“Baby it’s Cold out there!”
Concepts Of Thermoregulation: Myths and Truths about Thermoregulation

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Studies have shown that hypothermia is an independent risk factor for neonatal mortality and morbidity.
No other factor is as important in newborn survival as its temperature control.
A thorough understanding of thermoregulation is necessary to provide an optimal environment for the neonate to thrive.

Objectives
- Describe the primary physiological differences between temperature regulation in the premature and the full term infant
- List the 4 methods of heat transfer
- Explain the importance of measuring both axillary and skin temperatures when assessing cold stress
- Identify at least two signs/symptoms of hypo- and/or hyperthermia
- List two practice, equipment, or environmental modifications to consider when utilizing developmental support devices in the NICU

Definition of Terms
- **Neutral Thermal Environment (NTE)**—narrow range of environmental temperature without Δ or Υ heat production above resting levels minimal oxygen consumption (in-utero temp 37.9(100.2))
- **Thermo-neutrality**
  - state of normal body temperature/oxygen consumption with minimal heat production
  - optimal thermal condition supporting internal functions
- **Thermal Balance**—rate of heat generation/heat dissipation
- **Critical Temperature**—O2 consumption increases in an attempt to maintain body temperature
Risk Factors Contributing to Vulnerability to Thermal Stress

- Limited stores of metabolic substrates
- Heat production is by non-shivering thermogenesis
  - Burning of brown fat
- Greater surface to weight ratio
- High evaporative loss due to immature skin integrity
- Immature CNS delays response to cold stress
- Heat production obligates oxygen consumption

Factors Placing Infants at Risk for Cold Stress

- SGA
- Neurologic (HIE)
- Endocrine
- CV
- RDS
- Neural Tube & Abdominal wall defects
- Maternal analgesia/sedated infants
- Infection
- Hypoglycemia

3 Methods to Heat Production

**Motor, Tone & Activity**

- Motor tone and activity lead to heat production
- Low tone leads to inability to use flexion to reduce surface area
- Voluntary muscle activity
  - Flexion
  - Extension
**Shivering**

**The Central Nervous System**

- Hypothalamus - control center for temperature regulation
- Located at base of brain forming floor and lateral wall of 3rd ventricle
- Links nervous system to endocrine system via pituitary
- Part of the limbic system
- Responsible for metabolic processes
- Controls body temperature, hunger, fatigue, sleep and circadian rhythms

- 32 weeks
- 26 weeks
- Term

**White Fat**
- Serves as insulation
- Fetus makes white fat during development for energy source

**Brown Fat**
- Burning produces heat
- Mitochondria metabolizes fat to produce heat
- Present at 26-28 wks. - 3-5 weeks post-natally.
Non-Shivering (chemical) Thermogenesis

- Heat produced by metabolism of brown fat
- Thermal receptors transmit impulses to hypothalamus stimulating norepinephrine release in brown fat
- Nor-epi activates lipase, resulting in glycolysis and fatty acid oxidation
- Glycolysis increases metabolic rate increasing heat production
- Nor-epi released @ BF site as a result of cold stress
- Release of FFA undergoes combustion in mitochondria of brown fat cells releasing heat

Consequences of Cold Stress

- Infant responds to chilling by increasing metabolic rate
- Pulmonary vasoconstriction & decreased production of surfactant
  - Diminished effective ventilation or increased hypoxia
  - Atelectasis of alveoli
  - Increased cardiac shunting

Mechanisms of Heat Transfer

- Conduction: heat loss to the media can be caused by any one, or a combination, of the following factors: (A) Conduction: heat loss due to direct contact with a colder surface. (B) Convection: heat loss due to air movement. (C) Convection: heat loss due to the cooling effect of water loss on the skin. (D) Radiation: heat loss via infrared heat rays due to body metabolism.
Mechanisms of Heat Transfer

“Evaporative”

- Evaporative - transfer of body heat through conversion of liquid to vapor
  - >25% body water/skin permeability/surface area
  - 25% @ delivery
  - Respirations
  - Increases depending on air speed and activity
  - Increased with low humidity

Interventions
- Dry infant after birth/bath
- Pre-warm
  - blankets/hats, solutions, O2

“Convective”

- Convective - the transfer of heat to the air moving across/around the body
  - Dependent on speed of air movement
  - Dependent on amount of body surface exposed
  - Dependent on temp gradient between infant/air/liquid
  - Larger the gradient…the greater the heat loss

