watch?feature=player_detailpage&v=QXgMhnI3QOI#t=71s

This ain't no Party, this ain't no Disco,
This ain't no fooling around;
No time for Dancing, or Lovey Dovey,
I ain't got time for that now
Transmit the message to the receiver;

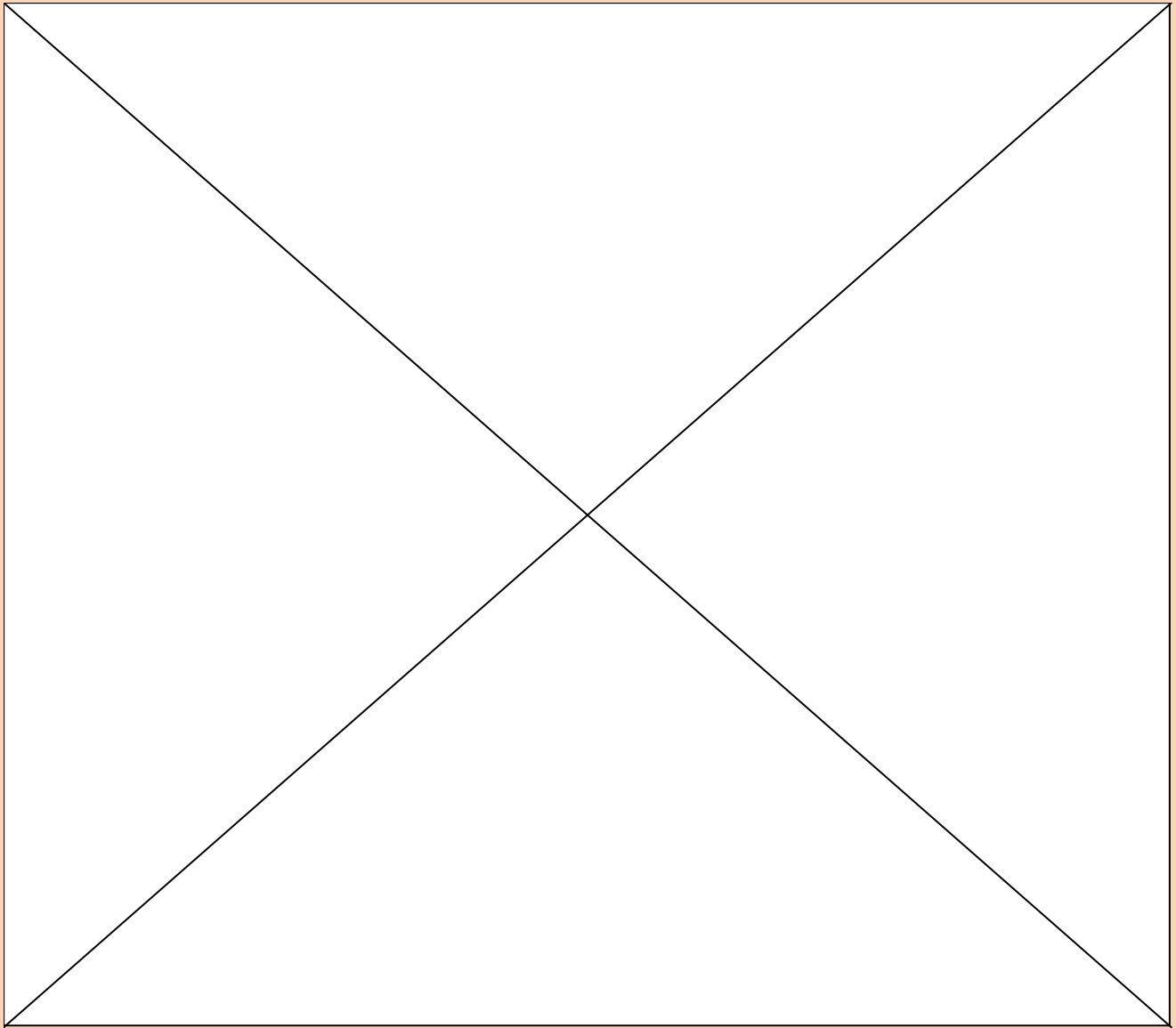
Hope for an answer some day...

Sources of uncertainty abound...

