

# 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

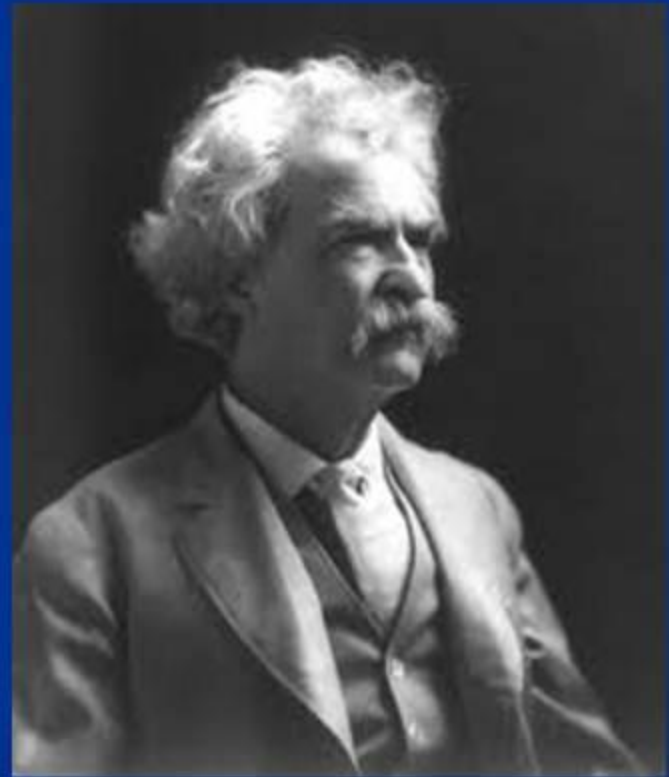
## ■ Imaging

- *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



# 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

Loepke AW. *Pediatr Crit Care Med* 2010; 11:271-226

### ■ How

- Feed prior MR
- Swaddle

Allaegaert K et al. *Paediatr Anaesth* 2008; 18(12):1270-1.

## ■ Tailor imaging

- Quietest sequences first
- Dim room lights

# Scanning Babies



... monitoring ventilator and infusion pumps



# 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
  - Caudothalamic
  - 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

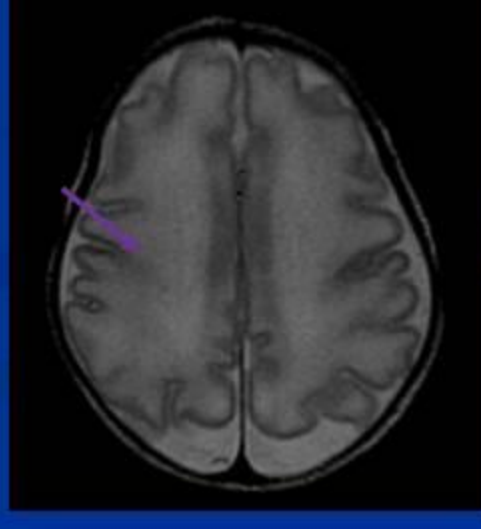
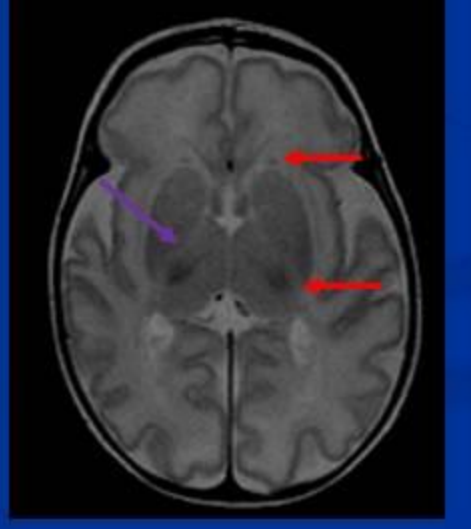
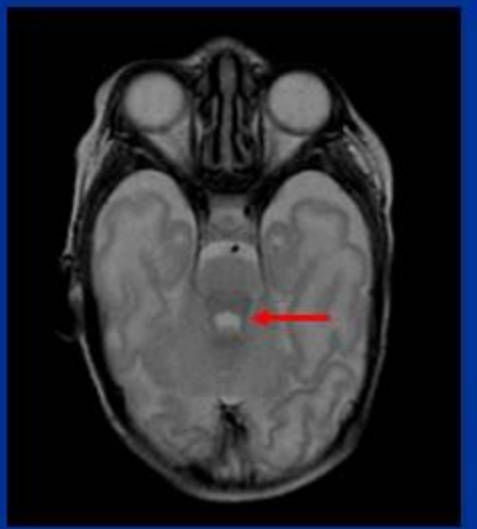
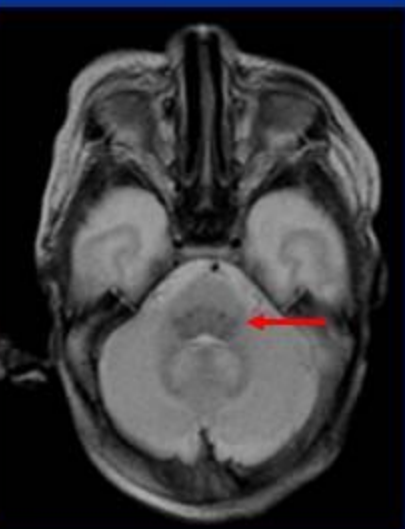
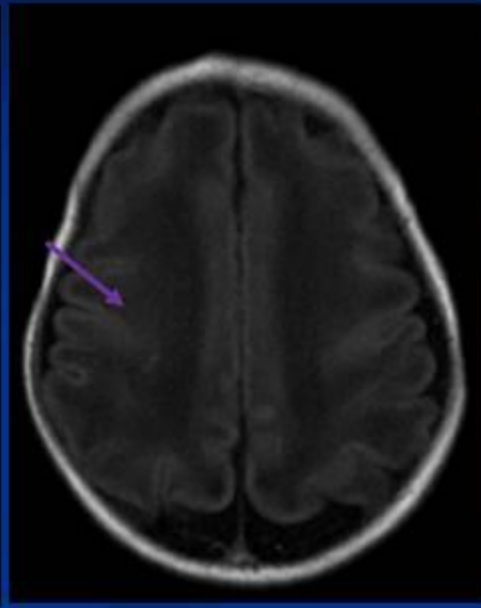
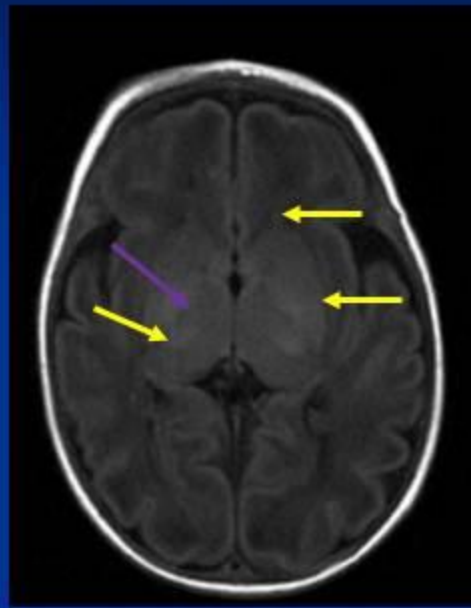
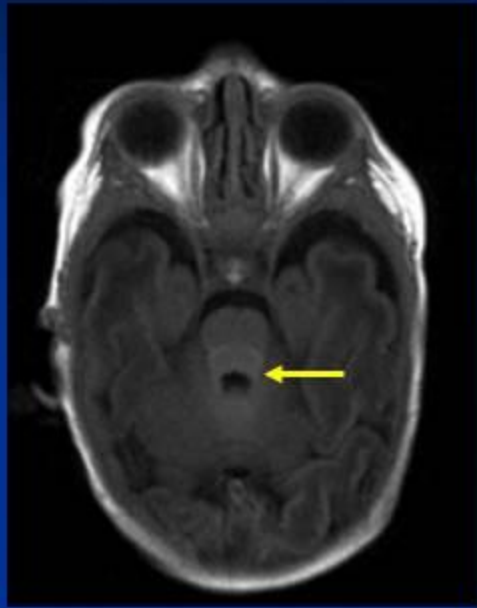
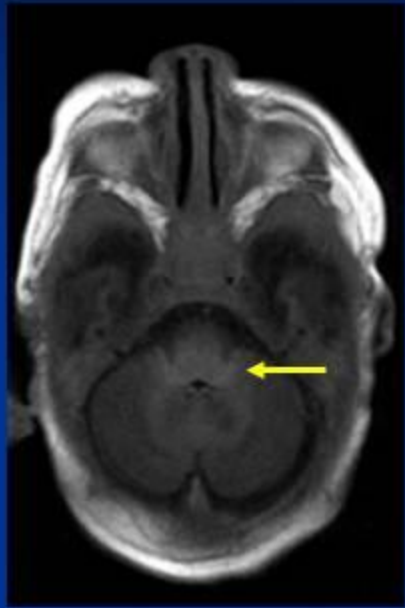
## ■ Sulcation

