5 Important Things to Know about the Motor System of the Preterm Infant!

Maureen Luther B.Sc (P.T) MA
Paediatric Physiotherapist
Toronto ON

Objectives

1. Discuss how stress influences the neurodevelopmental outcome of preterm infants
2. Describe the characteristics and developmental significance of various movements exhibited by preterm infants
3. Outline how this form of the infants’ communication could influence how we deliver developmentally supportive care within the NICU
Outline

1) The Motor System
2) Stress affects brain development
   - stress, pain and stability movements
3) General movements
4) Feeding “motor” cues
5) Clinical application in the NICU

#1: The Motor System

**Motor system consists of:**
- Muscle tone, postures and movement patterns

**Indicative of:**
- Disorganization
- Self-regulation
- Neurological integrity

**Reactive to endogenous and exogenous demands but also spontaneous**
Muscle Tone: what is it?

- Passive Muscle Tone:
  - Amount of resistance in response to passive movement or stretch
  - Contributes to postural control and coordination of the extremity movements

- Active Muscle Tone:
  - Sustained muscle contraction to maintain a posture against gravity, changing in response to movement

- Postures:
  - Reflective of muscle tone
  - Against gravity
  - At the “mercy” of gravity

Movement Repertoire of Preterm Infant

- Spontaneous General Movements
- Movements indicating pain
- Movements indicating stress
- Movements indicating stability, self soothing
- Feeding
#2: Contributions to Neurodevelopmental Outcome

- **Brain Injury**
  - Hemorrhagic or ischemic

- **Interrupted/Altered Neurodevelopment**
  - Secondary Cortical Dysplasia (Volpe, 2009)

- **Stress**
  - Reduced brain volumes and functional connectivity (Smith et al., 2011)

---

How stress affects the Brain

- **Activates the HPA axis**
  - Intertwined with the Autonomic Nervous System (Grunau R, 2003)

- **Maternal Separation**

- **Epigenetics** (Maddalena P, 2013)
  - Altered gene expression
**Causes of Stress**

- Types of stressors (concurrent):
  - Exogenous: Environmental Stressors
    - Macro Environment = NICU
      - Increase in lighting and sound have shown a positive correlation with increase in RR and O2 desat and motor activity
      - Reversing the condition in the smaller preterm neonate did not reverse the effect (Shogun, 1993)
    - Micro Environment = immediate area around the infant
      - Caregiving tasks, painful procedures and sleep disruption
  - Endogenous
    - Infant’s medical status

---

**Stress vs. Stability Cues**

<table>
<thead>
<tr>
<th>Autonomic</th>
<th>Stress</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>Bradycardia/tachycardia</td>
<td>Stable HR</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>Apnea/tachypnea</td>
<td>Stable RR</td>
</tr>
<tr>
<td>Oxygen saturation</td>
<td>Desaturation</td>
<td>Normal &amp; consistent saturation</td>
</tr>
<tr>
<td>Colour</td>
<td>Gray, pale, ashen</td>
<td>Pink</td>
</tr>
<tr>
<td>Visceral</td>
<td>Yawning, sneezing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gagging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hiccupping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bowel movements</td>
<td></td>
</tr>
<tr>
<td>State Regulation</td>
<td>Dysregulated/Disorganized</td>
<td>Regulated/Organized</td>
</tr>
</tbody>
</table>

Als, H 1982
Motor Stress Cues

- Stress cues tend to involve extension (Als, 1984)

Finger splay, facial grimace (extension of the upper face) and LE extension (Holsti, 2006)
  - Most prominent motor cues related to procedural handling

Finger splay
  - Reliable indicator of non-specific stress (Holsti & Grunau, 2007)

Grimace
  - Represents sensitization (Grunau et al, 2000; Peng NH et al, 2009)

Motor activity
  - Most often related to low O2 (Harrison et al, 2003)
Motor Stability Cues

Extremity Actions

General Extremity Actions
1) Trunk tuck
2) Flexion of UE’s & LE’s
3) Smooth Movements

Specific Extremity Actions
1) Hand to mouth
2) Hands together
3) Hand or foot grasp
4) Foot bracing
5) NNS
6) Soft face