- The science is constantly evolving;
- Evidence in the literature is challenging to apply to a specific patient:
  - e.g., Inclusion and exclusion criteria limit generalizability of trials
- Real world outcomes vary from research trial outcomes.
- Science reduces uncertainty, doesn't eliminate it

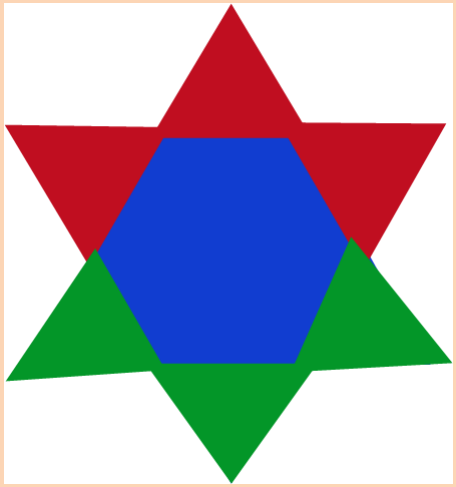
The Challenge of Evidence

http://www.youtube.com/watch?v=Dn1eT55sD6o&feature=player_embedded

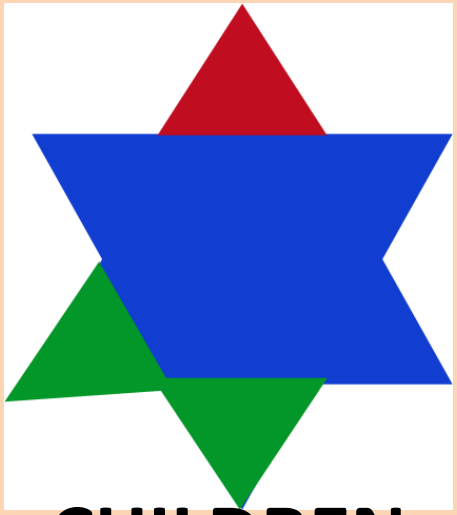


Uncertainty Index (UNI)

- Proportion of **care** that has not been shown to be **ineffective** and that we aren't sure is **effective**
- Children's health care is under researched compared to adults and thus ↑ UNI
  - In general ↓Research→ ↑ UNI