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

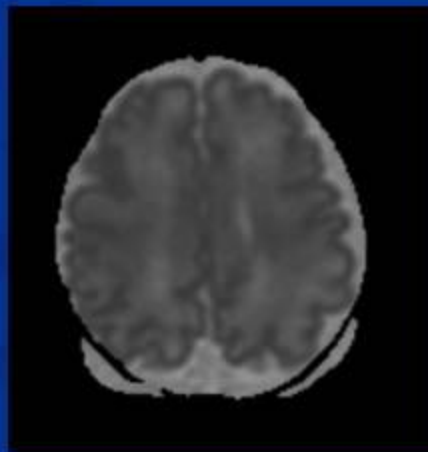
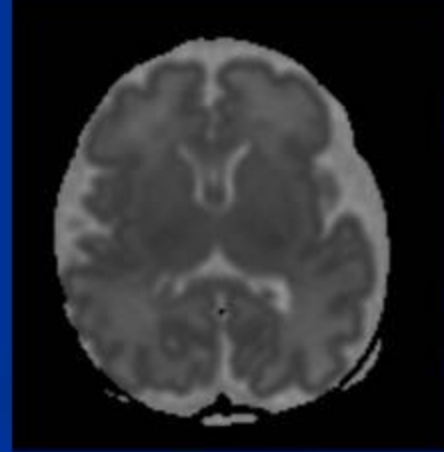
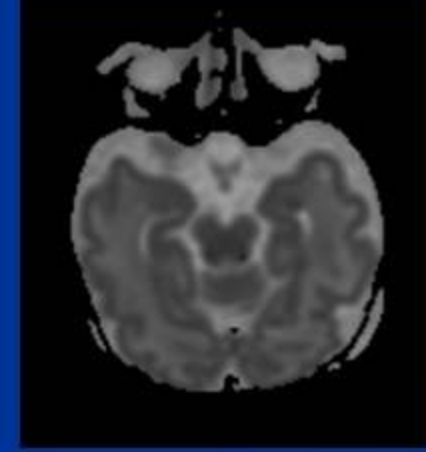
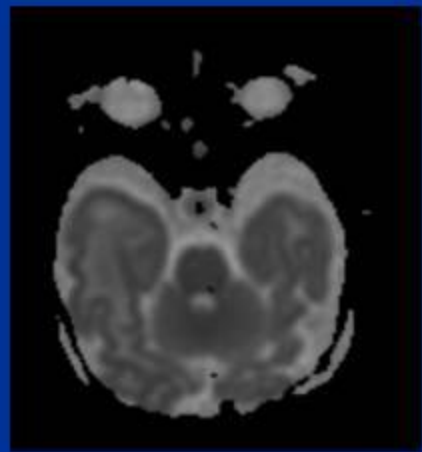
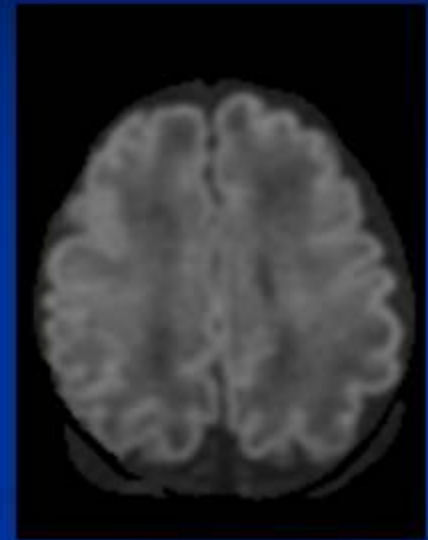
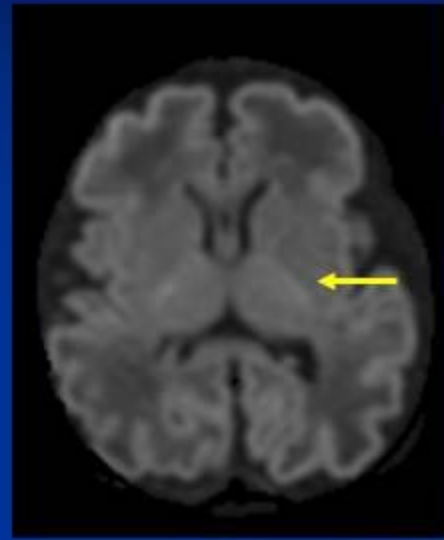
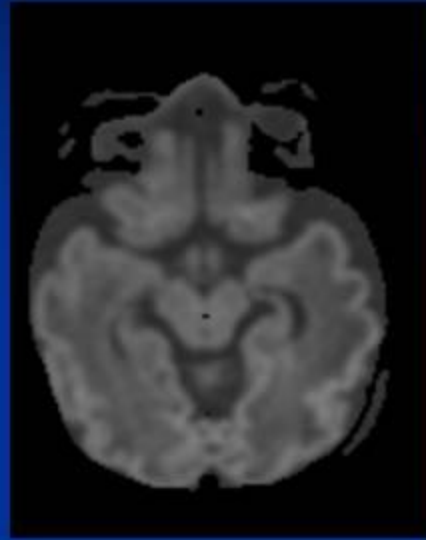
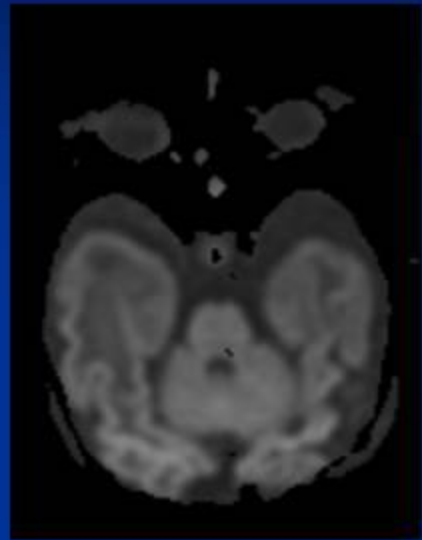
## ■ Myelination

