# Neuroimaging for Perinatal Brain Injury

Ji Hye Kim, M.D.

Department of Radiology,
Sungkyunkwan University School of Medicine,
Samsung Medical Center

# Neonatal Hypoxic Ischemic Encephalopathy (HIE)

- Major perinatal cause of neurological morbidity
- More risk in lower age & birth weight
- Improved survival of VLBW infants (<1.5 kg)
- Preterm survivors with long term deficits
  - 25%; permanent motor impairment (CP)
  - 25–50%; cognitive & learning disabilities

# Pathophysiology

# Asphyxia

Impaired exchange of $O_2$ and $CO_2$

- Diminished blood $O_2$ (hypoxia)
- Increased blood $CO_2$ (hypercarbia)
- Decreased systemic blood pressure
- Acidosis

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Impaired cerebral autoregulation
>> Pressure passive blood flow

# Asphyxia

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- Acidosis

+ Impaired cerebral autoregulation

↓

Cerebral hypoperfusion

→ Hypoxic Ischemic Encephalopathy

# Perinatal Asphyxia

- **Intrauterine asphyxia**
  - Interrupted placental blood flow & gas exchange
  - Impaired maternal oxygenation
  - Disrupted umbilical circulation
- **Postnatal asphyxia**
  - Severe RDS
  - Pneumonia
  - Meconium aspiration
  - Congenital heart anomalies

# Other Factors

- Maternal-fetal infection;

  - risk factor for CP in term

  - poor neurologic outcome in preterm

  - neuroinflammatory mediators (endotoxin, cytotoxic cytokin) exacerbate ischemic insult

- Genetic effect;

  - single nucleotide polymorphisms (endothelial NO synthase A(i922)G, factor VII (Arg353Gln), del(i323)10bp-ins, lymphotoxin *a* (Thr26Asn)) associated with CP in preterm

