“Everything Old is New Again”
Keeping Babies Warm

Opened in 1892

The first Children's Hospital

210 Bryant Street
Buffalo, N.Y.

Children's Hospital and Named Fundraising, Brown Street
History of Newborn Thermoregulation

- 1835, 1857: Russia and France developed “water tub”
- 1860: Winckel: Permanent tub where NB “floated”
- 1866: Crede: ↓ mortality 18%
- 1880-1881: Tarnier - Earliest version of heated incubator (Paris)

Alexandre Lion
- Lion incubator was a high point in technology at the end of 19th century (1889).
- Lancet 1897 – “the main features of this incubator is the fact that it requires no constant and skilled care, it works automatically; both ventilation and heating are maintained without any fluctuations whatsoever…the only attendance necessary is that needed for feeding and washing the infants”
- It was expensive.
- Received professional endorsement from a study by the physician-general of the City of Nice in which a 72% survival rate among 187 infants was reported.

Pierre-Constant Budin
  - If rectal temp, was < 32°C, mortality rate was 98%; between 32 and 35°C it was 96%; but if it remained normal it was only 23%!
- Designed an incubator that provided for heating of air, a one way air flow, additional humidity and temperature monitoring of the environment.
- Developed the concept of neonatal research and insisted on personnel specially trained in the care of preterm infants.
• Martin Couney
  - Budin’s assistant in the development of the incubator.
  - Professor Budin saw in the Berlin Exposition of 1896 a chance to publicize the conservation of premature infants. He chose his disciple Couney to demonstrate his discoveries.
  - Couney hit on the idea of placing live preterm infants in the exhibit incubators.
  - Virchow, the head of Berlin Chartile Hospital, willingly loaned him six premature infants from the maternity ward. This was considered a small risk since they were expected to die in any case.
  - Exhibit was named "Kinderbrutanstalt" [Child hatchery].

• Martin Couney
  - In 1898 he opened his first show utilizing prematures in incubators at the Omaha Trans Mississippi Exposition. He returned briefly for the Paris exposition of 1900 and again came back to America for the Buffalo exposition of 1901.
  - For the next half century “Couney babies” were exhibited in a variety of county fairs and traveling shows across large parts of America, particularly in the mid-west.
History of Newborn Thermoregulation

- By the time of his death in 1952, it was estimated that approximately 80,000 premature infants had been raised across the country in the course of Couney’s shows and exhibitions.
- Couney demonstrated, perhaps better than anyone else could have and certainly on a much larger scale, that the provision of adequate thermal support and an appropriate thermal environment was clearly capable of markedly influencing the outcome and enhancing the survival of premature infants.

Fast Forward

Buffalo 2010

Thermoregulation In The Newborn

- Adaptation to extraterine life involves a series of biological adjustments by the newborn infant.
- Accommodation to a thermal environment that represents a distinctly "cold" challenge.
- The failure to accommodate to this cold stress has historically been recognized as perhaps the earliest distinguishable characteristic of the premature as opposed to term neonate.
- It is in this difference lies the rationale for the history and origins of incubators in the care of the premature baby.
Hypothermia in Preterm

- 26 year old G4P3 arrives in PTL at 23 and 4/7 weeks GA. Develops SVT and converted with adenosine. She then delivers twins:
  - Twin “A” by SVD at 518g and twin “B” at 520 g by C/S under general anesthesia (breech).
  - Twin A: 21 minutes in DR with admit temp = 31.5
  - Twin B: 19 minutes in DR with admit temp = 33.5
  - Both with metabolic acidosis
  - Both expire within 48 hours
  - Does hypothermia play a role?

Thermoregulation: Theoretical Considerations

- Two methods of accomplishing increase in heat production –
  - Physical method of muscular contraction [shivering]
  - Chemical method [nonshivering thermogenesis]

- Newborns of most mammalian species, including man do not shiver in cold, yet show an increase in oxygen consumption and heat production when exposed to cold environment, suggesting that chemical thermogenesis is not only functional but also of paramount importance in maintaining the thermal stability of the newborn.

Thermoregulation: Theoretical Considerations

- Although the system is catecholamine dependent, the nature of the mediator itself differs in the adult as opposed to the newborn.
  - Epinephrine is the major mediator in adults.
  - Newborns show large increase in norepinephrine excretion with little change in epinephrine levels.
  - Thus newborn infant utilizes a different system that is mediated differently from the adults.

Maturation of the Thermogenic Responses

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Weight (g)</th>
<th>Warm</th>
<th>Cold</th>
<th>Change in Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>1285</td>
<td>0.898</td>
<td>0.867</td>
<td>-1.5°C</td>
</tr>
<tr>
<td>47</td>
<td>2400</td>
<td>1.197</td>
<td>3.314</td>
<td>-1.5°C</td>
</tr>
</tbody>
</table>

NE response is a major mechanism of the newborn infant’s defense against cold. Its maturation in time parallels the development of thermal stability in the premature infant.

