Development of Care in the NICU: Designing and Operating NICUs in the 21st Century

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I have no conflicts of interest to disclose

I will not discuss any off-label, experimental, or investigational use of a product, drug, or device
The NICU Environment of Care – Why it Matters

• For babies
  – Crucial period of brain growth & development

• For families
  – Defining moment for relationships – with their baby, each other, healthcare system, spiritual

• For staff
  – The NICU and what we do there largely defines who we are and how we feel about ourselves
Developmentally-appropriate design and care: why does it matter?

- Brain weight increases 400% from 26 weeks to term (in 3 months!)
- Brain weight increases 400% from term to adulthood (in 18 years)
“The neonatal synaptic big bang”, by Jean-Pierre Bourgeois

From The Newborn Brain, 2nd Ed, edited by Hugo Lagercrantz, MA Hanson, Laura Ment, and Donald Peebles, Cambridge University Press, 2010
Cortical Hubs in Infants vs. Adults
(modified from Fransson P, Aden U, Blennow M, and Lagercrantz H.
The functional architecture of the infant brain as revealed by resting-state fMRI.
Cerebral Cortex 2011;21:145-54)

<table>
<thead>
<tr>
<th>Adults (association, information processing)</th>
<th>Infants (visual, auditory, and sensorimotor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pancuneus</td>
<td>1. SMA/cingulate cortex</td>
</tr>
<tr>
<td>2. Dorsomedial PFC</td>
<td>2. Left temporal cortex</td>
</tr>
<tr>
<td>3. Medial PFC</td>
<td>3. Left sensorimotor cortex</td>
</tr>
<tr>
<td>4. Posterior cingulate cortex</td>
<td>4. Superior right sensorimotor cortex</td>
</tr>
<tr>
<td>5. Ventromedial PFC</td>
<td>5. Visual cortex</td>
</tr>
<tr>
<td>7. Left temporal cortex</td>
<td>7. Right inferior sensorimotor cortex</td>
</tr>
<tr>
<td>8. Left visual cortex</td>
<td>8. Left parietal lobe</td>
</tr>
<tr>
<td>9. Right insula region</td>
<td>9. Dorsolateral PFC</td>
</tr>
<tr>
<td>10. Left insula region</td>
<td>10. Right sensorimotor</td>
</tr>
</tbody>
</table>
Common Myths about the preterm infant brain

• A blank slate
• Extraordinarily resilient
• “At rest” during sleep
• Too young for memory, sensitization, habituation, or conditioning in response to external stimuli
The Preterm Newborn as an Altricial Mammal

- Altricial vs. Precocial
- Altricial newborns
  - Rely on mother for food, warmth, circadian cues
  - Receive gut flora, immune and trophic factors, and hormones via mother’s milk
  - Receive multisensory stimuli from maternal contact
“That kangaroo care idea is nice for moms, but does it really matter to the baby?”

<table>
<thead>
<tr>
<th>Environment of care</th>
<th>Mother’s Arms</th>
<th>Incubator/ Warmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate sound</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Familiar odors</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Circadian stimuli</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Kinesthetic</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Caress/massage</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hormonal/immunologic/neural communication</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Protection</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Myths about the incubator

• Optimal for temperature control?
  – Incubator temp control is precise, but...
    • Should temp that minimizes BMR be the set point?
    • Is it desirable to eliminate circadian rhythmicity?

• Optimal for infection control?
  – Pathogens as/more likely to be found in incubator as mother’s skin, but probiotic flora more likely to be found with the mother
  – Infection rates lowered by kangaroo care (Cochrane 2011)

• And perhaps other dangers?
  – e.g., electromagnetic fields (Bellieni et al Early Hum Dev 2012)

In fact, incubators were never shown to be better than STS care – comparison groups were babies in cribs
Benefits of Maternal Care in the NICU: Recent Evidence in Humans

• Scher et al – STS 1.5 hrs/day, 4 days/week x 8 weeks accelerated EEG signs of brain maturation (Clin Neurophysiol 2009).
• Karolinska – 24/7 presence of the family -> decreased LOS and BPD (Pediatrics 2010).
• Milgrom et al - Training parents about neurosensory needs of babies improved white matter development (Ped Research 2010).
• Cochrane Reviews 2010: Infant massage by parents improved weight gain.
Benefits of Maternal Care in the NICU (Cont)