ADULTS

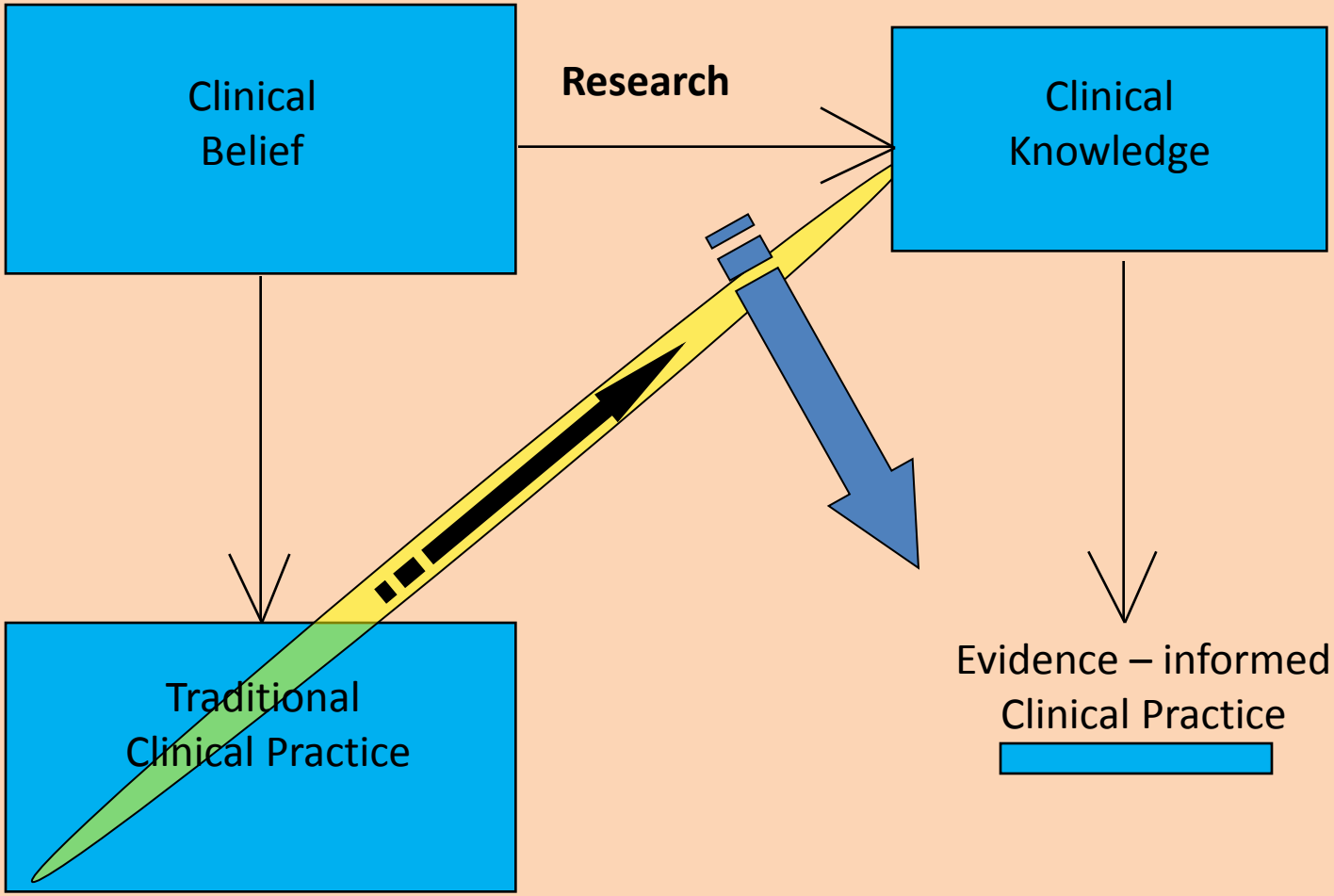


CHILDREN

$$UNI = \frac{Blue}{Blue + Green}$$

Kleinman LC, Am J Prev Med, 1998

Evidence is particularly limited when it comes to pediatric care



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We are looking for measures that represent the keys to high quality care

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One need for PQMP Innovation

- Develop and enhance methods that can produce meaningful measures even when the science does not reduce uncertainty enough to eliminate all important disagreements