- 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



# Diffusion at 32 w



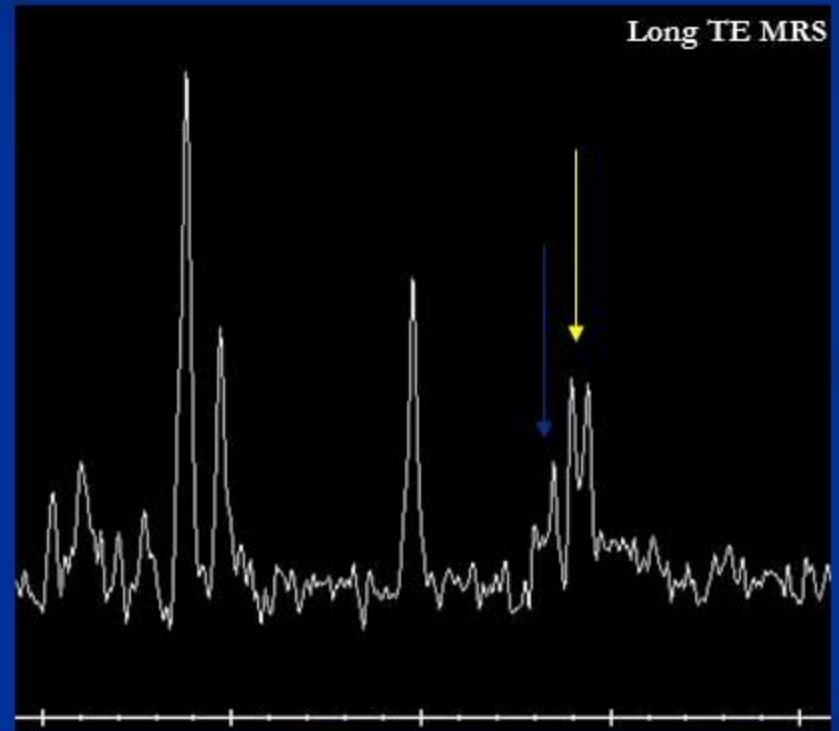
# Important Facts

## ■ 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 (PVHI)

- 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

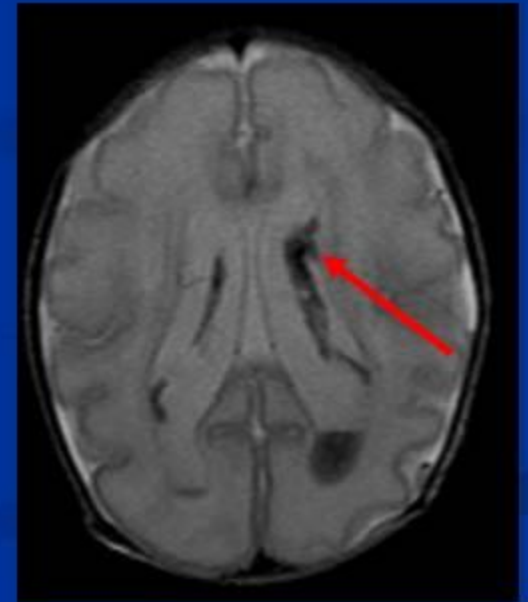
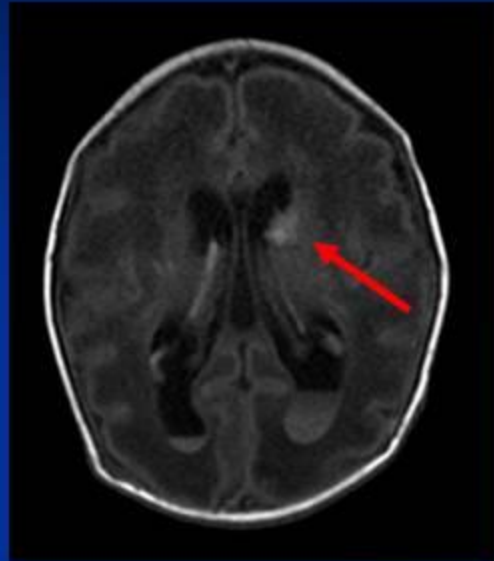


# Germinal Matrix Hemorrhage

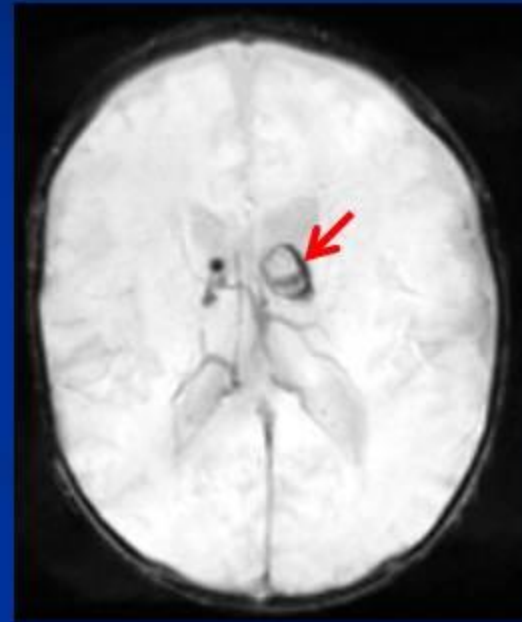
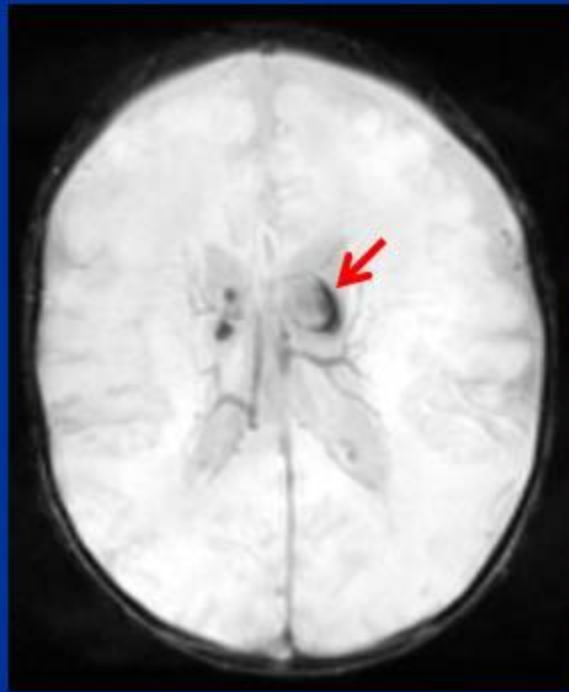
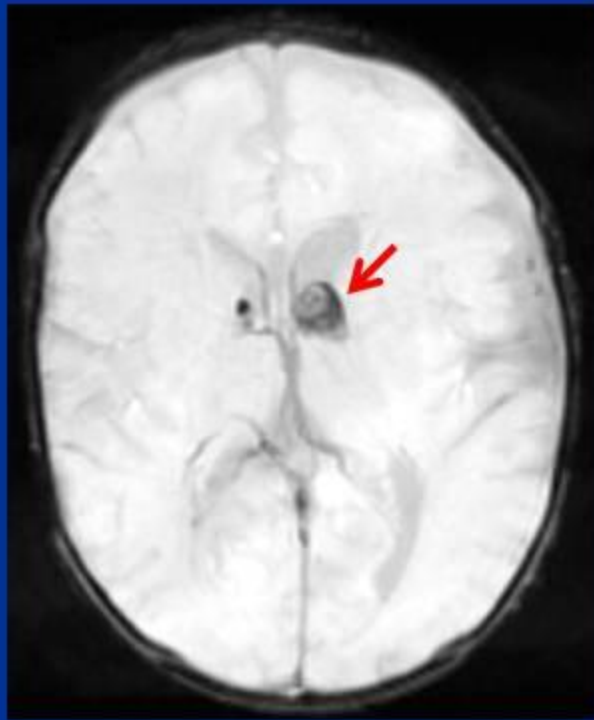
- Burstein and Papile
  - Grade I: Subependymal hemorrhage
  - Grade II: Intraventricular without hydrocephalus
  - Grade III: Intraventricular with hydrocephalus
  - Grade IV: Periventricular hemorrhagic infarction (PVHI) with or without hydrocephalus
  
- Hydrocephalus
  - 36 % with GR III
    - Arrest 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

