Objectives

- Review risks factors associated with adverse neurodevelopmental outcomes in NICU infants
- Outline methods used to screen infants for neurodevelopmental sequelae of prematurity and other NICU morbidities
- Discuss goals of developmental follow-up care

Developmental Follow-up Care

- There are currently no universal guidelines for the provision of developmental follow-up care
- How do we define who, how, what, when...?
Who needs developmental follow-up?

Prematurity

- Almost 12% of infants in the US are born preterm
- Up to 50% of preterm infants will have physical, behavioral and/or developmental difficulties as a result of their prematurity

Changes in perinatal care have resulted in improved survival for very preterm infants
- This extends to the most preterm infants (23 to 25 weeks)
- Improvement in survival has not been accompanied by improvement in neurodevelopmental outcomes
- This results in an ↑ number of infants discharged home at risk for neurodevelopmental impairment
- These infants require specialized follow-up care
Preterm < 37 weeks

Term 37-42 weeks

Definitions

• Late preterm
  • 34° – 36°

• Moderate preterm
  • 32° – 33°

• Very preterm
  • 28° – 31°

• Extremely preterm
  • 23° – 27°

→ higher risk

Definitions

• Low Birth Weight (LBW)
  • < 2500 grams

• Very Low Birth Weight (VLBW)
  • <1500 grams → higher risk

• Extremely Low Birth Weight (ELBW)
  • < 1000 grams → highest risk
More definitions…

• Threshold of viability
  • Limits of prematurity below which an infant is not viable despite maximum technologic and medical support
  • Usually considered to be 23 weeks gestation

Other neonatal risk factors

• Small for gestational age (SGA)
  • < 3rd %ile for weight
• Neonatal encephalopathy (including seizures)
• Other perinatal neurologic injury
• Central nervous system infection
  • Meningitis
  • TORCH
• Congenital brain malformations
• Congenital heart malformations
• Infants requiring major surgery (cardiac, thoracic, etc)
• Severe hyperbilirubinemia requiring exchange transfusion
• Need for mechanical ventilation in the newborn period
• Any neurobehavioral abnormality in the newborn period

Why do they need follow-up?
The consequences of neonatal morbidity do not end at NICU discharge.

In fact, for some they are only just beginning.

We are morally and ethically responsible for ensuring that these high risk infants have a trajectory of developmental care outlined prior to NICU discharge, to ensure the best possible outcomes for our graduates and their families.

Vulnerability of ELBW infants

- ELBW infants are at increased risk of brain injury from sepsis, under-nutrition & hypoxia-ischemia
- Brain development during the 2nd & 3rd trimester involves a complex sequence of events that includes the production of neurons, their migration & maturation, apoptosis, formation of inter-neuronal connections, & synaptic pruning, making the brain vulnerable to injury.

Impact of Preterm Birth on Developing Brain Volume

These differences persist into adulthood
The presence of significant brain injury* on cranial ultrasound is a strong predictor of neurodevelopmental outcome at 2-3 years.

*Grade 3-4 Intraventricular Hemorrhage
Periventricular Leukomalacia
However, severe brain injury is only present in about 11% of VLBW infants…

How about the other preterm babies? Are they guaranteed normal development?

Normal Cranial ultrasound does not always predict good outcome

• ELBW infants with normal cranial ultrasounds are still at risk of long-term neurodevelopmental impairment
  • Cerebral Palsy 9.4%
  • Cognitive impairment 25.3%
  • Motor delays 29.2%
  • Only 19% are “completely normal”

Neurodevelopmental Impairment (NDI)

• One or more of the following...
  • Moderate to Severe Cerebral Palsy
  • Blindness
  • Deafness
  • Severe Cognitive Impairment (MDI <70)
  • Severe Motor Delay (PDI <70)
Cerebral Palsy in Children by BW