- Caskey et al – exposure to parental talk increased infant vocalization (Pediatrics 2011) and 18-month Bayley language and cognitive scores (Pediatrics 2014)
- Feldman et al – STS in the first 2 weeks of life in premies improved executive functioning and mother-infant reciprocity at 10 years of age (Biological Psychiatry 2013)
- Kangaroo care reduces mortality, sepsis, LOS (Cochrane 2014).
Benefits of Maternal Care in the NICU (Cont)

- Welch et al - Family Nurture Intervention increases frontal EEG activity during sleep (*Clin Neurophysiol* 2013)
- O’Brien et al – Family Integrated Care leads to improved weight gain (*BMC Preg & Childbirth* 2013)
- Bystrova, et al - skin-to-skin in 1st two hours improved self-regulation in infant, maternal sensitivity, and dyadic reciprocity at 1 year, not compensated by rooming-in (*BIRTH* 2009)
- Mebler et al – this sensitive period also exists with preterm infants (*J Perinatatology* 2011)
- **Confirming a large body of work in animals and humans showing mother-infant interaction is crucial in the neonatal period.**
This is not a new concept...

“It must never be forgotten that, ultimately, the care of even very sick newborns is the responsibility of the parents and that medical and nursing staff exist to assist them in doing what needs to be done while not usurping the parents’ role.”

-1978
We have a long way to go...

% of time in contact with mother

- in utero
- Stockholm
- good US center
- typical US center
What We Know Today...

• Infants of all mammalian species studied suffer in the absence of extensive, intimate contact with their mothers

• STS care has been shown to be efficacious in all cultures studied – Africa, Latin America Sweden, and Cleveland (even 6 hours/week!)

• Most current NICUs were built without much consideration of these findings

• Neonatal caregivers have done a poor job of recognizing and responding to this science
  
  – *Especially since the long-standing practice of excluding parents from extended intimate contact with their baby was not founded on a scientific basis*
And Furthermore....

• The same thing is true for how we design for families and caregivers, i.e., –

We know the physical environment has a strong influence on human performance, sense of well-being, and health

And yet....we do not always build or operate our NICUs as if we were aware of this science
A full understanding of good NICU design requires knowledge of neonatal biology and:

- Sociology
- Anthropology
- Psychology
- Occupational Health
- And Much More
Working Premises

- Babies deserve the best available treatment
- Babies and parents should not be separated because of inadequate space or restrictive policies
- The commitment of a mission-oriented hospital to babies and families should be as great or greater than to any other program, because the stakes are higher
- The NICU environment should meet the needs of all those who inhabit it

Therefore, good NICU design requires space specifically designed for the needs of babies and their families, as well as separate spaces for the needs of caregivers
Which brings us to...

**Individualized environments for the NICU**

SFR = Single Family Room

- Private rooms are now the standard in every other area of US hospitals for new construction, and the growing trend in NICUs around the world

- Are they a good idea for NICU? What are the hazards? What are the pitfalls?
SFR – The Rationale

• Optimal environment for most babies
  – Individualized lighting and sound control
  – Infection control
  – Skin-to-skin contact has substantive biological impact, and most closely approximates the *in utero* sensory environment

• Optimal environment for most families
  – Privacy for interaction with baby
  – Privacy for interaction with med staff
  – A sense of control, belonging, family
SFR – The Rationale

• Caregivers also benefit from appropriate lighting and noise control.
• SFR design permits some nursing functions to be separated from direct patient care areas and provided with lighting and sound that is suitable for adult workers
This, too, is not a new concept.....
SFR – The Current Database

• Adult and Pediatric units proved that the concept was feasible
• Pioneering NICUs demonstrated that the concept was practical
• Pitfalls do exist – a bad SFR design can be worse than current NICUs
  – e.g., Building single-\textit{family} rooms without including the family!
Extended parental presence in SFR improves preterm infant outcomes

<table>
<thead>
<tr>
<th>&lt;30 weeks gestation</th>
<th>Standard Care</th>
<th>FCC (rooming-in)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS, ICU</td>
<td>43.1 days</td>
<td>32.4 days</td>
<td>p=.02</td>
</tr>
<tr>
<td>LOS, total</td>
<td>66.7 days</td>
<td>56.6 days</td>
<td>p=.04</td>
</tr>
<tr>
<td>mod/severe BPD</td>
<td>6.0%</td>
<td>1.6%</td>
<td>OR 0.18 (0.4-0.8)</td>
</tr>
</tbody>
</table>

- Adapted from Ortenstrand, et al. *Pediatrics* 2010;125:e278-85
Cabell Huntington NICU

- Mean/median GA 34 weeks
- Moderate severity of illness
- No change in staffing ratios