The narrow range of environmental temperature at which a given baby can maintain normal body temperature with minimal oxygen consumption is called thermo neutral temperature or zone of thermal comfort.

Narrow range of environmental temperature in which a baby can maintain core temperature between 36.7 – 37.3°C and the mean core and skin temperature does not change more than 0.2 to 0.3°C per hour when recorded continuously by an electronic thermometer.
Range of Environmental Temperatures needed to provide warmth for infants weighing 1 – 3 kgs.

Mechanisms of Heat Loss

- **CONDUCTION**: Transfer of heat between contacting solid objects of different temperatures.
- **CONVECTION**: Heat is lost from skin to moving air. The amount lost depends on air flow/speed and temperature.
- **RADIATION**: Heat dissipates from the infant to colder objects in the environment.
- **EVAPORATION**: The amount of loss depends primarily on air velocity and relative humidity. Typically from the lungs [alveolar ventilation] and body surface [relative humidity]. Wet infants in the delivery room are especially susceptible to evaporative heat loss.
  - For every milliliter of water that evaporates, approximately 580 calories of body heat is lost.
  - It accounts for the largest part of the difference in thermal requirements between term and preterm infant.

The Thermal Environment

- In clinical practice, the most important of these are the provision of adequate humidity to guard against evaporative losses and the prevention of heat loss due to radiation [Adamson et al. J Pediatr. 1965].
  - Oxygen consumption increase at a rate of approximately 0.6ml/kg/min once the value of skin-environmental gradient is > 1.5°C.
- At neutral thermal conditions, losses by conduction are negligible unless the subject is lying on cold surface [like in DR].
- Standard nursery conditions with higher air temps, even more so inside incubators and minimal air currents, effectively reduce convection losses to a point at which radiant losses account for 2/3rd of the total.
# Preventing Heat Loss

## HEALTHY INFANTS:
- Newborns dried and wrapped in a warm blanket after delivery and placed on a preheated radiant warmer.
- Skin probe with servo control for prolonged exams/resuscitation.
- Infants covered with blankets and cap.

## SICK INFANTS:
- Dried/heated incubators for transport/radiant warmers for procedures.
- Servo controlled open warmers when access is important.
- Incubators set at neutral thermal environmental temperature for relatively stable infants.
- Plastic heat shield:
  - ↓ convection HL / ↓ radiation HL.
- Stable preterm infants: double layered caps and clothes.
- Warm Humidified gas in ventilators and supplemental oxygen.

# Cold Stress

- **Hypothermia** is defined as a skin temperature of < 35.5°C or core temperature of < 36°C.
- Excessive heat loss: Cold environment, wet or naked baby, cold linen, transport, procedures.
- Poor ability to conserve heat: large SA, poor insulation, ↓ brown fat.
- Poor metabolic heat production: ↓ brown fat, CNS damage, hypoxia, hypoglycemia.

## WHO definition of hypothermia:
- Cold stress: Core temp. between 36.0°C – 36.4°C
- Moderate hypothermia: 32.0°C - 35.9°C
- Severe hypothermia: < 32.0°C

## Clinical Symptoms
- Incidence of cold stress depends on gestational age
- EPICure study – 40% infants <26 weeks had admission temps less than 35°C
- Temp <36°C in 79% of infants that died compared to 59% of controls


www.cemach.org.uk/publications/p2728/mainreport.pdf

## Vinyl Bags Prevent Hypothermia at Birth in Preterm Infants

- Comparison effect of standard care vs. use of vinyl bags on admission temperature in ELBW infants < 28 weeks GA. (August – November 2004)

## Standard care:
- Drying and placing under radiant warmer

## Vinyl Bag care:
- Include placing infant in a Vi Drape bag up to the neck immediately following delivery without drying.