Interventions
- Warm oxygen
- Avoid vents/drafts
- Swaddle/utilize clothing/products

“Conductive”

- Conductive - transfer of heat between 2 solid objects in contact with each other
  - Heat transferred proportional to size of temp gradient
  - Larger surface area in contact the > heat or cold transferred
  - Heat loss > on highly conductive surfaces such as metal
  - Heat gain from object warmer than body

Interventions
- Pre-warm: surfaces, scales, x-ray plates, circ. boards, incubator, warmer, clothing, stethoscope, blankets

“Radiation”

- Radiation - transfer of heat between 2 solid objects not in direct contact with each other
  - Highly undetected
  - Based on temp gradient of objects/surface facing object
  - Independent of ambient temp

Interventions
- Swaddle infant
- Pre-warm incubator/cover incubator
- Keep bed away from window or direct sunlight, keep blinds/drapes closed
**Symptoms of Cold Stress**

**Hypothermia** – Rectal/Axillary < 36.5

- Core temperature below range of (36.5 to 37.5 °C, (skin temp 0.5 to 1.0 °C lower).
- Cyanosis/Acrocyanosis/Mottling/Poor Perfusion
- Poor feeding/^ residuals
- Apnea/Bradycardia/^ O2 needs
- Decreased activity/Lethargy/Hypotonia
- Irritability/Weak Cry/CNS depression
- Seizures
- Hypoglycemia
- Acidosis

**Hypothermia Studies**

- Laptook 2003
  - 5,277 infants - 401-1499g.
  - 14.3% had admission temperatures < 35, 32.6% 35-35.9
  - Admission temperatures inversely related to mortality with 28% increase in death for every 1 °C decrease in temperature

- Miller (CPQCC) 2006
  - 8,782 vlbw infants
  - Mean admission temperature 36.3 (+) 0.8)
  - 30.5% had mild hypothermia on admission
  - 25.6% moderately hypothermic associated with risk of IVH/death

**Treatment of Hypothermia**

- Re-warm slowly – rapid causes heat induced apnea, hypotension & shock
- Place in NTE
- Asses ventilator temperature
- Monitor axillary and skin temperature
- Utilize other heat sources minimizing changing incubator temp
- Reduce heat loss mechanism

**Hyperthermia - Temperature > 37.5**

- Can be iatrogenic or symptomatic of a disease process
- Increased axillary temperature can also be symptom of cold stress
- Usually occurs by means of an external source
Causes of Hyperthermia

- Maternal Fever
- Radiant warmer/incubator/environment temperature
- Swaddling
- Infection
- CNS disorder
- Misuse of equipment
- Neonatal Abstinence Syndrome
- Use of Prostaglandin therapy

Effects of Hyperthermia

- Tachycardia
- Tachypnea in attempt to release excess heat
- Hypotension & dehydration from vasodilation and IWL
- Seizure activity
- Apnea
- Poor feeding
- Poor weight gain
- Oxygen requirements/apnea

Treatment of Hyperthermia

- Treat cause
- Remove heat source
- Remove barrier to heat loss
- Assess equipment function
- Cool slowly every 30-60 minutes
- Maintain in extended positions

Managing the Physical Environment

- No single environment is appropriate for all infants
- The medical condition other situations may require compromise of methods
Radiant Warmer

- **Advantages**
  - Infants who need observation
  - Easily accessible

- **Disadvantages**
  - Increase convective heat loss
  - Increased evaporative and insensible water loss
  - Decreases neuroprotective environment

Incubator

- **Advantages**
  - Infants requiring a controlled thermal environment
  - Minimizes evaporative and convective heat loss
  - Available in both ambient and servo mode

- **Disadvantages**
  - Radiant heat transfer to walls can occur

Warmer Management

- **Maintain in Servo/Skin mode**
- **Probe attached to skin surface with reflective device and exposed to heat source**
- **Set temperature to your desired skin temp**
- **Avoid use of thermal blankets**
- **Weaning**

Servo/Skin mode

- **Radiant Warmer and incubator**
- **Regulates ambient temperature to preset skin temp**
- **As infants temperature fluctuates above or below set temperature servo control changes**
- **Evaluate ambient temperature regularly**
- **Infants inability to maintain temperature in consistent environment can be an early sign of sepsis, ICH, NEC**
Monitoring Body Temperature

