MRI of the Preterm Infant

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Preterm Brain Imaging

- Imaging modalities
- Conventional sequences
- Normal brain
- Preterm injury
  - Germinal matrix
  - White matter
  - Severe
Imaging

- **US**
  - Unstable
  - MRI not available
  - Excellent
    - GMH
    - Hydrocephalus
    - Vascular
  - Limited
    - Small FOV
    - Differentiation ischemia/hemorrhage
    - Noncavitary
    - Cerebellum
    - Brainstem

- **MRI**
  - Gold standard
    - High soft tissue contrast
  - New modalities
    - Diffusion
    - Spectroscopy
Neonatal Imaging: MRI Difficulties

- Stability of neonate
  - Personnel
  - Monitoring
    - Thermoregulation
    - Instability
- Time
  - Preparation
  - Complex schedule
  - Transportation
    - Infection exposure
- Sedation
  - Time
  - Risk
- MRI safety
  - Contraindications
  - Acoustic noise
- Imaging
  - MRI compatible incubator
  - Adult size
  - Coils
  - High cost
What do some people think of Cincinnati?

- "When the end of the world comes, I want to be in Cincinnati because it's always twenty years behind the times."

- But....not when it comes to neonatal imaging....

Mark Twain
NICU MRI

- **Size**
  - Comfortable fit in MRI (< 4.5kg)

- **Safety**
  - Prescreening
  - Prepare at bedside
  - Transfer in prescan room
  - metal detector wand

- **No sedation**
  - **Why**
    - Neuronal cell death
    - Increased bradycardia
  - **How**
    - Feed prior MR
    - Swaddle

- **Tailor imaging**
  - Quietest sequences first
  - Dim room lights

Scanning Babies
Conventional Neonate MR

- Sag T1
  - 3D SPGR
  - FLAIR
- Axial FSE PD/T2
- Axial T1 (IR)
- Cor/Sag T2
- Gradient echo
  - SWAN
  - MPGR
- DTI/DWI

- +/- MRS
- +/- ASL
- +/- MRA
- +/- MRV
- +/- Post Gadolinium

FLAIR poor due to high water content of neonatal brain

Imaging for pathology best after 1-2 wk
Normal Preterm MRI

- Germinal matrix (low T2, high T1)
  - Roof temporal horns
  - Lateral wall occipital
  - Caudothalamaic
  - Frontal periventricular (olfactory)

- White matter little myelination
  - Low T1 and high T2
  - 20-30 w
    - Band low T2/high T2 – migrating cells
    - Crossroads-high T2 signal by frontal horns (36 w)
Normal Preterm Brain

- Sulcation
  - Dependent age
  - >30 w many
  - Shallow → deep

- Myelination
  - 20-32 w- medulla to midbrain
  - 29 w superior & inferior cerebellar peduncles
  - 32 w- inferior colliculus, lateral putamen, ventrolateral thalamus
  - 36-40 w - posterior limb internal capsule, corona radiata, perirolandic, vermis, calcarine, medial temporal
Brain 32 weeks
Important Facts

- **Spectroscopy**
  - Varies
    - Maturity
    - Location
  - Lactate (CSF)
    - Preterm/term contain lactate
    - Solvent for phenobarbital 1.15 ppm

- **Diffusion**
  - False neg/underestimate
    - <24 h
  - Pseudonormalize
    - 6 day
Factors that affect Preterm Hypoperfusion Injury

- Physiologic
  - Lack of autoregulation
  - Instability of cardiovascular system

- Duration/severity of hypotension
  - Mild - moderate
  - Severe

- Maturity of brain
  - Glial response 6-7 months gestation
Preterm Hypoperfusion

- 11% live births = infants <32 w
  - >85% survival

- High neurodevelopmental delays
  - 9% cerebral palsy or severe impairment
  - 40-50% neurologic disability

Larroque B et al, Lancet 2008
Preterm HIE

- Mild-moderate
  - Germinal matrix hemorrhage (GMH)
    - Intraventricular hemorrhage (IVH)
    - Periventricular hemorrhagic infarction (PVHII)
    - Cerebellar hemorrhage/ischemia
  - White matter disease of premature (periventricular leukomalacia-PVL)
Germinal Matrix

- Cerebral
  - VZ/SVZ
- Cerebellar
  - External granular layer
- Hemorrhage
  - Vascular thin walled vessels
  - Sensitive oxygen/blood flow
  - Hypoperfused/reperfused
  - Increased venous pressure
Germinal Matrix Hemorrhage

- Incidence 10-25%

- Greatest risk
  - < 30 w/ 1500 g

- Timing
  - Day 1 - 50%
  - Day 2 - 25%
  - Day 3/4 - 15%
  - Rare beyond 1 w
Germinal Matrix Hemorrhage

- Burstein and Papile
  - Grade I: Subependymal hemorrhage
  - Grade II: Intraventricular without hydrocephalus
  - Grade III: Intraventricular with hydrocephalus
  - Grade IV: Periventricular hemorrhagic infaction (PVHI) with or without hydrocephalus