(Als.H 1982)

Stress vs. Pain (pain/extreme stress)

<table>
<thead>
<tr>
<th>Stress</th>
<th>Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physiology</strong></td>
<td>+ ANS &amp; HPA (hypothalamic-pituitary-adrenal) axis</td>
</tr>
<tr>
<td><strong>Definition</strong></td>
<td>Reaction induced by: 1. tactile stimulation of noninvasive procedural handling 2. environmental factors</td>
</tr>
<tr>
<td><strong>Behavioral</strong></td>
<td>Tends to involve extensor posturing and subtle facial responses</td>
</tr>
<tr>
<td><strong>Management</strong></td>
<td>Micro and Macro-environmental modifications</td>
</tr>
</tbody>
</table>
• **Facial Movements:**
  • Brow Bulge
  • Eye squeeze
  • Nasolabial Furrow
    (Stevens et al, PIPP – R, 2014)

• **Body Movements:**
  • Extension of arms and legs
  • Finger splay
  • Fisting
  • Flexed legs and arms
  • Hand on face
    (Holstil et al, 2005, Morison et al, 2003)

• **Physiologic Indicators:**
  • Heart rate*, Oxygen saturation

• **Contextual:**
  • Behavioral state and gestational age
    (Holstil et al, 2005, Stevens et al, 2014)

---

**#3: General Movements**

“A window into the brain” (Prechtl, H. 1997)

• Primary movement patterns of the fetus (9 wks) and infant
• Spontaneous movement patterns which involve all body parts in variable sequences
• Movements wax and wane in intensity, speed, sequence, and amplitude
• Spontaneously driven
• Motor behaviour in the healthy fetus and infant shows profuse variation and complexity (Prechtl, H. 1979; Hadders-Algra, M. 2000)
General Movements

- GM’s emerge with synaptic activity of the Cortical Subplate (Hadders-Algra M.2007)
- Central Patterns Generators (CPG’s)
  - Neuronal networks providing motor control of rhythmic movements
  - Cortical subplate neurons descending pathways to CPG networks
- Modulation of CPG’s provides variability

Developmental Course of General Movements

(Einspeler & Prechtl 2005)
Normal Term Movements

39 weeks
GA = 24+3

May 30, 2019
Luther

General Movements Assessment (GMA)

Quality of general movement on overall impression
Is there variability?
Is there fluency?

Normal GMs

Abnormal GMs
Literature on GM’s

- Significant relationship between GM’s at term/writhing stage (1 month) and fidgety movement stage (3 mos) and cerebral white matter abnormality on MRI at term age.
  - Strong correlation between normal GM’s and no white matter abnormality
  - Abnormal GM’s at 1 mos followed by normal GM’s at 3 mos displayed mild white matter injury
  - Persistence of ABN GM’s at 1 and 3 months had white matter abnormality (moderate to severe)
- Presence of cramped synchronized movements correlated to evidence of white matter injury (Spittle, Brown, Doyle et al, 2008)

#4: Movements associated with Feeding

Distinct movement patterns:
- Feeding Readiness Cues
- Stability with feeding
- Stress - subtle or “Potent” (NCAST, 2015)
Feeding Readiness® Scale
1 or 2 – can attempt to orally feed
3-5 – do not attempt to orally feed Ludwig and Waltzman, 2007

1. Alert or fussy prior to care. Rooting and/or hands to mouth behavior. Good tone.


5. Significant HR, RR, O2, or WOB outside of baseline
   HR <100 bpm, RR > 60 bpm, SaO2 <80 %, WOB=nasal flaring, tracheal tugging
   Action: Stop feeding, reassess, if scores 1-2 and physiologically returns to baseline, retry once more

“Stability” Motor Feeding Cues

- Oral Motor:
  - Coordinated SSB, rhythmical preterm suck (pause= burst)

- Facial:
  - Soft, open eyes, brow raising

- Body: Flexion
  - Hands open, fingers slightly flexed
  - Feeding posture: upper arms adducted, lower arms held closely into abdomen
## “Subtle” Stress Motor Feeding Cues