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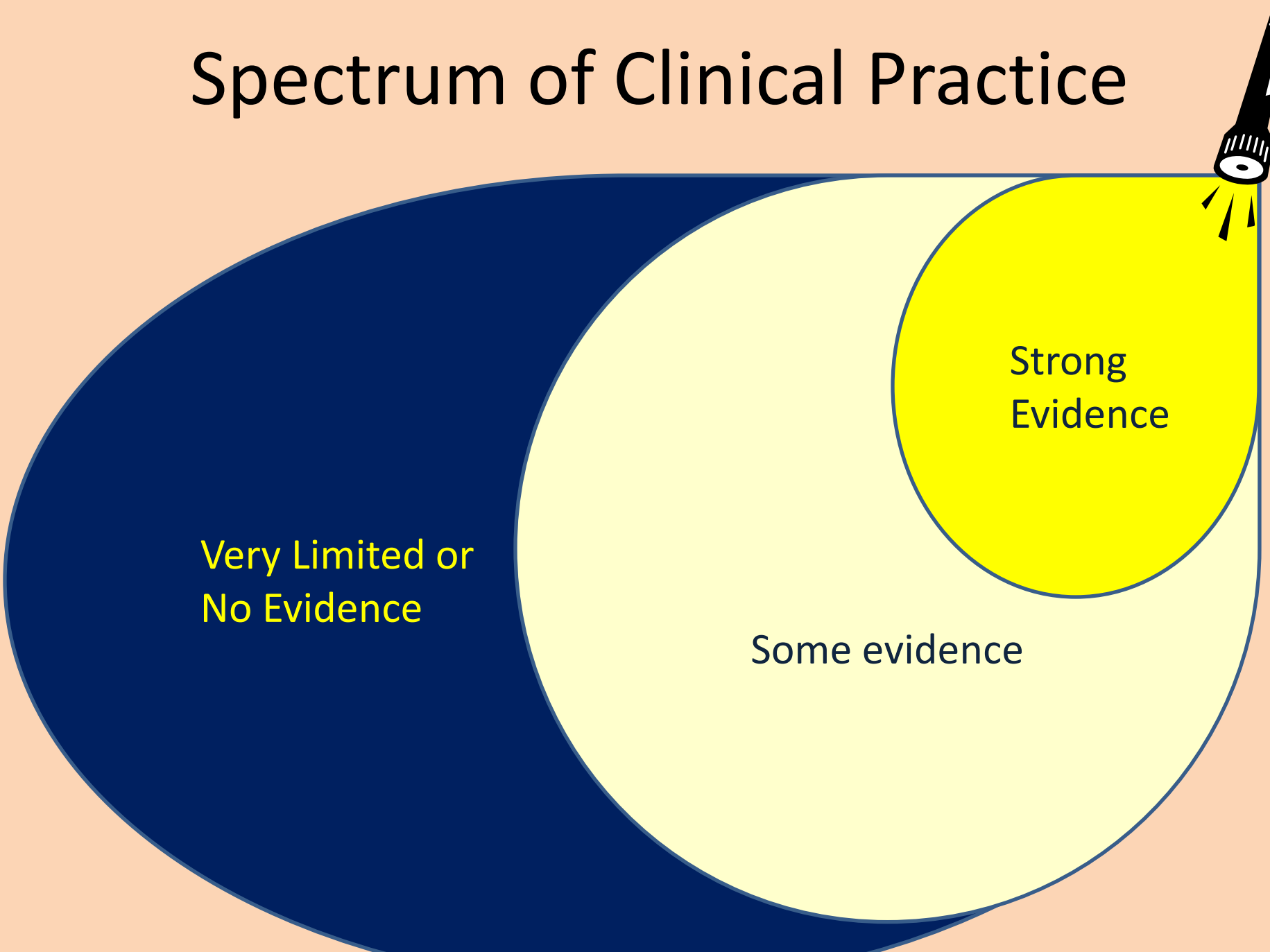