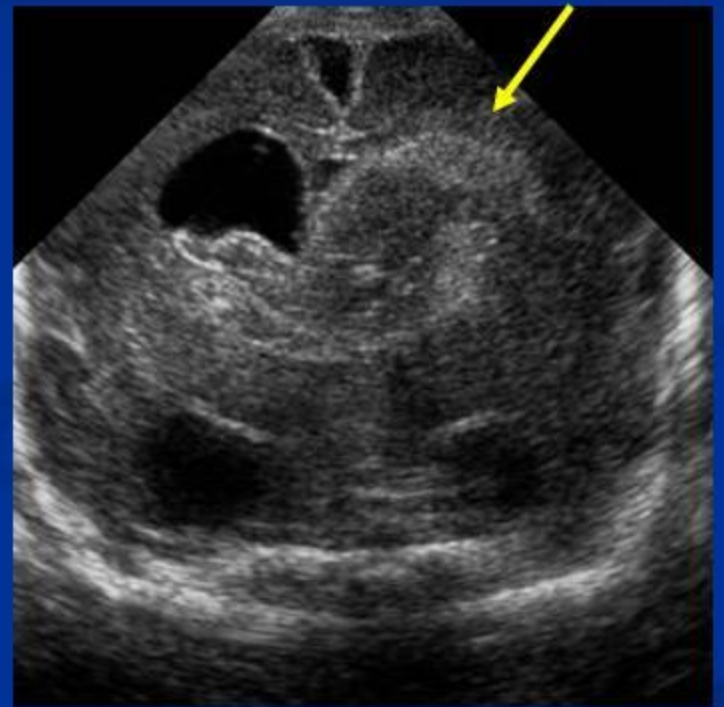


# GM –SWAN (susceptibility-weighted images)

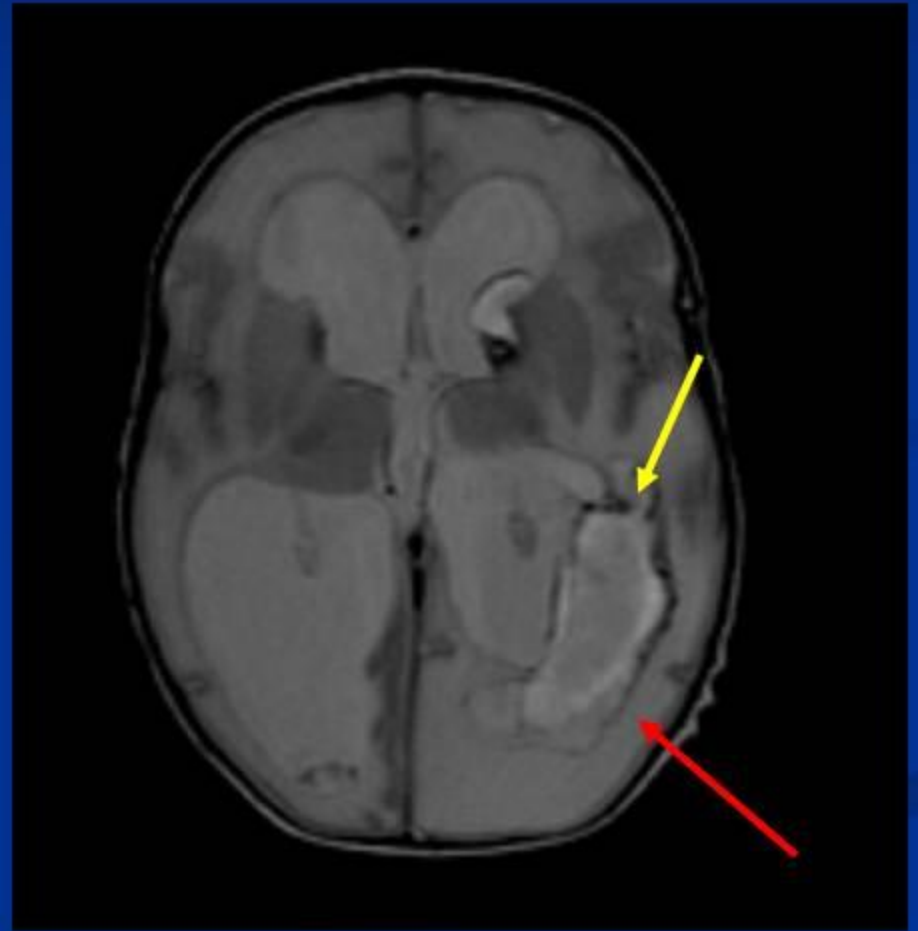
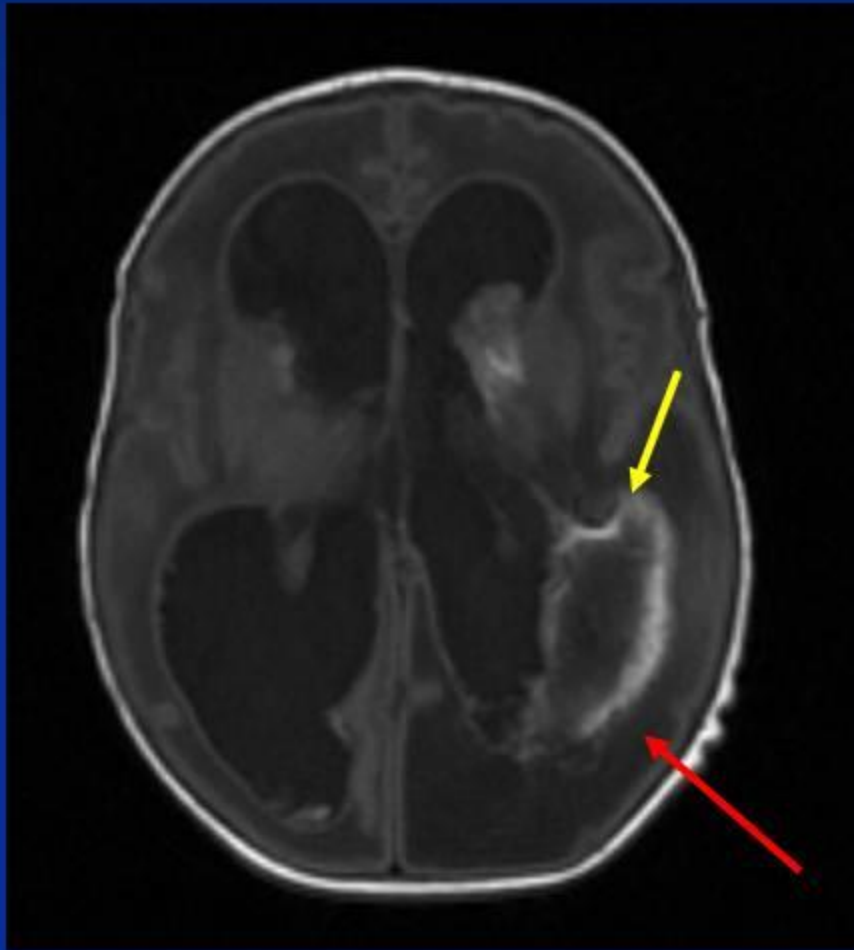


# PVHI or Grade IV

- 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

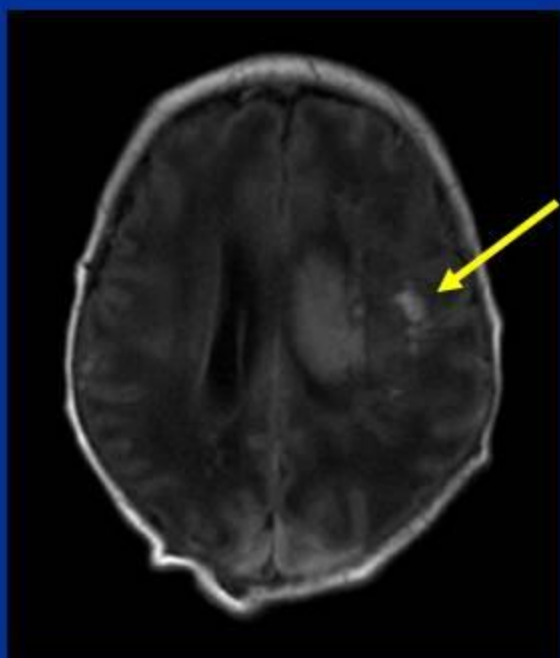
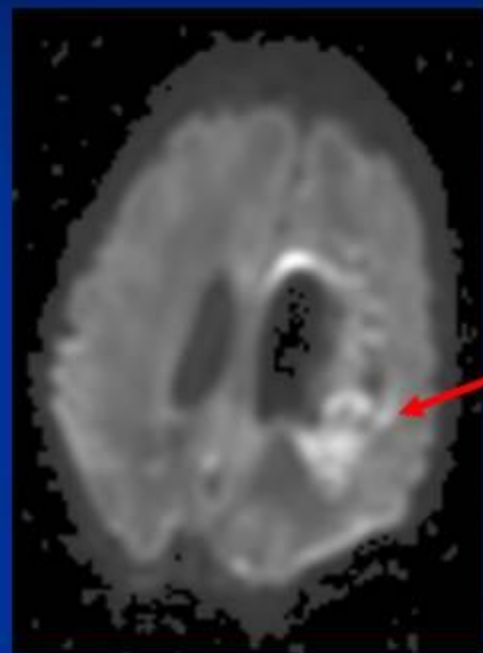
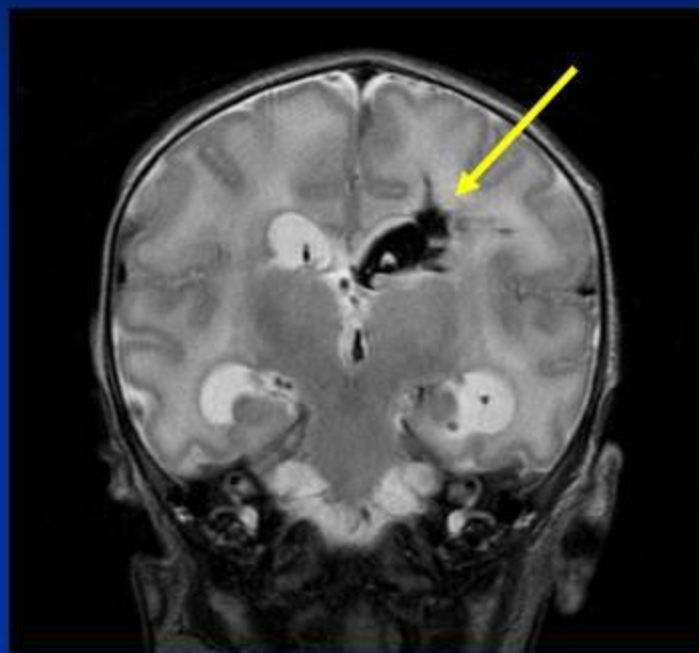
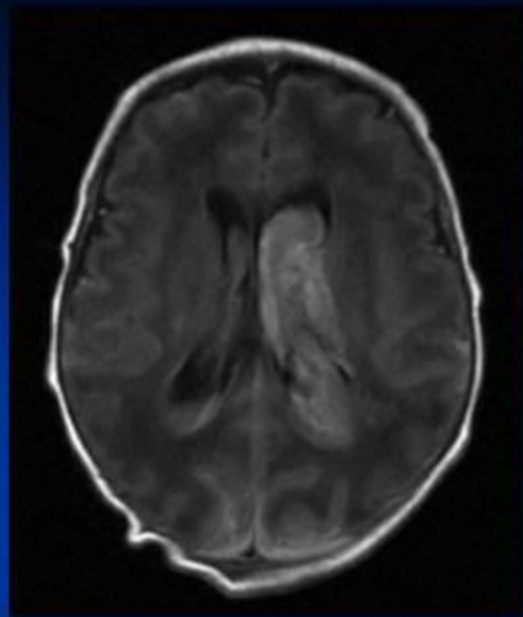