**Oral Motor:**
- Loss of rhythm and coordination of SSB

**Facial**
- Eye blinking – multiple
- Frowning, grimace, raised eyebrows
- Gaze Aversion
- Lip compression
- Tongue flattens

**Body**
- Arms straightened by side
- Diffuse body movements
- Finger splay
- Immobility
- Increased feet movement

## “Potent” Stress Motor Feeding Cues

**Oral Motor:**
- Gagging, vomiting, coughing

**Facial:**
- Cry face

**Motor:**
- Back arching, body extension
- Pulling away, pushing away
- Increased limb movement
- Maximum lateral gaze aversion
#5: Clinical Application in the NICU

## NICU Interventions: Cluster of Care

**Routine nursing care: A stressful event!**

- **Cluster of Care: to allow longer rest periods?**
  - Balance between shorter rest period, fewer tasks — less intense response (Holsti et al, 2005)

- **Infants born < 32 weeks GA** — significant physiologic and motor responses indicating stress during care and persisted beyond the time of handling (Holsti et al, 2005)

- **Timing of procedural care vs a painful procedure affects infant’s response** (Holsti L et al, 2006)

- **Associated handling of the infant accounted for 37.5% of Unplanned Extubations (UE)** (Aydon, 2018)
Behavioral Responses to Pain Are Heightened After Clustered Care in Preterm Infants Born Between 30 and 32 Weeks Gestational Age

Lisa Holtei, PhD.*†‡ Ruth E. Grunau, PhD.*‡ Michael F. Whitfield, MD.*‡‡ Tim F. Oberlander, MD.*‡‡ and Venice Lindh, PhD.

### TABLE 2. Facial (Neonatal Facial Coding System Total Scores) and Heart Rate (Mean±SD) Responses to Phases of Blood Collection (Baseline, Heel Lance, and Recovery) Before or After Clustered Care by GA Group

<table>
<thead>
<tr>
<th>Facial Activity</th>
<th>Mean HR</th>
<th>25-29wk GA at Birth</th>
<th>30-32wk GA at Birth</th>
<th>25-29wk GA at Birth</th>
<th>30-32wk GA at Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clustered care before blood collection</td>
<td>Baseline</td>
<td>6.7 ± 7.6</td>
<td>2.6 ± 6.4</td>
<td>158.3 ± 10.2</td>
<td>148.1 ± 10.8</td>
</tr>
<tr>
<td>Heel lance/squeeze</td>
<td>46.2 ± 21.0</td>
<td>37.8 ± 23.3</td>
<td>182.9 ± 14.3</td>
<td>168.8 ± 13.8</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td>16.0 ± 22.6</td>
<td>8.6 ± 15.9</td>
<td>160.7 ± 15.4</td>
<td>151.0 ± 14.4</td>
<td></td>
</tr>
<tr>
<td>Rest before blood collection</td>
<td>Baseline</td>
<td>8.1 ± 8.1</td>
<td>3.9 ± 5.5</td>
<td>164.7 ± 11.5</td>
<td>152.6 ± 9.9</td>
</tr>
<tr>
<td>Heel lance/squeeze</td>
<td>42.1 ± 17.9</td>
<td>35.6 ± 19.6</td>
<td>183.5 ± 14.1</td>
<td>167.4 ± 10.1</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td>14.5 ± 17.9</td>
<td>20.6 ± 24.4</td>
<td>157.7 ± 14.1</td>
<td>158.7 ± 14.6</td>
<td></td>
</tr>
</tbody>
</table>

*Baseline recording after undisturbed 30 min period. **P < 0.05.

Prior pain induces heightened motor responses during clustered care in preterm infants in the NICU

Lisa Holtei, PhD.*†‡, Ruth E. Grunau, PhD.*‡, Tim F. Oberlander, PhD.*‡, Michael F. Whitfield, PhD.