<table>
<thead>
<tr>
<th>Birth weight (grams)</th>
<th>CP prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal birth weight (&gt;2500)</td>
<td>0.1%</td>
</tr>
<tr>
<td>1500-2499</td>
<td>1%</td>
</tr>
<tr>
<td>&lt; 1500</td>
<td>10%</td>
</tr>
<tr>
<td>&lt; 1000</td>
<td>10-20%</td>
</tr>
<tr>
<td>&lt; 500</td>
<td>30-50%</td>
</tr>
</tbody>
</table>

Spastic diplegia (50%); Spastic quadraplegia (25%)

Cerebral Palsy

- Most common cause of severe physical disability in childhood
- Umbrella term for group of disorders caused by injury to the developing brain
- Non-progressive but often changing
- Abnormal muscle tone, strength, reflexes, postural control, coordination and movement
- Delay in motor milestones
- No 2 children with CP are the same

Causes of CP
Other impairments
• NDI defines only the most severe and disabling impairments
• Prematurity also results in increased rates of other, less severe impairments
  • Motor
    • Torticollis +/- Plagiocephaly
    • Transient dystonia
    • Minor motor dysfunction
    • Developmental Coordination Disorder
  • Neurosensory
  • Cognitive
    • neuropsychological deficits (memory, executive function)

Torticollis
• Tilting of the head to one side with turning of the head toward the other side
• Caused by tight muscles in the neck
• Acquired in premies from positioning (always looking to one side) leading to muscle tightening until the infant can’t turn to the other side easily

Plagiocephaly
• Flattening of one side of the head
• In premies is caused by torticollis combined with Back to Sleep positioning
Torticollis and Plagiocephaly

- Treatment
  - Stretching of tightened neck muscles
  - Strengthening of weak neck muscles
  - Tummy Time!!
  - Positioning to encourage baby to look the other way
    - Place crib, bassinet, car seat so infant has to look the other way to see all of the interesting things going on in the room (mommy, toys, etc)
    - Feeding baby in the opposite arm
    - Helmet (if all else fails or if severe)

Transient dystonia

- 50% of all LBW infants
- Shoulder retraction, hip rotation
  - Increased extensor tone in trunk and lower extremities
  - Increased adductor tone in lower extremities
- Persistent primitive reflexes
- 80% disappear between 8 and 12 months
- 20% diagnosed with Cerebral Palsy

Minor Motor Dysfunction

- Fine motor dysfunction frequent
  - 70% ELBW
- Visual-motor abnormalities
  - Up to 25% of ELBW
- Developmental Coordination Disorder (DCD)
  - Mild abnormalities on exam
  - “Clumsy child”
  - 1/3 of VLBW and 1/2 of ELBW infants
Oromotor Dysfunction

- Less common
- Choke, Gag, Cough, Gasp when fed
- Drool continually
- Weak cry
- If severe...
  - May result in failure to thrive
  - May require tube feeds

Cognition in Preterm Children

- Lower mean cognitive scores at 18 months (70-86)
- Lower mean IQ at school age (82-105)
- Higher rate of Cognitive impairment
  - Scores ≤2 standard deviations below the mean (≤ 70)
  - 39% at 18 -36 months
  - 16% at school age

Cognition in Preterm Children

- Language
  - Initial expressive language delay with normal receptive language common
  - Good understanding of single words but difficulty with complex and abstract language
  - Vocabulary improves but difficulty with syntax, abstract verbal skills, and verbs
  - High risk for Learning Disabilities (25-40%)
- Memory impairments
- High rate of Academic Underachievement
Cognitive impairments associated with prematurity

- Poor school performance/school failure
- Lower IQ scores
- Learning disabilities
- Language impairments
- Impairments in executive function/organization
- Attention deficits
- Poor judgment and self-control
- Difficulties with visual-spatial tasks

ELBW Infants at School Age

- Standard Placement: 50%
- Resource: 24-41%
- Special Education: 25-62%
- Repeat a grade: 15-34%

Long-Term Vision Development

- Ex-preterm children have higher rates of:
  - Reduced visual acuity, color vision and contrast sensitivity
  - Strabismus
  - Myopia
  - Visual processing difficulties
  - Blindness

Even with no Retinopathy of Prematurity

Fielder & Moseley, 2000; Dowdenwell; Moseley, et al, 1995;
Development of Blind Children