# Imaging modalities

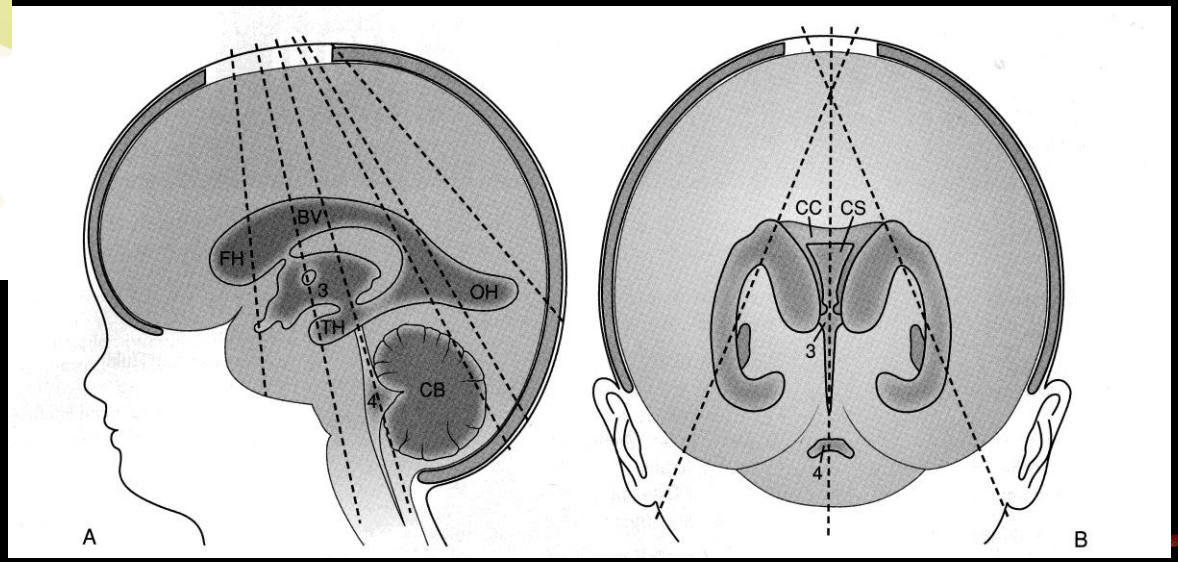
# Imaging modalities for neonatal brain

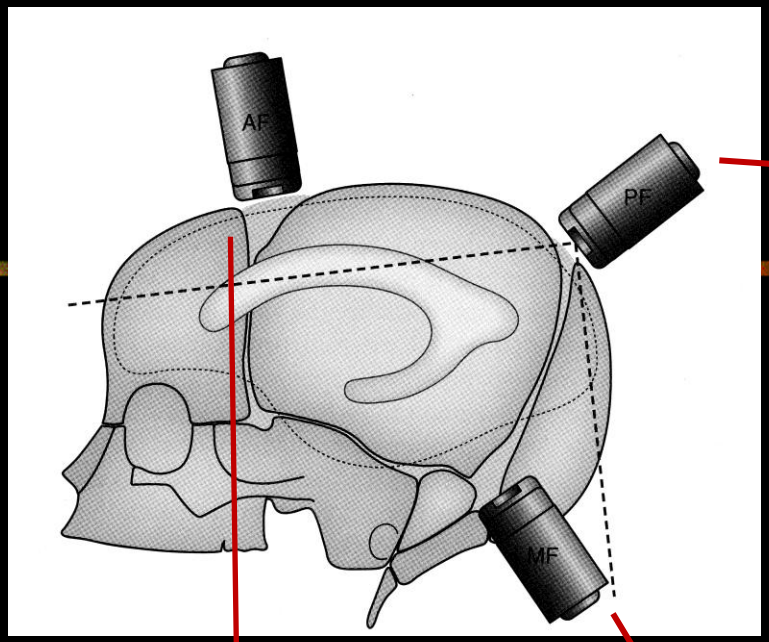
- USG
- MR imaging
  - Conventional imaging
  - DWI-DTI
  - Perfusion imaging
  - MR spectroscopy
  - Functional MRI
- CT

# US for neonatal brain


- Bedside screening for unstable neonate
- Convenient, noninvasive, low-cost
- No radiation exposure
- Doppler interrogation

- Operator dependent
- Less sensitive
- Non-specific

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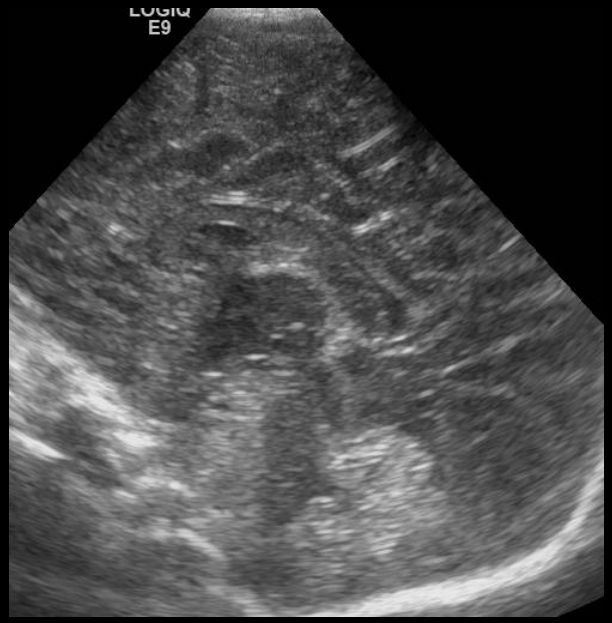
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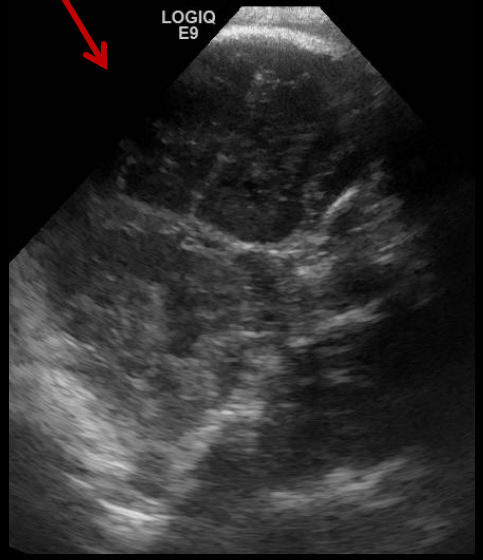
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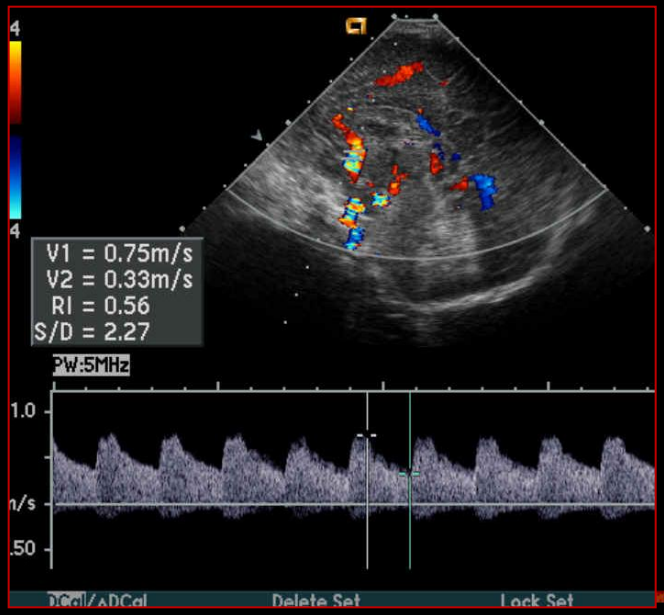
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4
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V2 = 0.33m/s
RI = 0.56
S/D = 2.27
PW:5MHz
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Delete Set
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# MR Imaging for Neonatal Brain