### Table 3. NIDCAP® stress and stability cues across three phases of Clustered Care following Rest (RCC) and Clustered Care following Pain (PCC) (n=54)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Baseline [mean (S.D.)]</th>
<th>Handling [mean (S.D.)]</th>
<th>Recovery [mean (S.D.)]</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCC stress cues</td>
<td>2.3 (4)</td>
<td>14.3 (7)</td>
<td>6 (8)</td>
<td>17.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>RCC stability cues</td>
<td>1.8 (3)</td>
<td>5.3 (4)</td>
<td>4.4 (7)</td>
<td>4.6</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>PCC stress cues</td>
<td>3.8 (6)</td>
<td>16.7 (8)</td>
<td>4.2 (6)</td>
<td>23.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PCC stability cues</td>
<td>3.5 (5)</td>
<td>7.4 (6)</td>
<td>3.6 (6)</td>
<td>4.4</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>
NICU Interventions: Handling

- **Two person care:**
  - Allows provision of cue responsive care for the baby with one set of hands to perform tasks and one set for comfort throughout (Atwater, A – NICQ Small Baby Collaborative 2016)
  - During routine care, painful procedures and head turning when intubated (Powell, 2016)
  - Provide the infant with self-regulatory/stability behaviours
  - Prevent combination of physiological and motor stress behaviours
  - Monitor complex multiple stimuli

NICU Interventions: Developmentally Supportive Positioning

- Cannot be a static intervention
- Needs to change with medical needs, neurological maturation and gestational age

“Developmentally supportive and age appropriate”
Phases of Positioning: Acute

- **<30 wks: 1st 72 hours**
  - Head in midline
  - Supine or side lying
  (Malusky, S & Donze, A. 2011; Carteaux, P. 2003)

- **> 72 hours or 30-34 wks or >34 weeks with respiratory distress**
  - Minimizing stress movements
  - Promote sleep and stability
  - Prone, side lying or supine with positioning aides
  - No prone with UAC

- **> 34 weeks - no respiratory distress**
  - Supine, flat bed, no positioning aides
Phases of Positioning: Transitional

- > 30 weeks, medically stable
- Allow movement
  - Reduce containment
  - Provide supports and boundaries
  - Monitor stress movements
- Nest vs containment
- Supine and side lying

Effects of prone and supine positions on sleep state and stress responses in preterm infants
T. Jarus, O. Bart, G. Rabinovich, A. Sadeh, L. Bloch, T. Dolfin, I. Litmanovitz

![Graph showing number of reactions in prone vs supine positions.](image)

Fig. 1: Approach and withdrawal reactions during prone and supine position.
Phases of Positioning: Preparing for Discharge

- At least two weeks prior to discharge (AAP, 2011)
- Supine
- Flat bed
- Eliminate positioning aides, swaddling, blankets
- Parent education
NICU Interventions: Infant Directed Feeding

Infant directed feeding: NANN guidelines 2013

- infant provides cues to parent (who is the primary feeder) using physiological, motor and state systems for non-nutritive and nutritive oral feeding experiences

- **A neuroprotective strategy!!**

Recognizing and Responding to Infant Feeding Cues

**Stability**

**Subtle stress**

**Potent Stress**
**NICU Interventions: Pain Management**

- **Prevention/ Avoid unnecessary painful procedures**
- **Non-pharmacological pain management**
  - Sucrose + NNS (Gibbins et al, 2014)
  - Non-nutritive sucking (NNS) (Pinelli & Symington, 2010)
  - Sucrose (Stevens et al, 2005)
  - Skin to skin (Cong et al, 2011)
  - Breastfeeding/ Use of Breast Milk (Shah et al, 2007)
  - Positioning with containment (Grunau et al, 2004)
  - Facilitated tuck by parents (Axelin et al, 2009)

**Parental Involvement**

**Infant Benefits:**
- Physiological stability (Ludington Hoe, 2013)
- Organized sleep wake cycles (Ludington Hoe, 2006)
- Reduces stress (Morelius et al, 2005)

**Parent Benefits:**
- Improved milk production & duration of breast feeding
- Improved attachment (Johnson, AN, 2007)
Conclusion

- The movement repertoire of the preterm infant is a form of communication
- Allows NICU caregivers to be:
  
  **Developmentally Supportive:**
  - Inhibit stress movements
  - Promote movements of stability
  - Recognize and diminish pain

  **Age Appropriate:**
  - Allow “normal” spontaneous movement
  - (GM’s) with transitional and dynamic positioning

Questions???

maureen.luther@sunnybrook.ca