The NeuroNICU
From Concept to Clinical Service
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What is a NeuroNICU?

• Collaboration between Neonatology and Neurology
• Neonatal Neurology: a new field
  – Helping NICU graduates have better developmental outcomes
• We can make our NICU graduates have better cognitive and developmental futures.
Adults Are Far Better Served Than Kids

**Adults**
- >1500 neuroICU specialists in the US
- Accredited specialty
- Literature-supported standards of care
- Multiple ways to continuously monitor brain function

**Babies**
- ~30 neuroICU specialists in the US
- **No** dedicated training programs
- One consensus-based standard-of-care
- One way to continuously monitor brain function
What We Are Doing

• Neonatal Neurointensive Care
  – 6 centers across the US
  – We are the second in California
Neonatal Neurointensive Care

• Care of critically ill baby brains
  – Seizures
  – Asphyxia
  – Brain hemorrhage
  – Stroke
  – Infection
  – Post-operative
  – Hydrocephalus
  – Brain malformation
What Can We Do?

• Therapeutic hypothermia for HIE
• EEG monitoring for seizure
  – Over half of neonatal seizures are subclinical
  – Neonatal seizures are bad for outcomes
• Research studies (current)
  – Novel methods of brain monitoring
  – Levetiracetam for neonatal seizures
  – Outcomes for perinatal stroke
  – Passive/transport cooling
Therapeutic Hypothermia

• Hypoxic ischemic encephalopathy (HIE)
  – Reduces deaths from HIE
  – Improves developmental outcomes
• First widely-used therapy for the neonatal brain
• The realization that neurologists can DO STUFF for the brain!
  – Stimulated growth of neonatal neurology
Big Questions about Neonatal Seizures

• What do they look like?
• Why do newborns have seizures?
• What is the best way to treat them?
• Do they affect cognitive outcomes?
• Does a diagnosis of neonatal seizures mean epilepsy?
• Why do we do continuous EEG recording?
Seizure Recognition in the Neonate

- Volpe’s four described semiologies
  - Subtle
  - Clonic
  - Tonic
  - Myoclonic

- http://www.youtube.com/watch?v=0j-pwZSKOpc
Seizure Recognition in the Neonate

• A large percentage of neonatal seizures (some say HALF) are clinically silent

• Behaviors that cause concern over seizure activity (so called “subtle” seizure activity)
  – APNEA
  – Eye deviation
  – Staring
  – Oral-buccal-lingual movements
  – Limb movements
  – Autonomic phenomena
A Word about the Annoying Apnea

- Apneic seizures are less likely to be associated with bradycardia.
- Apneic spells are more likely to be a seizure in a term neonate than a preterm one.
Pearl: Jitteriness or Seizure?

- Jitteriness does not have ocular phenomena.
- Jitteriness is stimulus-sensitive.
- Jitteriness looks tremulous and seizures look jerky.
- Jitteriness is not accompanied by autonomic changes.
Basic characteristics of neonatal seizures

- Random
  - Not situational, like with handling or suctioning, etc.
- May not see ANYTHING clinically
- Majority of neonatal seizures are provoked
WHAT TO DO if they’re doing something weird

• Observe and describe
  – Type of movement
  – Parts of body involved
  – Alterations in vitals
  – Number and duration of occurrences
  – Situation surrounding occurrence (i.e. “the baby arches their back whenever we try to get the IV”)

• While observing and describing: TRY TO INTERRUPT THE BEHAVIOR.
  – Rule of thumb: if you can’t interrupt it, it’s more likely to be a seizure.
And then...

• Call neonatology/neurology and discuss whether to hook up to continuous EEG monitoring.
• It is never the wrong decision to try and capture an event on monitoring if you are concerned.
• It is always the wrong decision to blow off something if you’re not sure what it is.
Why are neonates predisposed towards seizure?

• A seizure is excessive depolarization of neurons.
• Neurons in the newborn are predisposed towards excessive depolarization because of fundamental differences in their physiology with respect to:
  – Sensitivity to energy supply decreases
  – Excess of excitatory neurotransmitters
  – Deficiency of inhibitory neurotransmitters
  – Hypocalcemia or hypomagnesemia
Causes of Neonatal Seizures

• Hypoglycemia
• Hypomagnesemia
• Hypocalcemia
• HIE
• Stroke
• Intracranial bleed
• Cerebral dysgenesis
• Genetic problems
• Inborn errors of metabolism
• “Benign neonatal convulsions”

The “Hypos”
Other examples of seizures

http://www.youtube.com/watch?v=0j-pwZSKOpc
Nothing clinical—only on EEG

- 1mo term baby, wasn’t waking up after bladder surgery
  - Was in status
- 2 week old term baby, came to ER as a r/o sepsis, turned out to be NAT
  - Seizures every 3 minutes
- Term baby, hiccups during rewarming
  - Seizures every 5 minutes
Nothing clinical—only on EEG

• Term baby with decline of mental status at home, undiagnosed metabolic problem
  – Multiple seizures evolving to status
  – Died

• 4do ex 24 week premie with grade III IVH
  – Seizures, easily controlled with phenobarb
Neonatal Seizures and Outcomes

• Neonatal seizures are bad for the brain and bad for developmental outcomes
  – We treat them aggressively
  – This is an opportunity to improve outcomes as much as possible by recognizing and treating seizures early!