- Hydrocephalus
  - 36% with GR III
    - Arrest or resolve 65-75%
    - Shunt 10%
GMH/IVH MRI Findings

- <3 days
  - Hypointense T1
  - Mark hypo on T2/T2*
- 3-7 days
  - Hyper T1
  - Hypo T2/T2*
- 7 days to months
  - Hypo to CSF T1
  - Hyper to CSF T2
GM – SWAN (susceptibility-weighted images)
PVHI or Grade IV

- 15% with IVH
- Injury to periventricular white matter
  - Hemorrhagic venous infarction
  - Occlusion of vein along ventricular wall (terminal vein)
- MR
  - Hemorrhage surrounded T2 hyperintense
  - Late porencephaly
MRI Grade III and PVHI, day 15
34 w MRI 5 days
GMH/IVH/PVHI

- Neurologic deficits
  - Cognitive
  - Motor (hemiparesis)
    - GMH with normal ventricles < 10%
    - IVH and large ventricles 50%
    - PVHI 50-90%

Volpe IJ. Neurology of the Newborn, 2008
Cerebellar GM Hemorrhage

- 15-25% < 32 w
- Location
  - Isolated 23%
  - Unilateral 71%, bilateral 9% and vermis 20%
- Impaired cerebellar growth
- Silent with high neurologic deficits

Limperopoulos et al, Pediatrics 2005
Cerebellar Hemorrhage 26 w
White Matter Injury of Premature

- **Prevalence**
  - Low birth weight < 1000g
  - US 5-10%
  - MRI - 50%
  
  Inder et al, AJNR 2003

- **Pathology**
  - Coagulation necrosis
    - 25% hemorrhagic
    - 50% noncavitary

- **Pathogenesis**
  - Immature vessels in watershed
  - Lack autoregulation
  - Preoligodendrocyte vulnerability
    - Lack of antioxidant enzyme to break down free radicals
    - Glutamate
    - Microglia
White Matter Injury of Premature

- Site
  - WM
    - Periventricular
      - Optic radiations by trigones
      - Foramen Monroe
    - Deep or subcortical
    - Secondary gray
      - Thalami
      - BG
      - Cerebral cortex
      - Cerebellum
MRI Findings in WM Disease Premature

- **Acute**
  - Hyper T1
  - Hypo T2
  - <1 week restricted diffusion
  - Reduced FA

- **Delayed**
  - Cavitary
  - Disappear \(\rightarrow\) gliosis Flair signal abnormality
  - Volume loss
  - Delayed myelination
  - Reduced FA
  - Increased diffusion

Counsell et al, Arch Dis Child Fetal Neonatal Ed, 2003
Acute Premature WM Disease at 5 dol, 28 w
Hemorrhagic Premature WM Disease at dol 11, RDS, 32 w
Premature WM Disease?
Differential

- 18 day term s/p coarctation repair

- Consider
  - Cardiac ischemia
  - Infection
  - Inborn errors of metabolism
  - Hydrocephalus
  - In utero events
Chronic WM Injury
33 w TE NEC
Chronic Premature WM Disease in 17 m premature infant
Neurodevelopmental Deficits in WM Disease of the Premature

Outcomes
- Cognitive/motor delay
  - Spastic diplegia or quadriplegia
- Neurosensory impairment
  - Visual

Predictors/Term equivalent
- Moderate to severe WM abnormalities
- Gray matter less strongly associated
- US evidence of Grade III/IV and Cystic PVL
- Postnatal use of corticosteroids

Woodward et al, NEJM 2006
Diffuse Excessive High Signal Intensity in WM (DEHSI)

- Controversial
  - White matter injury
    - Increase diffusion
    - Poor neurologic outcome
      Counsell et al, Arch Dis Child Fetal Neonatal Ed, 2003
  - Transient normal process
    - No difference neurodevelopmental outcome
    - No difference ADC values with controls
      Hart et al Pediatric Radiology, 2011
Premature Severe Injury
Abruption 5 dol 32 w

- Severe
  - Deep gray nuclei/brainstem
    - Thalami
    - Dorsal brainstem
    - Anterior vermis
    - Lentiform nuclei
    - Perirolandic gyri
  - Cerebral cortex spared
  - WM and GMH
MRI vs US

- Predicting neurodevelopmental outcome
  - MRI
    - Sensitivity 100% and specificity 79%
  - US
    - Sensitivity 67% and specificity 85%

- MRI
  - Late-absent T1 shortening in PLIC

Valkama et al, Acta Paediatr 2000
Roelants-van Rijn et al, Neuropediatrics 2001
Conclusion

- Know normal
- Techniques
  - Conventional
    - MRA/MRV
  - Diffusion
    - Diffusion tensor imaging
  - Spectroscopy
- Aware patterns
- Differential
- Timing
  - 3-5 days
    - Diffusion positive
  - >1-2 weeks
    - Conventional imaging