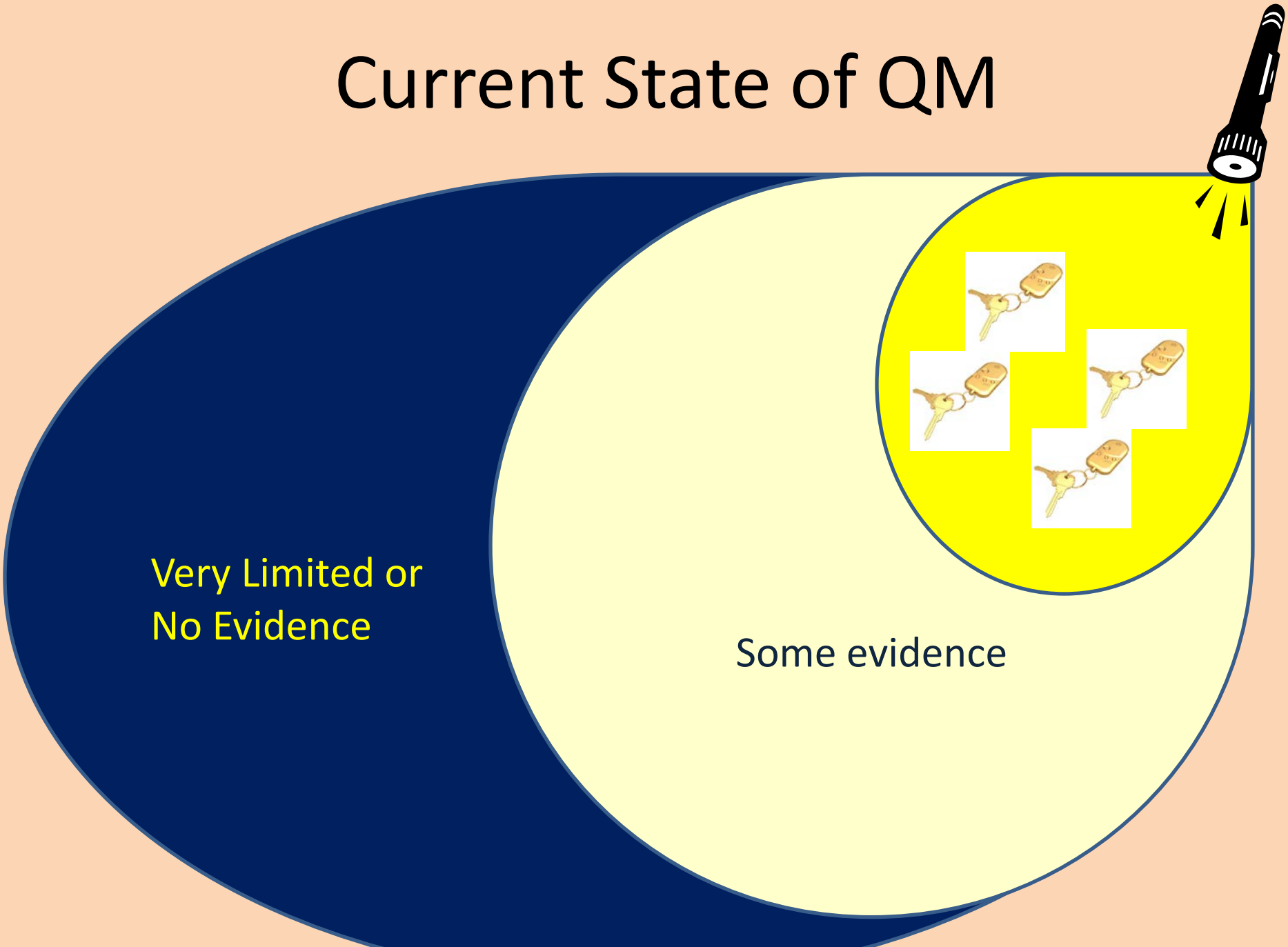
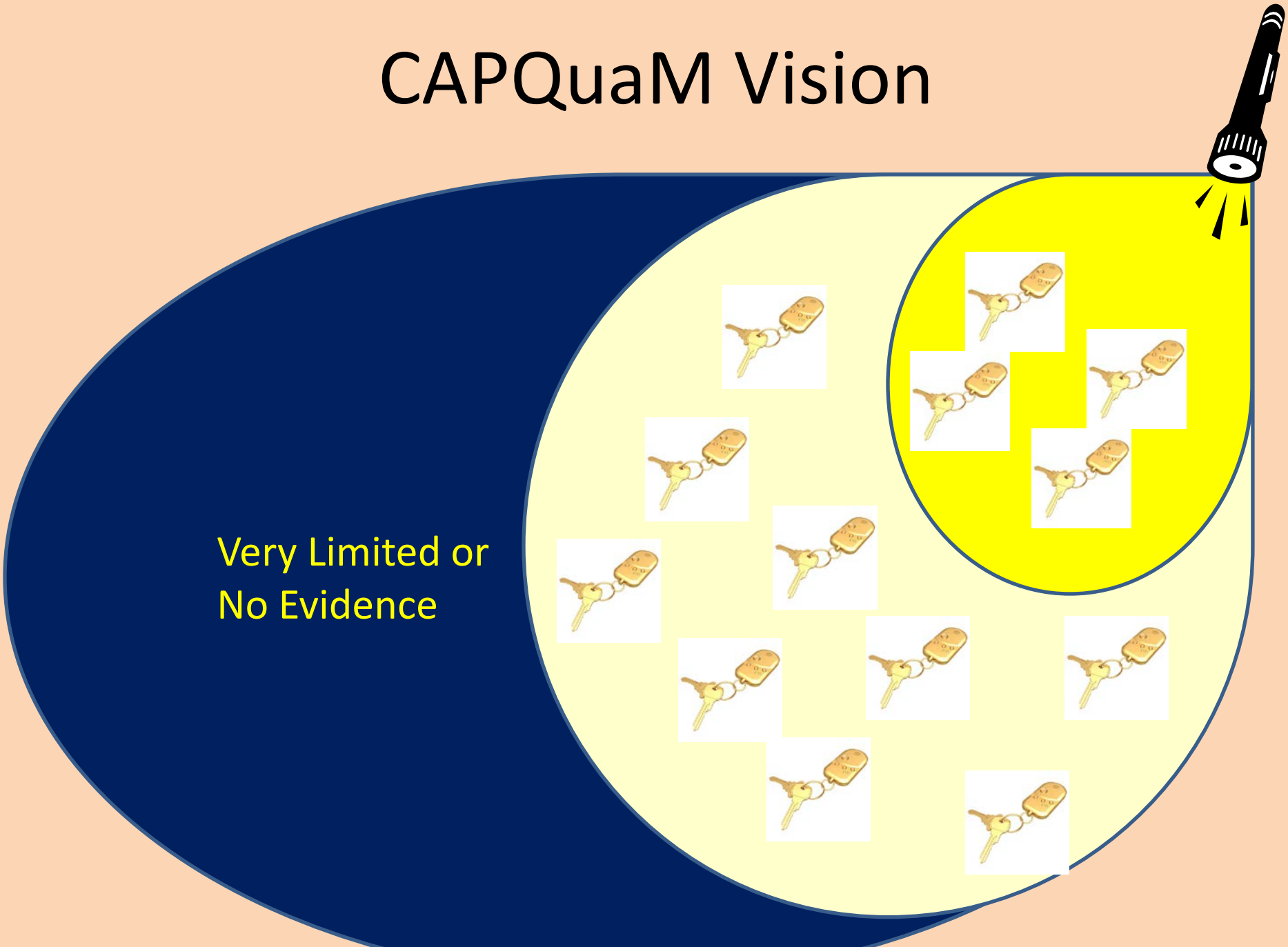
Spectrum of Clinical Practice