Largely dependent upon nursing staff recognition!
NeuroNICU Components

• **Nurses: the most important**
• NPs and MDs
  – Neurology
  – Neonatology
• Follow-up Clinic
  – HRIF
  – Neurology: neurodevelopmental/neurobehavioral expert
• EEG techs
• IT
• RESEARCH: the second most important
Basic Setup

• Team of trained neuroNICU nurses
  – At least 1-2 on every shift
• Co-directors: one neurologist, one neonatologist, one neoNP
• Rounds
  – Twice weekly
  • One of these is with all the neonatologists
Who needs to be a neuroNICU patient?

- All newborns receiving EEG
- Seizures or suspicion of seizures
- Stroke
- Encephalopathy (HIE, metabolic, etc.)
- Meningitis/encephalitis
- High grade IVH (III +)
- All CNS malformation
- Abnormal neuro exam (hypotonia, weakness)
Who should get continuous bedside EEG recording?

• Any baby suspected of seizure
• All hypothermia patients
• All ECMO patients
• All paralyzed patients
• Unexplained fluctuations in vital signs
Has the right type of EEG been ordered?

• Standard 1-hour EEG
  – NOT good for seizure detection

• Bedside EEG recording
  – OK for seizure detection

• Video EEG recording
  – BEST for seizure detection
Co-Management

- Neonatology still the primary service
- Neurology rounds daily
- NeuroNICU core team 8a-5p M-F
- Nights and weekends revert to general inpatient neurology
- Neurology available 24-7
- EEG now available 24-7 and can be accessed remotely
NeuroNICU Nurse Training
NeuroNICU Nurses

• Can perform a neurological assessment of the newborn
• Can identify suspected clinical seizures
• Can screen for newborns needing EEG monitoring
• Can set up, troubleshoot and end an EEG
NeuroNICU Nurses

- Can recognize basic EEG seizure patterns
- Can provide clinical documentation on EEG machines
- Can document a flowsheet
- of seizure management
NeuroNICU Nurse Training

• Set-up of a NeuroNICU service
• Core Competencies
• Clinical Seizure Recognition
• Basics of Neonatal EEG
• Setting Up an EEG Study
• The Neonatal Neurological Exam
• Seizure Treatment Documentation
The Neonatal Neurological Exam

General:
  Intubated?
  Sedated?
  Pharmacologically paralyzed?
  Anterior fontanelle open and flat?

Mental Status
  Opens eyes spontaneously?
  Moves spontaneously?
  Supporting own airway?

Cranial Nerves:
  Pupils equal size and reactivity?
  Conjugate eye movements?
  Symmetric strong grimace?
  Strong cry?
  Intact gag?

Motor:
  Lying posture: flexion, extension, or frogleg?
  Tone:
    Moves all extremities against gravity?

Sensation:
  Withdraws all extremities to light touch?
  If not light touch, painful stim?

Primitive reflexes:
  Palmar and plantar grasps?
  Suck?
  Root?

Deep tendon reflexes:
  Symmetric?
Changing Dynamic in the NICU

• NeuroNICU nurse preferentially assigned to neuroNICU patients
• If not, acts as a resource for other nurses
  – Screens for EEG candidates
  – Screens for clinical seizures
  – Can place an EEG
  – Basic EEG interpretation
  – Seizure charting
  – Neuro exam
Current Research
Music Therapy

• Babies with congenital cardiac lesions requiring surgery
• RCT: music tx versus no music
• Stress (salivary cortisol) measured during peri-operative period
Transport Cooling

• All RCHSD NICU patients are outborn
• If HIE and need cooling
  – Need to initiate cooling within six hours of birth
• Studies babies cooled at OSH and during transport
  – Passive cooling versus device cooling
Keppra for Neonatal Seizures

• Evidence that Keppra has predictable PK in newborns
• Efficacy as a first-line agent for neonatal seizures versus phenobarbital
• Cross-over RCT: newborns will start with either phenobarb or Keppra
Focal Lesion Outcomes

• Breaking News: strokes in newborns are AS COMMON as in the elderly
• Instability of placental vasculature
• Fetal heart circulation enables clot travel to brain
• Perinatal stroke newborns are at risk for epilepsy, hemiplegia, behavioral problems, language and cognitive delay
• Outcomes in this population
Temporary Tattoo Electronics

• For the detection of neonatal seizures
The EES: Epidermal Electronic System

Circuitry applied to the skin using a temporary tattoo.
Noninvasive Multi-Modality Neuromonitoring

- EEG
- Near-Infrared Spectroscopy
- Ultrasound
- Intracranial pressure
Current Projects

• Pilot tattoo versus conventional EEG
  – Term neonates with seizures
  – EES detection of seizures versus EEG
• EEG acquisition in the human
• Preterm labor monitoring in pregnancy
Using EES to detect electrical rhythms of the brain
EES versus EEG
The Goal: Our NICU Graduates Have Better Outcomes...and Better Lives
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