• Delays in motor skills, learning, attachment due to lack of visual experience and absent face to face visual contact
  • Walking 3 steps alone
    • 15 months vs. 12 months
  • Smiling to a familiar face
    • 6 months vs. 6 weeks

• Similar language development to sighted children

Hearing Loss

• Hearing loss is more frequent
  • 0.1% term
  • 0.5% preterm
  • 1-2% ELBW

• Undetected hearing loss has serious negative consequences
• Even mild or unilateral hearing loss increases risk of speech/language delay and grade repetition

Outcome of Undetected Hearing Loss

• Language impairment
• Reading impairment
• Academic difficulties
• Psychosocial difficulties
• Emotional difficulties
Universal Screening

- All newborns, whether preterm or term, are screened for hearing loss prior to discharge from the nursery or NICU
- Early identification and intervention has dramatic benefits on language, communication, literacy, behavior and quality of life

Behavior Disorders of Former Preterms

- Attention deficit, hyperactivity disorder
- Anxiety and depression
- Internalizing and thought problems
- Poor social skills
- Sensory disorders
- Autism spectrum disorder
- Regulatory disorders

Outcomes related to...

- Survival and Rates of Morbidities are highly dependent on
  - Gestational age
  - Birth weight

- Other factors
  - SGA/IUGR
  - Cause of Preterm Birth
  - Short term outcomes influence Long term outcomes
    - Neonatal morbidities
    - Interventions
What else effects long term outcomes?

- Social and environmental factors (maternal education, race, social class)
- Biological factors (morbidities related to prematurity, genetics)

Environmental risk factors have a greater effect on the long-term cognitive outcomes than do biological risk factors.

Survival Without Disability

18-22 Month Outcomes by Gestational Age in ELBW

Survival Without Disability

18-22 Month Outcomes by Birth Weight in ELBW
Late Preterm (34-36 weeks gestation)

- 3.3 times higher risk for cerebral palsy
- 1.25 times higher risk for mental retardation
- More likely to have learning disabilities
- More likely to qualify for special education services

What about those other neonatal risk factors?

- Small for gestational age (SGA)
- Neonatal encephalopathy (including seizures)
- Other perinatal neurologic injury
- Central nervous system infection
- Congenital brain malformations
- Congenital heart malformations
- Infants requiring major surgery (cardiac, thoracic, etc)
- Severe hyperbilirubinemia requiring exchange transfusion
- Need for mechanical ventilation in the newborn period
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increase the risk of long term neurologic sequelae

Goal of Follow-up

- Early detection of developmental delays
- Parental support and education
- Link to services
  - Early Intervention (0-3 years of age)
  - School system (> 3 years)
  - Other therapies, treatments, specialists, etc
- Fill knowledge gaps
How/when do we provide developmental follow-up?

What does the ideal follow-up program look like?

Components of Follow-up

- Medical
  - Nutritional guidance
  - Oxygen management
  - Medication management
  - Infection control/immunizations
- Neurodevelopmental
- Behavioral
- Parental stress
Timing of follow-up

- Serial exams over time
  - Presentation and Diagnosis may change over time
- Some abnormal findings resolve over first 12-24 months (Plasticity)
- Clinical signs of Cerebral Palsy become more evident by 12-24 months
- Fine motor, Language, and Learning abnormalities become more evident with increasing age

Timing of follow-up

- Every 6 months for first 2-3 years
- Prior to Kindergarten
- Every 3 years through school years

Age

- Chronologic age: Age since date of birth
- Corrected age: Age since due date
  - Example:
    - Infant born at 28 weeks
    - Chronologic age: 12 months
    - Corrected age: 9 months

- Development and growth should be interpreted by corrected age until 2 years
Developmental Follow-up Evaluation

- History
  - Parental Concerns
  - Inter-current illnesses/hospitalizations
  - Medications
  - Services received
  - Dietary intake
  - Feeding, Sleep, Behavioral problems
  - Oxygen/Monitor usage
- Physical exam including growth parameters
- Standardized Neurologic exam
- Developmental Assessment