Current State of QM



CAPQuaM Vision



Definition: High Risk Obstetrical Services

How do we identify the target population?

- By conditions present in the woman?
- By clinical services required?
- By the clinicians providing the services?

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Definition: Availability*

- Geographic: Density and Distance
  - Accepts Medicaid?
- Timeliness:
  - Delays for appointments?
- Process availability
  - Barriers to care?

*(AHRQ commissioned paper: Kuhlthau; 2010)

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Construct of Availability

- Derived from Aday, Andersen, et al, 1974
- Availability necessary for accessibility
- Often necessary to measure availability indirectly by measuring access

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CHIPRA Availability Measure

- Measure should capture impact of health care system on availability
- Differences in access reflect both system and individual contributions
- CHIPRA measure should capture differences across health care systems that reflect system contributions/differences

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What is Availability

- System's contribution to *potential* access*
- Contrast to utilization, which is a measure of *realized* access
  - Both system and individual contributions
- High levels of utilization are evidence of availability
- Underutilization (or over-utilization of rescue services) may indicate care not available

*Andersen RM, et al 1974
Aday & Andersen, 1983

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Measuring Availability

- Lack of availability may be measured directly or indirectly
- Sufficient availability typically measured indirectly through access/utilization measures

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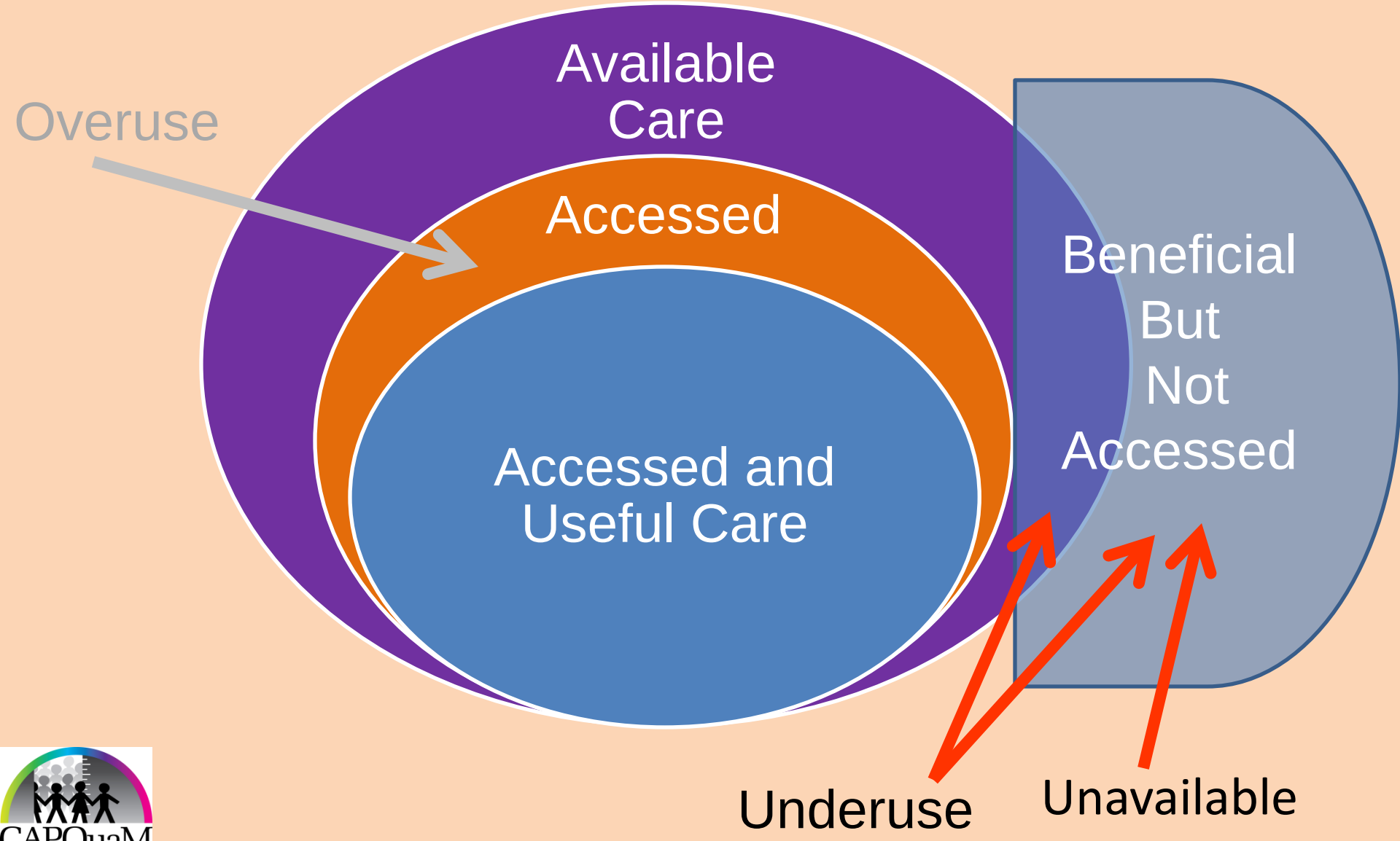
Measure: Availability of HROB Care