# MRI Grade III and PVHI, day 15





34 w MRI 5 days



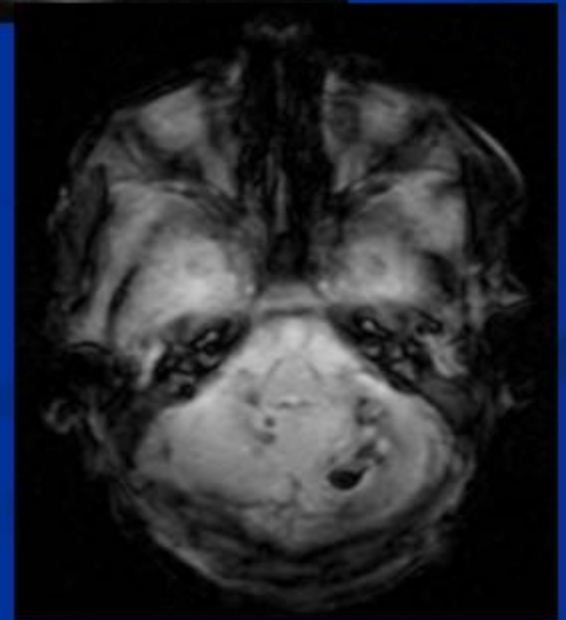
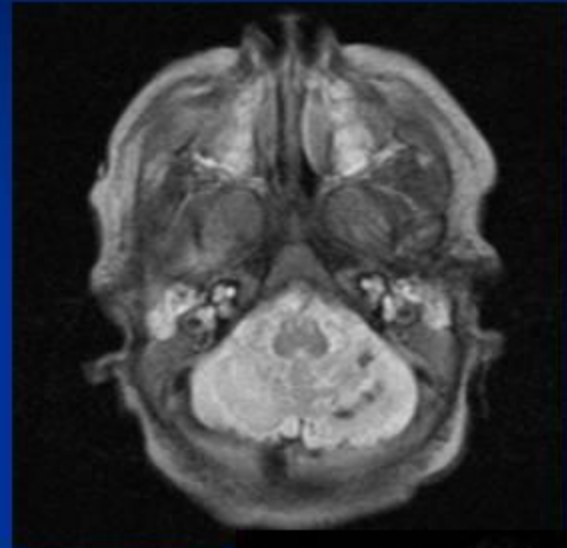
# GMH/IVH/PVHI

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

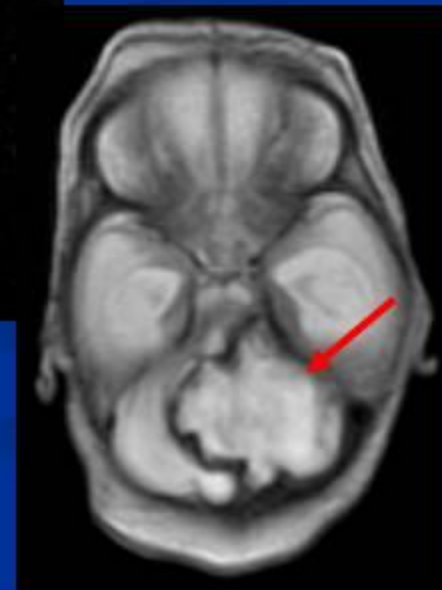
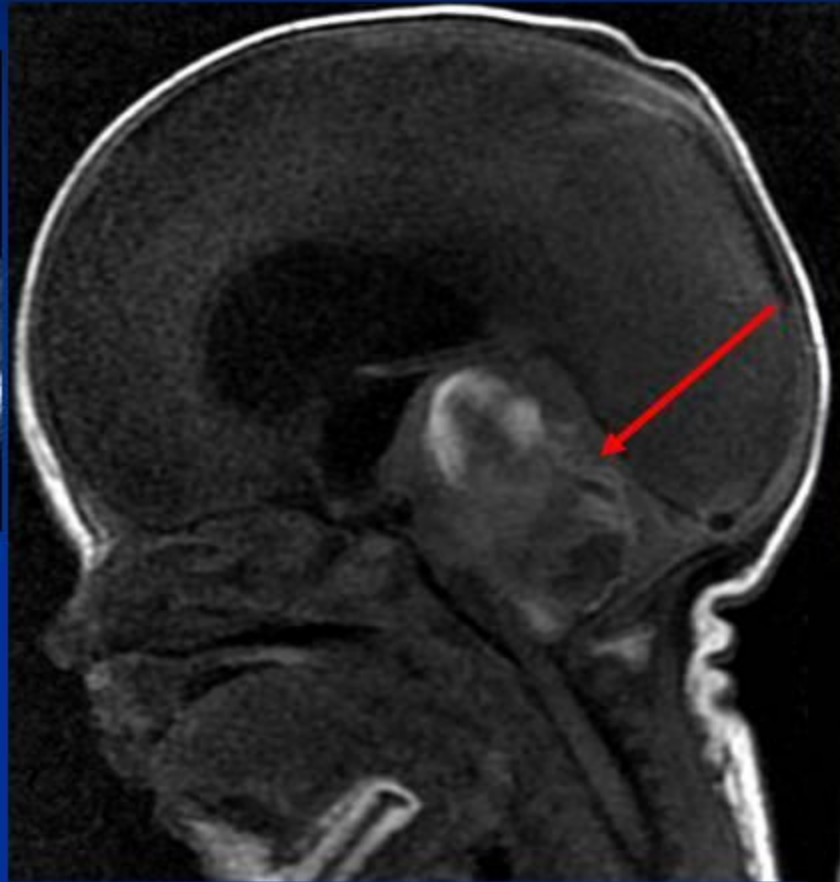
Volpe IJ. Neurology of the Newborn,  
2008

