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Disclosures
Occasional legal consulting work

Neonatal Hypoxic Ischemic Encephalopathy
• Brief clinical overview
• Patterns of injury on MRI
• Timing of injury after cooling therapy
• MR Spectroscopy

Why Image HIE?
• Confirm diagnosis
• Approximate timing of injury
• Direct goals of care
• Advocate for services
• PROGNOSIS
  • MRI is gold standard for evaluation of neonatal HIE

Neonatal Hypoxic Ischemic Encephalopathy
1. Known or suspected hypoxia / ischemia
   A. Cord blood pH ≤ 7.0 or
   B. Perinatal event; and
   e.g. cord prolapse, uterine rupture, placental abruption, major trauma or CPR to mother; sustained FHR decel
   C. APGAR ≤ 5 at 10 mins
2. Encephalopathy
   e.g. lethargy, weak/absent Moro reflex, hypotonia, seizure

Neonatal Hypoxic Ischemic Encephalopathy
2-3 per 1000 live births
• 40-60% risk of death or major disability
  • Cerebral palsy significantly impacting daily activities
  • IQ < 70
Injury Patterns

Watershed
- "Partial-prolonged" insult, e.g. cord prolapse
- Affects cortex and white matter in arterial borderzones
- 10-30% risk of poor outcome

Basal ganglia
- "Profound" but brief insult, e.g. placental abruption
- Affects most metabolically active areas
- 40-70% risk of poor outcome

Global
- Profound and prolonged insult
- Affects entire cortex and deep gray nuclei
- 90-100% risk of poor outcome

Normal: 5-10% risk of poor outcome

Watershed Pattern

Injury to:
- Parasagittal cerebral cortex and white matter
- Insular cortex
- Spares:
  - Deep gray nuclei
  - Brainstem
  - Cerebellum

Watershed Pattern

3 days old

Watershed Pattern

4 days old

Watershed Pattern

4 days old

Watershed Pattern

4 days old

Watershed Pattern

4 days old

Watershed Pattern

10 days old
**Time Course of Injury Appearance**

DWI/ADC:
- ↓ ADC on Day 1
- Minimum ~ Day 2-3
- Pseudonormalizes Day 6-7
- T1 weighted signal:
  - ↑ Day 2-3
  - Remains ↑ for 2-4 weeks
- T2 weighted signal:
  - ↑ Day 2-3
  - ↓↓ Day 6-7 (variable)

Without cooling!

**Watershed Pattern – Insular Involvement**

5 days old

5 days old

11 days old

8 months old

**Basal Ganglia Pattern**

Injury to:
- Thalami
- Putamina
- Perirolandic regions
- Corticospinal tracts

11 days old
Basal Ganglia Pattern – Long-Term Follow-up

2 years old

10 days old

6 months old

Chronic basal ganglia injury can be subtle

Global Pattern

Injury to:
- Entire cortex and deep gray structures
- Usually accompanied by diffuse brain swelling

Global Pattern – Absolute Diffusion Values

ADC = 427 x 10^-6 mm² / s

ADC = 319 x 10^-6 mm² / s

<table>
<thead>
<tr>
<th>ADC x 10^-6 mm² / s</th>
<th>Deep gray structures</th>
<th>Periventricular white matter</th>
<th>Cerebral cortex</th>
</tr>
</thead>
<tbody>
<tr>
<td>850-1300</td>
<td>1200-1800</td>
<td>1000-1400</td>
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Adapted from Forbes, et al., Radiology 2002; 222:405-409

**Treatment - Hypothermia**

- Head or whole-body cooling
- Reduces sequelae of HIE
- Children’s National protocol:
  - Begin < 6 hrs. of age
  - Core temperature of 33.5°C
  - Maintain for 72 hrs.
  - NNT 6-8 to prevent one case of death / major disability

**Brain MRI after Neonatal Hypothermia**

- Injury patterns do not change
- Predictive ability of MRI does not change
- Timing of MRI findings changes
Cooling prolongs diffusion abnormalities.

When to Scan?

- Early (1-5 days):
  - Visualize DWI/ADC abnormalities
  - Earlier awareness of severe injury
  - Better for establishing timing of injury
  - Difficult or impossible to scan during cooling

- Late (9-14 days):
  - T1 abnormalities are maximized
  - More sensitive for full extent of injury
  - Patient may have been discharged

When to Scan?

- 1 day old with seizures → Prenatal Injury

When to Scan?

- ACOG/AAP recommend 2 scans
  - At 1-4 days, and again at 10+ days
  - Children’s National protocol: MRI at 3-5 days and 10-12 days
  - Some interest in a single “middle” scan at 5-7 days

MRS lactate predicts poor outcome

- Early (1-2 days) lactate predicts long-term outcome
- Provides independent information from conventional images
MRS lactate predicts poor outcome

Pitfall at 3.0T
- Lactate doublet theoretically best visualized at 144 ms echo time
- Theory developed at 1.5T
- PRESS technique at 3.0T can suppress lactate peak up to 80% at 144 ms echo time

T. Lange, et al., AJNR 2006, 27:895-901

Take Home Points
- Neonatal watershed is broader than adult, includes insula
- Chronic findings of basal ganglia pattern HIE can be subtle
- Absolute ADC measurements can help with diffusely positive scans
- Optimal timing of MRI for HIE is still debated
  - Need at least one scan < 7 days
- Be careful with MRS at 144 ms TE and 3.0T