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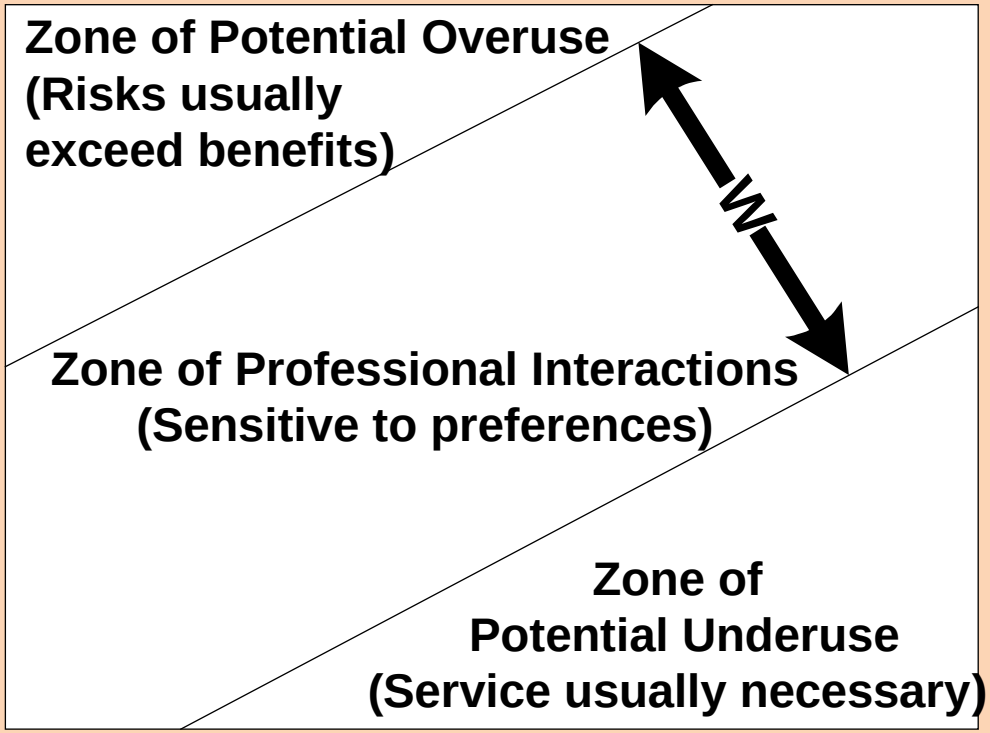
Our Approach

- Build Coalition of Strong Institutional Partners
  - Accreditors (TJC, NCQA)
  - Clinicians (AAP, AAFP, ACOG)
  - Consumers (Consumer Reports, IPFCC, NAMI)
  - Insurers
- Offered things of opposing value(s)
  - Overuse on the one hand
  - Validation of clinical process on the other