Developmental Follow-up Neurologic Exam

- Assessment of tone, strength, reflexes, angles

- Modified Claudine Amiel-Tison
  - Normal
    - no neurologic abnormality
  - Suspect
    - Deviations in tone, posture, movement patterns, reflexes, cranial nerves, head growth, or well controlled seizure disorder
  - Abnormal
    - Cerebral palsy, blind, deaf, poorly controlled seizure disorder, other neurologic finding impacting on function (hypotonia)

Gross Motor Function Classification

<table>
<thead>
<tr>
<th>Level</th>
<th>Walks without restrictions</th>
<th>Can run and jump with less speed, balance and coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>Walks without devices (except for AFOs)</td>
<td>Uneven surfaces, inclines, and crowds are difficult Can climb stairs using the railing Cannot run or jump</td>
</tr>
<tr>
<td>Level II</td>
<td>Walks with assistive devices (walker)</td>
<td>Use a wheelchair for longer distances</td>
</tr>
<tr>
<td>Level III</td>
<td>Use wheelchairs in the community</td>
<td>May achieve independence with a powered mobility system</td>
</tr>
<tr>
<td>Level IV</td>
<td>Self mobility is severely limited even with the use of supporting technology</td>
<td>Cannot sit, stand or walk Unable to hold up their head or trunk against gravity</td>
</tr>
</tbody>
</table>
Developmental Follow-up Screening/Assessment

- Screening/Surveillance
  - Pediatrician’s office at every visit
  - Should screen for
    - Delays in several domains of development
      - Ages and Stages
      - Denver Developmental
      - Autism Spectrum disorders
    - Identify children who MAY have developmental delays/deviations

Developmental Follow-up Screening/Assessment

- Assessment
  - Standardized assessment
  - Assess
    - Multiple domains of development
    - Behavior
    - Social-emotional
  - Provide standardized scores
  - Diagnose deviations/delays
  - Identify areas of strengths and weaknesses
  - Help direct therapies/educational strategies

First few months (0-6 months)

- Assess for ...
  - Growth failure
  - Feeding problems
  - Torticollis and/or Plagiocephaly
  - Transient dystonia
- Motor assessment
  - Prechtl’s General Movements Assessment
  - Alberta Infant Motor Scales (AIMS)
  - Test of Infant Motor Performance (TIMP)
  - Neurosensory Motor Development Assessment
First 3 years...

- Bayley Scales of Infant Development III
  - Cognitive Composite Score and Age Equivalent
  - Language Composite Score
    - Expressive Communication Age Equivalent
    - Receptive Communication Age Equivalent
  - Motor Composite Score
    - Fine Motor Age Equivalent
    - Gross Motor Age Equivalent

First 3 years...

- Infant-Toddler Social and Emotional Assessment (ITSEA)

- Modified Checklist for Autism in Toddlers (M-CHAT)
  - Follow up of any positive screen with an assessment
    - Autism Diagnostic Observation Schedule (ADOS)

After 3 years...

- Cognitive
  - Wechsler Scales
    - Wechsler Preschool and Primary Scales of Intelligence (WPPSI)
    - Wechsler Intelligence Scales for Children (WISC)
  - Stanford-Binet Intelligence Scales
  - Differential Ability Scales (DAS)
  - Kaufman Assessment Battery for Children