# 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



# 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

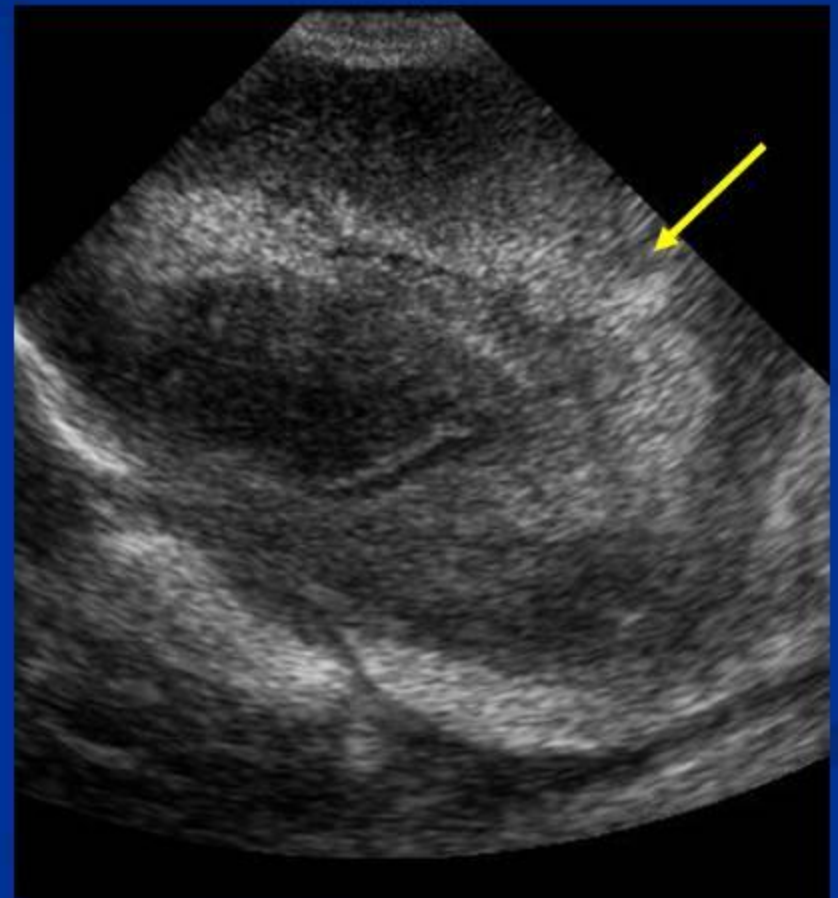
#### ■ Periventricular

- Optic radiations by trigones
- Foramen Monroe

#### ■ Deep or subcortical

#### ■ Secondary gray

- Thalami
- BG
- Cerebral cortex
- Cerebellum



# MRI Findings in WM Disease Premature

## ■ Acute

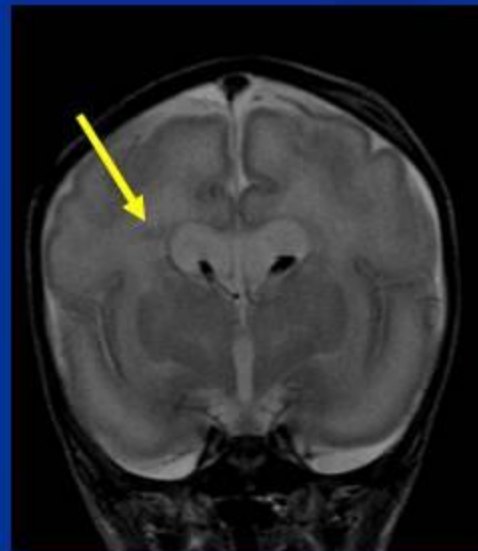
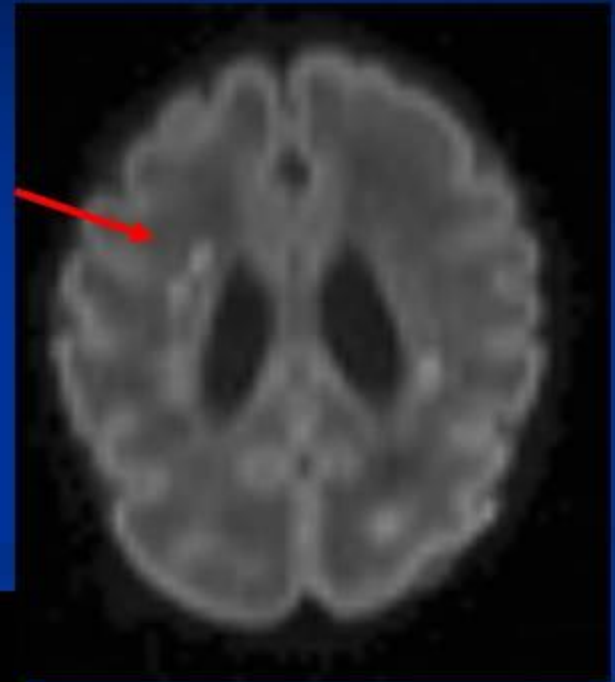
- Hyper T1
- Hypo T2
- <1 week restricted diffusion
- Reduced FA

Counsell et al, Arch Dis Child  
Fetal Neonatal Ed, 2003

## ■ Delayed

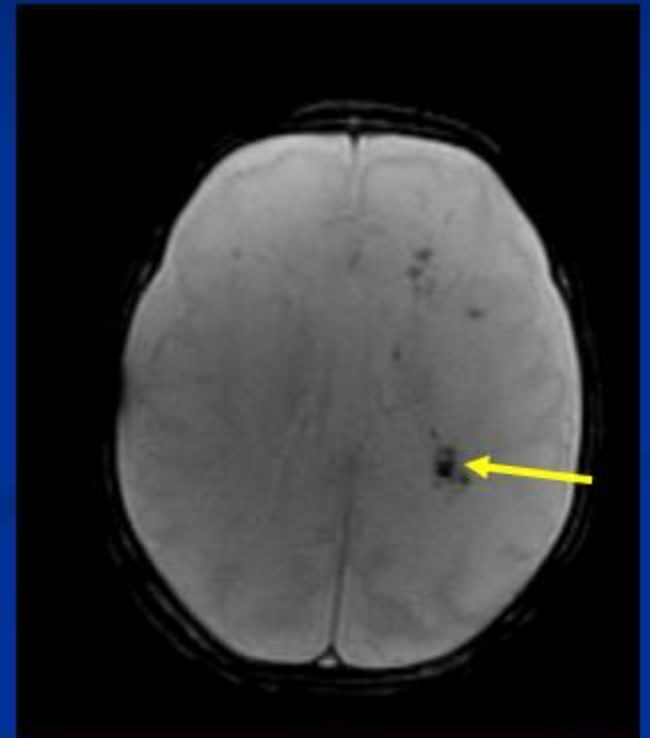
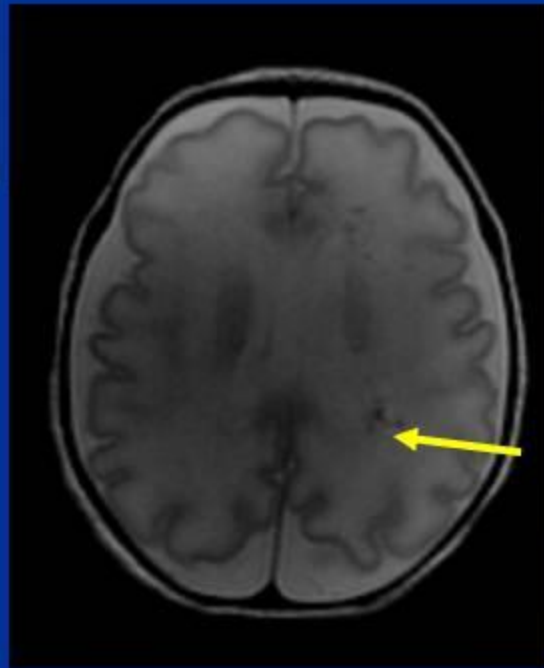
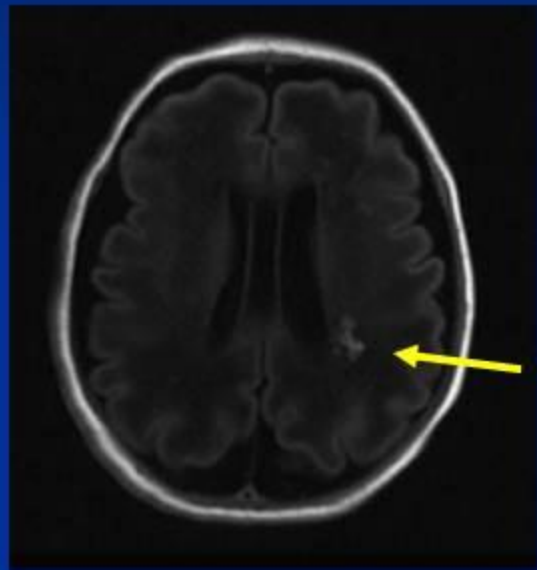
- Cavitory
- Disappear → gliosis Flair signal abnormality
- Volume loss
- Delayed myelination
- Reduced FA
- Increased diffusion