<table>
<thead>
<tr>
<th></th>
<th>OPEN</th>
<th>SFR</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>17.9</td>
<td>15.7</td>
<td>NS</td>
</tr>
<tr>
<td>Vent days</td>
<td>7.3</td>
<td>5.0</td>
<td>NS</td>
</tr>
<tr>
<td>CPAP days</td>
<td>7.4</td>
<td>7.1</td>
<td>NS</td>
</tr>
<tr>
<td>Apnea events</td>
<td>29.3</td>
<td>12.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Caffeine days</td>
<td>10.3</td>
<td>7.5</td>
<td>NS</td>
</tr>
<tr>
<td>TPN days</td>
<td>7.3</td>
<td>5.1</td>
<td>0.048</td>
</tr>
<tr>
<td>MBM days</td>
<td>23.2</td>
<td>34.4</td>
<td>0.031</td>
</tr>
<tr>
<td>Late sepsis</td>
<td>11%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Leq</td>
<td>46-53</td>
<td>32-34</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Domanico R, Davis DR, Coleman F, Davis BO. *J Perinatol* 2011;31:281-8.
Boekelheide NICU at Sanford Children’s Hospital
Single-Family Room

Stevens, et al.
### Overall Assessment

Stevens, et al., HERD 2012

<table>
<thead>
<tr>
<th>Category</th>
<th>Old NICU</th>
<th>New NICU</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Family Friendly</strong></td>
<td>38.2</td>
<td>65.1</td>
<td>+26.9</td>
</tr>
<tr>
<td><strong>Staff Work Together</strong></td>
<td>60.7</td>
<td>71.8</td>
<td>+11.1</td>
</tr>
<tr>
<td><strong>Care Given to Baby</strong></td>
<td>69.1</td>
<td>81.2</td>
<td>+12.1</td>
</tr>
<tr>
<td><strong>Care to Family</strong></td>
<td>55.4</td>
<td>68.6</td>
<td>+13.2</td>
</tr>
<tr>
<td><strong>Likely to Recommend</strong></td>
<td>71.4</td>
<td>82.6</td>
<td>+11.2</td>
</tr>
</tbody>
</table>

No change in staffing levels and a **15% reduction in costs** when adjusted for acuity and inflation.
Vanderbilt Family Study


• 53 parents who spent time in both open and private rooms said that private rooms facilitated
  – More time with infant
  – More privacy
  – Less overstimulation by noise and light
  – Greater access to doctor; comparable access to nurses
  – Better supported; comparably informed

• Although physicians continued to round in the usual fashion, presence and participation of families became normal in the private rooms

• No changes in nursing ratios occurred
Two Sides of the Same Coin...

- Privacy
  - Families need it, we are mandated to provide it
- Isolation
  - An inevitable by-product of privacy
  - Can produce adverse effects (Pineda et al 2014)
  - Perception varies according to culture, situation
  - Addressed by good design (e.g., welcoming, easily accessible gathering areas), programs (e.g., MoD Family Support), and high level of awareness by staff
Private Room Views
St. Paul Children’s
St. Paul Children’s – Conclusions
Smith, Schoenbeck, Clayton (Work 2009;33:211-27)

• Staff perceive the private room environment to be consistently better than open bay in relation to:
  – Work environment quality
  – Patient care quality
  – Job quality
  – Interaction with NICU patient care technology
  – Interaction with NICU patients and parents
  – Quality of life off-the-job

  BUT....

• Staff perceive open bay to be substantially better than private room for interaction with other members of the NICU patient care team
Some Reasons to Consider Some “Open” Space Along With SFRs.....

Single family rooms may lead to:

- Isolation of babies when families are absent
  – Pineda, et al 2014

- Isolation of families who prefer frequent social interaction

  And for

- Higher order multiples

So some open rooms may still be desirable
• SFR + parents = “home”,
  natural neonatal neuroprotection
• SFR without parents = isolation,
  sensory deprivation
Neuroprotective Elements of the Newborn Environment

- Normal flora
- Mother’s milk
- Appropriate sensory stimuli
- Extended maternal contact
  - Important in its own right, but also promotes all of the others, thus reinforcing a virtuous cycle
  - If all the baby’s senses are engaged even when asleep, where is the best environment for them?