Indian J Pediatr 2007; 74(2)
Mathew,Lashminrusimha,Cominsky,Shroeder,Carrion

## Table: 2008 Live Births: BW 501-1000g

<table>
<thead>
<tr>
<th></th>
<th>Center 1</th>
<th>Center 2</th>
<th>Center 3</th>
<th>WCHOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Admissions to Hospital</td>
<td>67</td>
<td>100</td>
<td>89</td>
<td>53</td>
</tr>
<tr>
<td>DB Survivors Admitted by Day 7</td>
<td>59</td>
<td>85</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>Excluding Admissions &gt; 7 Days</td>
<td>80%</td>
<td>82%</td>
<td>81%</td>
<td>82%</td>
</tr>
<tr>
<td>Admissions to NICU, Alive, &lt; 7 Days</td>
<td>59</td>
<td>85</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>Mean BW (Grams)</td>
<td>800</td>
<td>786</td>
<td>801</td>
<td>756</td>
</tr>
<tr>
<td>Mean GA (Decimal Weeks)</td>
<td>25.9</td>
<td>26.11</td>
<td>26.3</td>
<td>25.9</td>
</tr>
<tr>
<td>% Inborn</td>
<td>83%</td>
<td>84%</td>
<td>91%</td>
<td>88%</td>
</tr>
<tr>
<td>% of Inborn with Admission Temp &lt;36.0°C</td>
<td>22%</td>
<td>21%</td>
<td>47%</td>
<td>31%</td>
</tr>
</tbody>
</table>

Results

- Average temperature in vinyl bag group was $(35.9 \pm 0.13$ vs. $34.9 \pm 0.24$, $p = 0.002$)

- There was significant increase in maximal oxygen requirement during the first 24 hrs in the control group (82.9 vs. 43.3% in the vinyl bag group, $p = 0.0004$)

- Worst pH in the first 6 hrs of life was seen in the control group.

- Conclusion: Vinyl bags prevent heat loss in ELBW and are effective in preventing hypothermia in the DR.
Fast Forward 2008, 2009

- Review of < 1500 gram infants admitted to NICU. 31% of these were hypothermic defined as < 36°C. (2008)
- QA review of 2009 infants < 1000 g
- 24/70 admitted with temperature < 36°C (34%)
- 23/24 were inborn
- Average weight: 732 g
- Average GA: 26 weeks
- Mortality: 25%

Contributing factors

- Length of time in DR (av = 17.25 minutes).
- Incorrect use of Vi Drape bag or non – use.
- Weighing infant in the delivery room.
- Subsequent post admission hypothermia:
  - length of time to line placement (av = 41.6 minutes).
- Failure/inability to pre-warm Giraffe isolette.
- Use of thermal mattress in ELBW instead of Vi Drape.

Vi Drape vs. Thermal Mattress

Baseline Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Vinyl bag (14)</th>
<th>Thermal mattress (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age in weeks (SD)</td>
<td>25.5 (1.1)</td>
<td>25.8 (1.3)</td>
</tr>
<tr>
<td>Birth weight grams (SD)</td>
<td>691 (92)</td>
<td>701 (127)</td>
</tr>
<tr>
<td>Apgar score (median)</td>
<td>6 at 1, 8 at 5</td>
<td>6 at 1, 8 at 5</td>
</tr>
<tr>
<td>Mode of delivery (CS / Vaginal)</td>
<td>12/2</td>
<td>10/3</td>
</tr>
<tr>
<td>Multiple gestation (%)</td>
<td>5 (35)</td>
<td>7 (54)</td>
</tr>
</tbody>
</table>

Results

<table>
<thead>
<tr>
<th>Clinical Parameters</th>
<th>Vinyl bag</th>
<th>Thermal Mattress</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer time (DR to NICU) in minutes (SD)</td>
<td>22.4(6.7)</td>
<td>22.5(9.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Admission temperature °C (SD)</td>
<td>35.7(0.7)</td>
<td>35.8(1.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Hypothermia &lt;35°C</td>
<td>2</td>
<td>3</td>
<td>NS</td>
</tr>
<tr>
<td>Worst pH in first 6 hrs (SD)</td>
<td>7.3 (0.06)</td>
<td>7.3 (0.07)</td>
<td>NS</td>
</tr>
<tr>
<td>Worst base deficit in first 6 hrs (SD)</td>
<td>-4.6 (3.2)</td>
<td>-5.3 (4.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Hypotension</td>
<td>7</td>
<td>8</td>
<td>NS</td>
</tr>
<tr>
<td>IVH Grade 2 or greater</td>
<td>6</td>
<td>2</td>
<td>NS</td>
</tr>
</tbody>
</table>

All Infants

Infants < 700 g
Process Improvement

- Correct Use of thermal control: (Vi Drape or Mattress)
- Decrease LOT in delivery room
- Anticipation: Pre-warmed Giraffe in delivery room
- No weighing in DR (OR Temp: 20 -21°C)
- Post admission hypothermia: LOT for stabilization

2011 NRP Guidelines

- *Pediatrics volume 126, No.5, November 2010*
  - Temperature control "additional warming techniques recommended for < 1500 g infants, (prewarming the delivery room to 26°C, covering the baby in plastic wrapping (food or medical grade heat resistant plastic), placing the baby on an exothermic mattress and placing the baby under radiant heat."

Hannah was a 26 weeker who was on the ventilator for 1.5 months. She is about 11 months old in this picture and doing well.