# Acute Premature WM Disease at 5 dol, 28 w

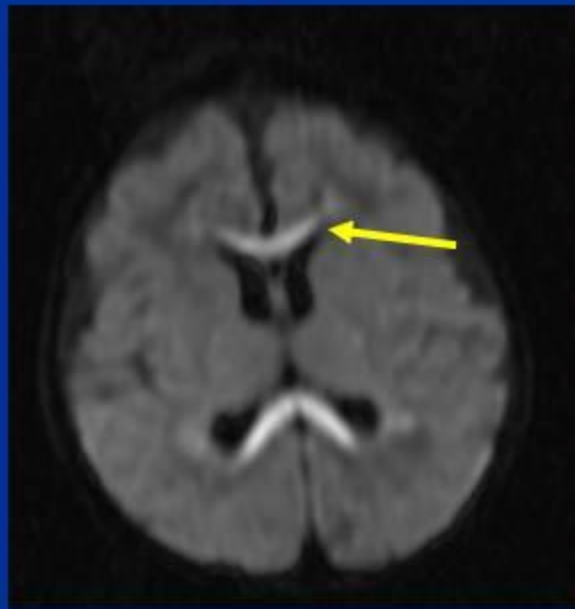
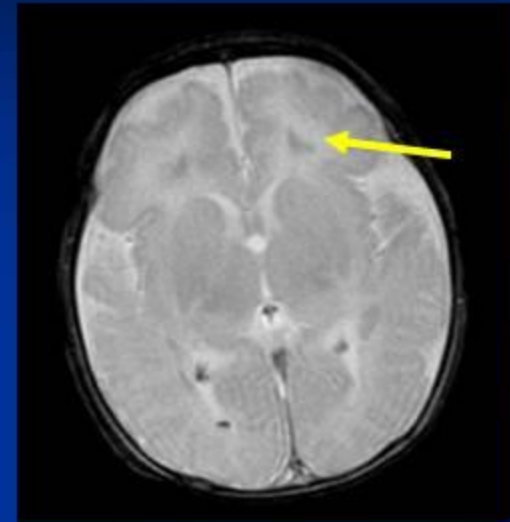
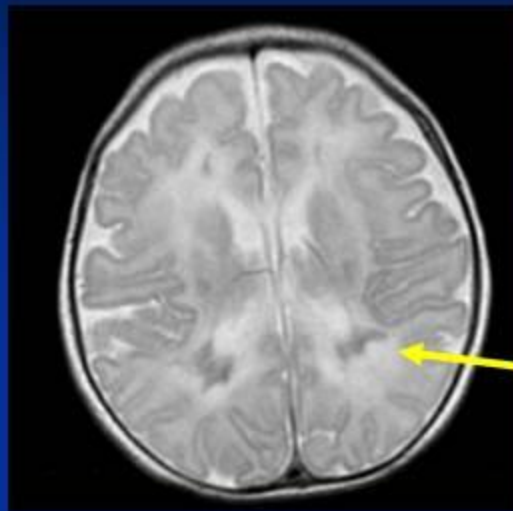
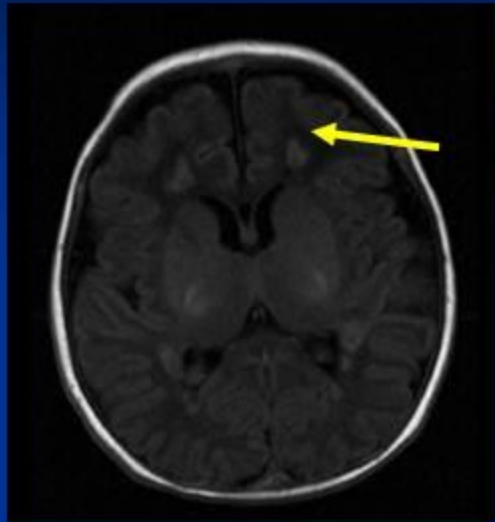




# Hemorrhagic Premature WM Disease at dol 11, RDS, 32 w



# Premature WM Disease?

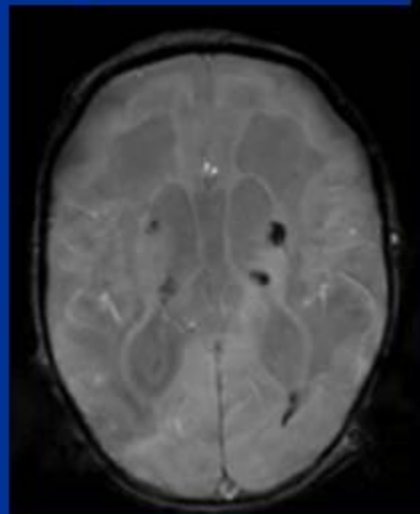
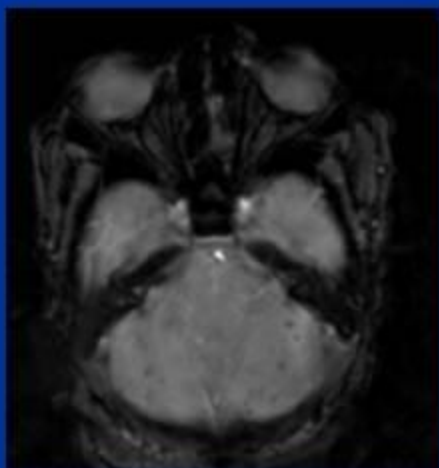
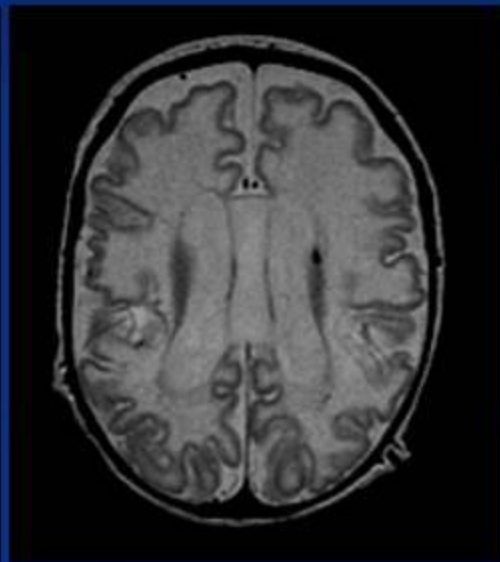
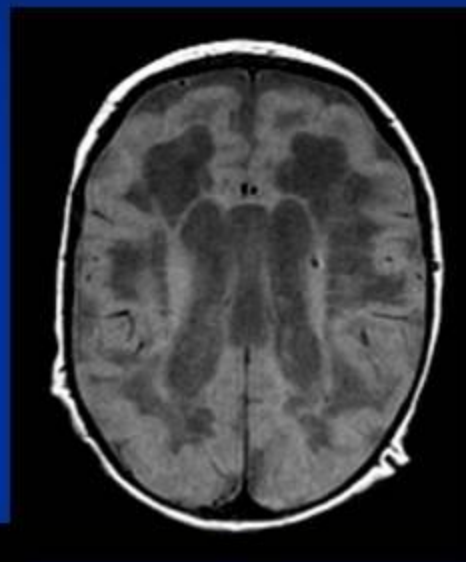
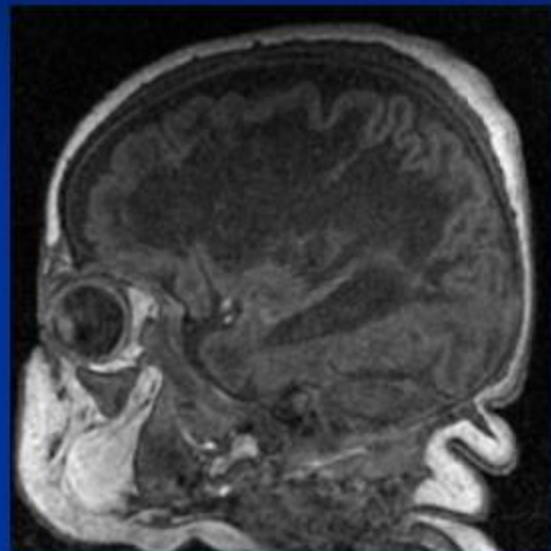