- Executive Function
  - NEPSY
  - Behavior Rating Inventory of Executive Function (BRIEF)
<table>
<thead>
<tr>
<th>After 3 years…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic Skills</strong></td>
</tr>
<tr>
<td>• Wechsler Individual Achievement Test (WIAT)</td>
</tr>
<tr>
<td>• Wide Range Achievement Test (WRAT)</td>
</tr>
<tr>
<td><strong>Adaptive functioning</strong></td>
</tr>
<tr>
<td>• Vineland Adaptive Behavior Scales</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>After 3 years…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Language</strong></td>
</tr>
<tr>
<td>• Preschool Language Scale (PLS)</td>
</tr>
<tr>
<td>• Clinical Evaluation of Language Fundamentals (CELF)</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
</tr>
<tr>
<td>• Movement Assessment Battery for Children</td>
</tr>
<tr>
<td>• Bruininks-Oseretsky Test of Motor Proficiencsy (BOT)</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>After 3 years…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social-Emotional/Behavior</strong></td>
</tr>
<tr>
<td>• Child Behavior Checklist (CBCL)</td>
</tr>
<tr>
<td>• Behavior Assessment System for Children (BASC)</td>
</tr>
<tr>
<td>• Strengths and Difficulties Questionnaire</td>
</tr>
<tr>
<td><strong>Autism specific</strong></td>
</tr>
<tr>
<td>• Gilliam Autism Rating Scale (GARS)</td>
</tr>
<tr>
<td>• Childhood Autism Rating Scale (CARS)</td>
</tr>
<tr>
<td>• Social Communication Questionnaire (SCQ)</td>
</tr>
<tr>
<td><strong>ADHD specific</strong></td>
</tr>
<tr>
<td>• Conners Parent/Teacher Rating Scales</td>
</tr>
</tbody>
</table>
Throughout childhood…

- Assess need for services
- Monitor response to services
- Assist with transition from Early Intervention to the Public School System at 3 years of age
- Assess kindergarten readiness

Supporting and Empowering Families

- Providing care coordination with the medical home
- Providing education to parents and providers
  - What do the scores mean?
- Referring to/collaborating with EI/consultants
  - What do we do now?
- Identify barriers and work with family to rectify
- Assess parent mental health

Scores – what do they mean?

- Mean 100
- Below average <85
  - Low < 70
Developmental Follow-up Team

- Neonatologist/Developmental-Behavioral Pediatrician
- Neonatal Nurse
- Family Support Specialist
- Physical Therapist
- Speech and Language Pathologist
- Coordinator

Other important players

- Ophthalmology
- Audiology
- Pulmonology
- Cardiology
- Gastroenterology
- Neurology
- Pediatric surgery
- Psychology
- Occupational therapy

What is the reality?
Specialized Follow-up Clinics

- Often State funded or funded by research grants
- Typically can’t justify follow-up beyond 2-3 years due to costs of care/lack of reimbursement
- Often not run by professionals with formal training in infant and child development

Early Intervention Program

- Federal and State funded
- Birth to 3 years of age
- Developmental support for children with developmental delays and/or medical conditions associated with developmental delays
- Evaluation/Monitoring/Intervention

Early Intervention

- Qualification based on
  - Diagnosis associated with developmental delay (Down Syndrome, Spina bifida, head trauma, etc.) or
  - Developmental delay
- Family financial need is not a qualifying factor
- Individualized Family Service Plan (IFSP)
- Least restrictive environment (often home)
Early Intervention

• Initial assessment
• Periodic Reassessment
• Provides Family Support Specialist
  • “Coaching” and Parent Support
• May also provide therapies
  • Occupational, Physical, Speech/Language, Nutrition
• Assist with transition to school system
  • Head Start
  • Special education

Individuals with Disabilities Education Act (IDEA) 1997

• All children are entitled to a public education
• Children from birth to 21 years of age with a disability that adversely affects the student’s educational progress and performance are entitled to special education services
• An Individualized Education Plan (IEP) must be designed to meet the unique educational needs of that one child in the Least Restrictive Environment appropriate to the needs of that child
  • Emphasizes special education and related services designed to meet their unique needs and prepare them for further education, employment, and independent living

Plasticity

Do extremely low birth weight infants have the potential to recover from insult with increasing age?

Do infants at 23-24 weeks gestation have the same potential to recover as infants> 25 weeks gestation?
Evidence for recovery with increasing age

- Cognitive Scores at 18-36 months are poorly predictive of IQ Testing at school age
- 18-36 months
  - Mean cognitive scores 70-86
  - 39% cognitive impairment
- School age
  - Mean IQ 82-105
  - 16% cognitive impairment

Plasticity

It is fortunate that infants have an inherent ability to recover from perinatal injury and stress

Parents, Physicians and Educators can actively contribute to their recovery to help every infant achieve his/her potential