- Study of choice for CNS evaluation
- Natural sleep or sedation with monitoring
- MR compatible incubator & coil
- T2WI ;longer TR/TE (high water & lower myelin/lipid content of newborn brain)
- T1WI; fast IR or 3D gradient > SE in 3T
- IV contrast injection is not recommended

**Sagittal T1WI, axial FLAIR, fast spin echo T2WI, fast inversion recovery T1WI, DWI, Grad echo**

# Imaging Findings of Neonatal HIE

# Regional selectivity

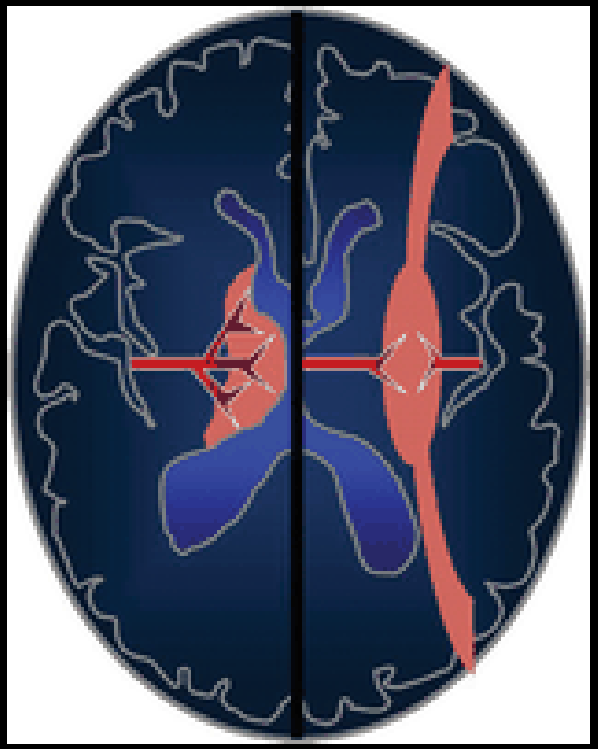
- Selective vulnerability depending on
  - Severity/duration of hypoperfusion event
    Mild to moderate vs. severe hypoperfusion
  - Degree of brain maturation
    Preterm vs. term neonates