Single-family rooms are means to an end – they do not replace the mother’s arms as the optimal environment for all newborns.
Natural Neonatal Neuroprotection
(courtesy of Dr. Nils Bergman)
Developmental Care:

Getting it “Just Right”
<table>
<thead>
<tr>
<th>Sensory Modality</th>
<th>Too Much</th>
<th>Too Little</th>
<th>Just Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory</td>
<td>Noise</td>
<td>Isolation</td>
<td>Conversation, ?music?</td>
</tr>
<tr>
<td>Visual (rods/cones)</td>
<td>???</td>
<td>???</td>
<td>???</td>
</tr>
<tr>
<td>Light (melanopsin)</td>
<td>Continuous bright</td>
<td>Continuous dim</td>
<td>Circadian (beyond 28-32 weeks)</td>
</tr>
<tr>
<td>Movement/kinesthetic</td>
<td>Disturbing sleep</td>
<td>Inert bed</td>
<td>Gentle rocking</td>
</tr>
<tr>
<td>Touch</td>
<td>Disturbing sleep</td>
<td>Inert bed</td>
<td>Infant massage</td>
</tr>
<tr>
<td>Taste</td>
<td>noxious</td>
<td>NPO</td>
<td>Breast milk</td>
</tr>
<tr>
<td>Smell</td>
<td>noxious</td>
<td>NPO</td>
<td>Breast milk, gentle pleasant scents</td>
</tr>
<tr>
<td>Pain control</td>
<td>Continuous drip</td>
<td>No pain control</td>
<td>PRN meds and strategies</td>
</tr>
<tr>
<td>Skin-to-skin</td>
<td>???</td>
<td>What most of us are doing now</td>
<td>Whenever possible</td>
</tr>
<tr>
<td>Devt. Care</td>
<td>Too Much</td>
<td>Too Little</td>
<td>Just Right</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
<td>-----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Auditory</td>
<td>The <strong>Goldilocks</strong> Principle:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual (rods/cones)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light (melanopsin)</td>
<td><strong>STS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement/kinesthetic</td>
<td></td>
<td><strong>Gets</strong></td>
<td><strong>ALL</strong></td>
</tr>
<tr>
<td>Touch</td>
<td></td>
<td></td>
<td><strong>of these</strong></td>
</tr>
<tr>
<td>Taste</td>
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<tr>
<td>Smell</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pain control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin-to-skin</td>
<td><strong>JUST</strong></td>
<td><strong>RIGHT</strong></td>
<td><strong>!!!</strong></td>
</tr>
<tr>
<td>Feeding choices</td>
<td>1970</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td><strong>Formula</strong></td>
<td>Preferred – convenient, sterile, varied “recipes”, cheap</td>
<td>Used in only a few ELBW babies, formulated to be as much like breast milk as possible</td>
<td></td>
</tr>
<tr>
<td><strong>Breast milk</strong></td>
<td>Rarely used, and then only with precautionary measures</td>
<td>Used preferentially; considered the gold standard</td>
<td></td>
</tr>
<tr>
<td>Environment of Care -&gt;</td>
<td>Incubator/ Warmer</td>
<td>Mother’s Arms</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>Today</td>
<td>Warm, secure</td>
<td>Hassle, risky</td>
<td></td>
</tr>
<tr>
<td>NICU of the Future</td>
<td>Devoid of human contact and normal stimuli; used sparingly</td>
<td>Natural extension of fetal environment; rich source of natural stimuli</td>
<td></td>
</tr>
</tbody>
</table>
A 3-Step Approach to Developmental Care

• Create a nurturing physical environment for babies, families, and caregivers

• Get babies into their parents’ arms whenever possible

• Use principles of developmental care – the unit culture is probably more important than the method used
Design that Lifts the Spirit

• A well-recognized concept, but of particular importance in healthcare facilities
• Important elements include
  – Access to daylight and nature
  – Scale
  – Color
  – Form (angular is not natural!)
  – Life

*A design that is optimal from a functional standpoint but does not nourish the spirit treats patients, families, and caregivers as less than fully human.*
The “Elevator Speech”:

• **Nowhere** in the hospital is the need greater:
  – Crucial period of brain development
  – No patient needs their family more – emotionally **and** biologically.
  – Potentially just as life-changing for the family

• Important, profound things are also happening elsewhere in the hospital, but not with the frequency or long-term impact of the NICU – for better or worse, brains and families are being formed for a lifetime every day in the NICU.
Resources

• Recommended Standards for Newborn ICU Design – www.nd.edu/~nicudes/
  – Also published in supplements to the Journal of Perinatology in 2007 and 2012, with several accompanying articles of interest

• Clinics in Perinatology – June ‘04 and December ‘11

• Gravens/March of Dimes Conference – Clearwater Beach, FL – March 4-7, 2015

www.cme.hsc.usf.edu and on Facebook
We shape our buildings and afterwards our buildings shape us.”

-Winston Churchill (former premie)

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