Explicitly incorporate uncertainty

- Example: CAPQuaM's Boundary Guideline
  - Incorporates evidence and uncertainty

Figure 2: Illustrating Boundary Guideline



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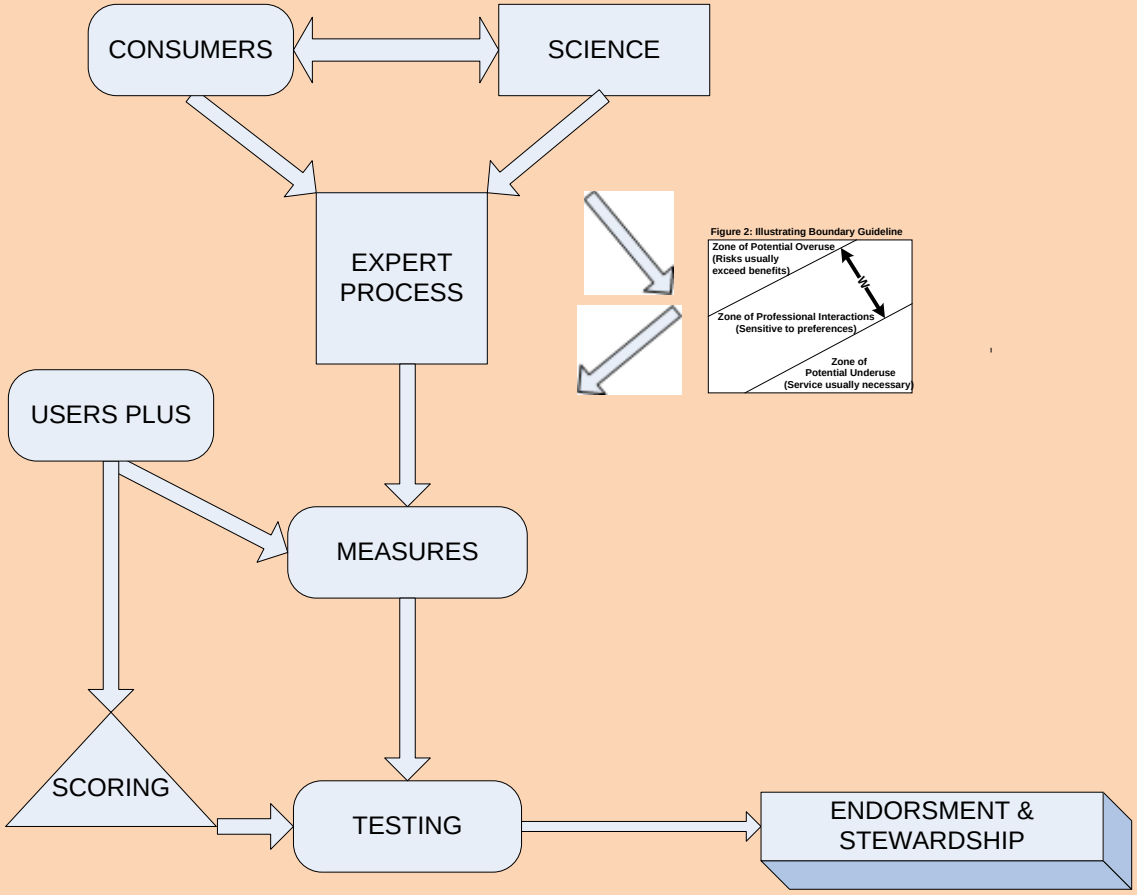
Develop Consensus around the Process, not the Measure



Engagement

- Consumer Stakeholders
  - Share their beliefs, priorities, values based upon relevant experiences (CFLR is novel)
- Clinician Stakeholders
  - Share their beliefs priorities, values and relevant experiences
  - Staff expert panels to develop criteria to support boundary guideline
- Organizational Stakeholders
  - Assist with specification of measures
  - Plan for interpretation of measures

Assigned Measures, Phase 1

- Availability of High Risk Ob Care
- Inpatient Perinatal
  - Temperature on admission to NICU
- ER Visits for Asthma
  - As an indicator of chronic asthma care
  - As an indicator of adequacy of primary care

Highly engaged and engineered approach

- Expert process, informed by science and stakeholders
- Anticipate that structured integration of literature, judgment, and engagement will be sufficient to meet evidence standards for federal endorsement

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Evidence: What do you see?