- Rectal temperature closely approximates core temperature
  - Measure is invasive and difficult to maintain
  - Possible risk of perforation
- Axillary and abdominal skin temperature most used
  - Accessible, convenient, and safe
  - Not an ideal estimate of core temperature
- Axillary and abdominal temperatures are highly dependent on skin temperature and influenced by environment

Skin Temperature

- Warmer
  - Reflective shield in alignment with heat source
  - Probe cover should not be covered by any other equipment or blanket

Monitoring Body Temperature

- Rectal Temperature: Core Temperature, Late indicator
  - Normal Range 36.5-37.5 (AAP, WHO, IICOR)
- Axillary Temperature
  - Normal range: 36.4-37.4 (AAP)
- Skin Temperature – early indicator
  - Normal Range: 36.2-37.2 (avg 36.8-36.9) for preterm
  - 36.0 - 36.5 in term infant

Skin Temperature

- Incubator
  - Probe can be covered
  - Avoid insulation
  - Probe cover
    - Tape
    - Reflective/hydrogel
Delivery Room Practices

- Room Temperature – WHO, llcor 2010, > 25° -26° C
  - Admission temp increased by 0.5 and decreased hypothermia 66.8% to 34.9%
  - DR/s need individual adjustable thermostats and humidity controls

- Study: Polyethylene cap RCT:
  1) polyethylene cap with only body dried
  2) polyethylene bag with body wet up to neck and head dried uncovered
  3) control group with infant dried, placed in pre-warmed towels with head left uncovered

Warming mattresses

- Studies
  - Infants < 28 weeks in polyethylene bags had mean rectal of 36.5
  - 44% of < 29 weeks in polyethylene bags had mean temp < 36.4
  - Mortality fell from 252/1000 in control to 229/1000 in the bag and to 175/1000 in the bag and mattress group.

Combining Interventions

- Delayed Cord Clamping

Modes of Temperature Control

"Both effective.....skin needs more attention"

<table>
<thead>
<tr>
<th>Air</th>
<th>Skin</th>
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<tbody>
<tr>
<td>Early temperature changes noted</td>
<td>Automatically regulates air temperature to preset skin temperature</td>
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<tr>
<td>Infant’s temperature could fluctuate if in and out of incubator</td>
<td>Ambient temperature changes creating fluctuations (NTE?)</td>
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<tr>
<td>Simple to use</td>
<td>Can miss early signs of sepsis, NEC or changes</td>
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Humidity

- First mentioned in 1933
- Decreases IWL, fluid intake, UO, less weight loss and decrease hypernatremia during 1st week of life
- No standards for how much and how long
- General Practices
  - Range of 45-100% RH – avg. 60-80 in ELBW
  - 1st 10 days of life to 32 weeks
- Goal – create a unit standard to practice

Warming Practices

- Warm formulas
- Humidify air and oxygen
- Cohort study: humidified gas supporting infants < 32 wks
  - reduction in postnatal fall in temperature in cohort with control admission temperature 35.9 °C versus heated: 36.4 °C
- Clothing, developmental supports, incubator covers
- Kangaroo Care: skin to skin contact

Temperature regulation in Developmental Supports

Things to consider

- How do we approach cares?
- Minimal entry
- Incubator - Use of heat shield
  - Pull off blanket – radiation heat loss
  - Open port-hole doors/Popping top - loss of humidity
- Infant
  - Unwrapping infant - convective/evaporative heat loss
  - Suctioning and disconnect humidified heat source
Weaning from incubator

- Things to consider:
  - Infant > 1500 grams, gaining weight, other milestones
  - Infant can tolerate incubator temperature of 25-26
    - 25°C = 77°F, 26°C = 78.8°F
  - Consistent weight gain
  - Time out of incubator
  - Parent Education
    - How are adults dressed?
  - Maintain skin temp monitoring in crib for 24 hours

Scenario

- 30 week infant in incubator in air mode
  - No skin temp probe on
  - Axillary temp - 99°F
  - What would you do?

- 28 week infant in incubator in servo mode
  - Skin temp is reading 36.2
  - Axillary temp 99.8
  - What would you do?

Where do we go from here?

- Develop interdisciplinary thermoregulation guidelines
  - Charts are dated
  - Nursing practice and nursing driven
- Modifications for developmental products, KC, etc.
- Avoid using absolutes
  - When 28 weeks
  - When 1500 grams
  - Only skin mode/or air mode

Questions

- References available via email @ lizdcnnp@aol.com