# Differential

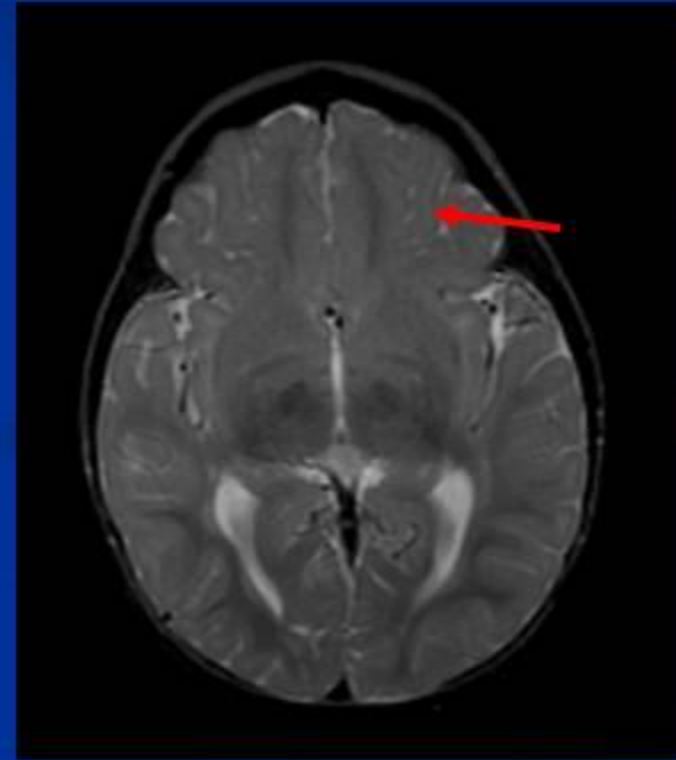
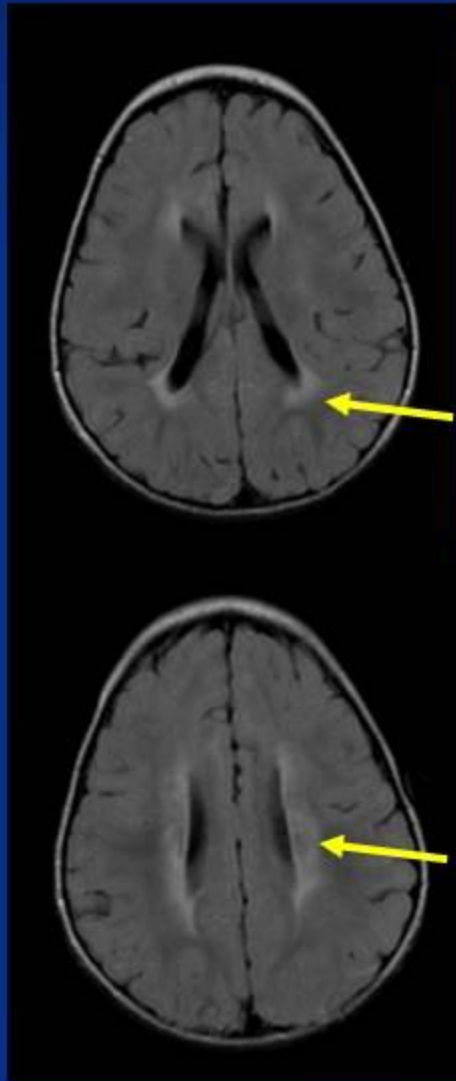
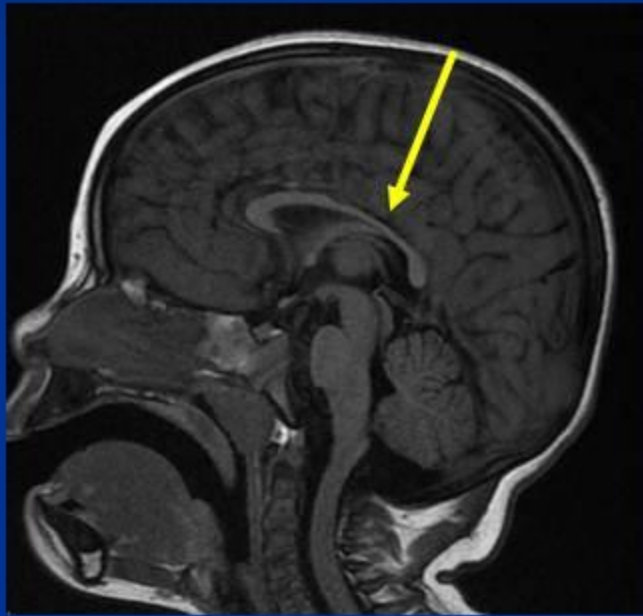
- 18 day term s/p coarctation repair
- Consider
  - Cardiac ischemia
  - Infection
  - In born errors of metabolism
  - Hydrocephalus
  - In utero events

# 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

# Diffuse Excessive High Signal Intensity in WM (DEHSI)

## ■ Controversial

### ■ White matter injury

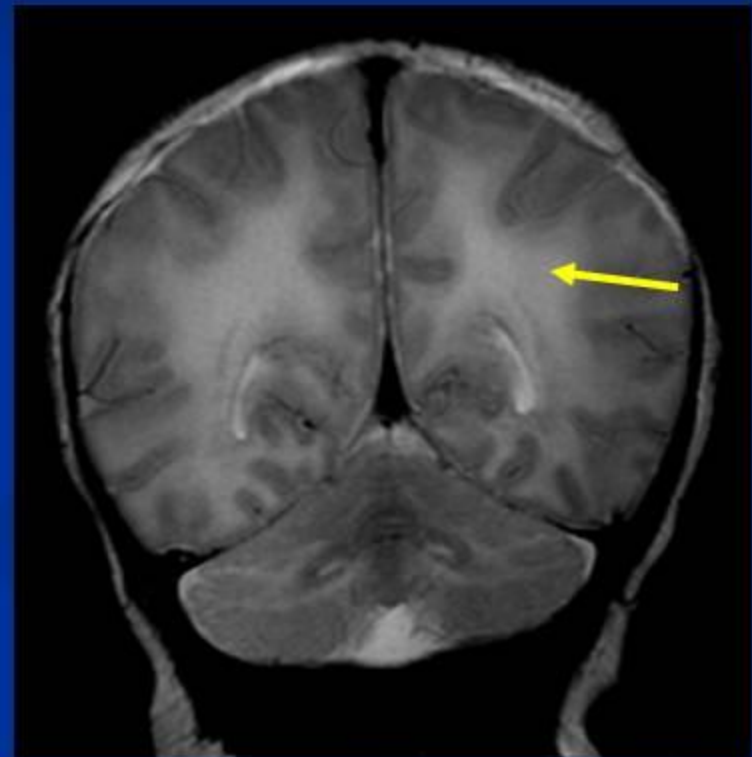
- Increase diffusion
- poor neurologic outcome

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

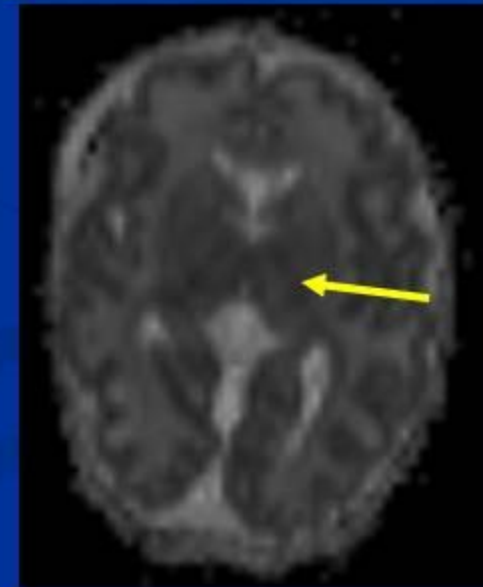
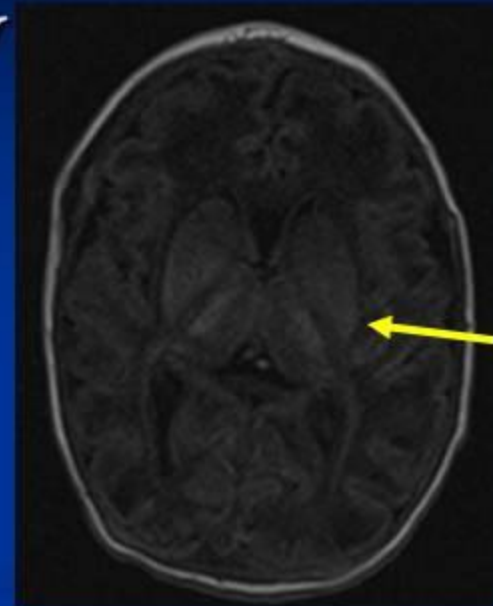
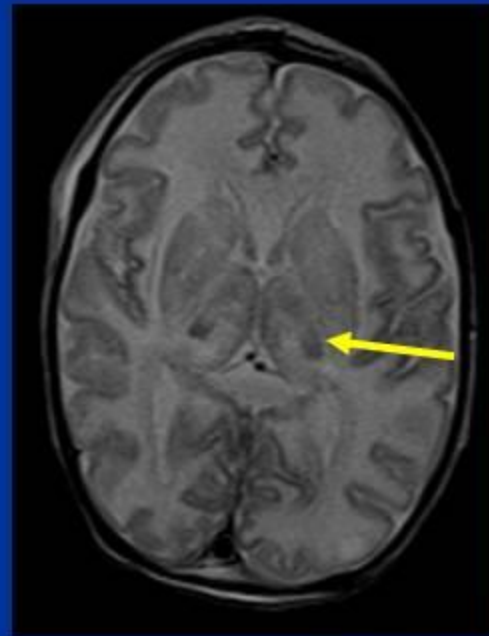
### ■ Severe

#### ■ Deep gray nuclei/brainstem

- Thalami
- Dorsal brainstem
- Anterior vermis
- Lentiform nuclei
- Periolandic 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%

Valkama et al, Acta Paediatr  
2000

- MRI

- Late-absent T1 shortening in PLIC

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