- Term infants; excitotoxic neuronal injury
  (deep gray, perirolandic cortex)
- Premature infant; developing oligodendrocyte,
  subplate neuron

# Mild to moderate hypoperfusion ; intervascular (watershed) zones injury

- Different configuration of vascular supply & regional metabolism

  - Term; parasagittal
  - Preterm; periventricular

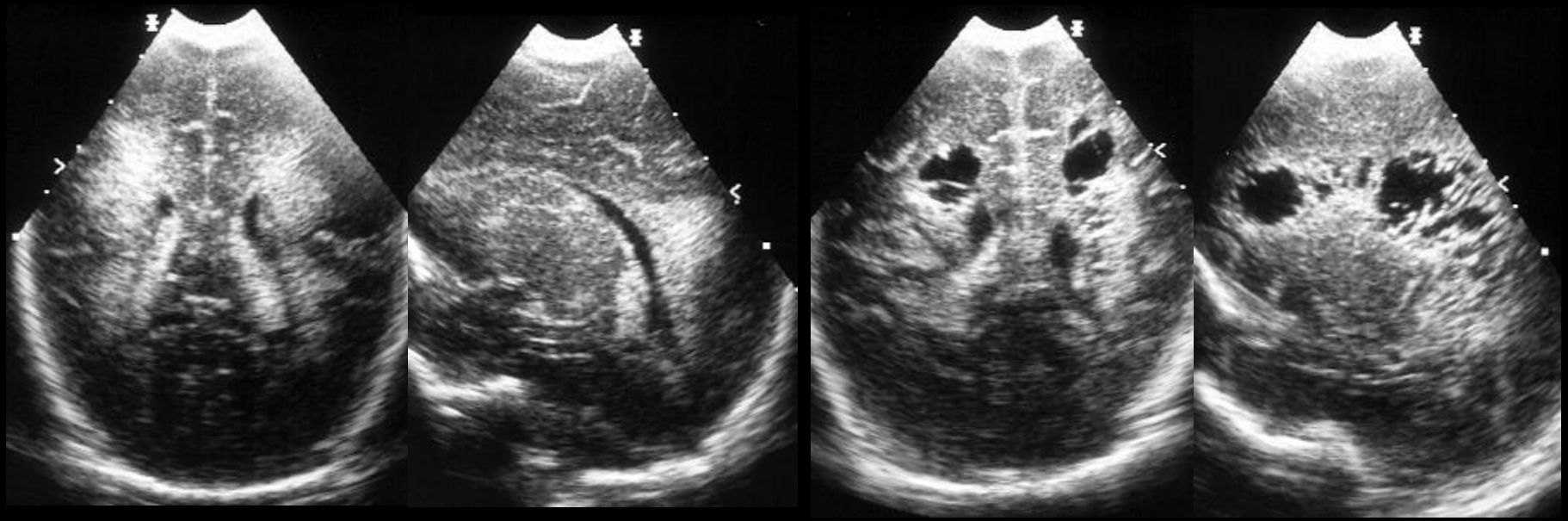


*- Christine P. et. al. RadioGraphics 2006*

# Spectrum of WM injury on Neuroimaging

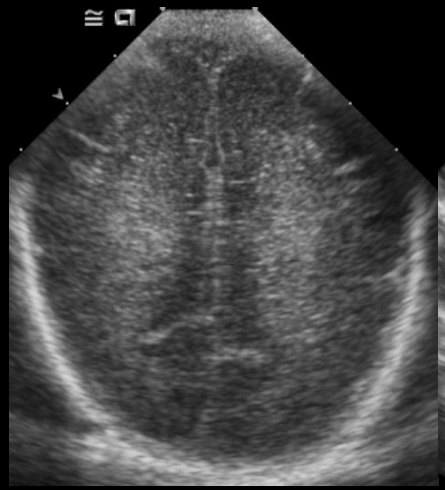
- Focal cystic necrotic lesions (PVL)
- Focal non-cavitary injury
- Diffuse Excessive High Signal Intensity of white matter (DEHSI)

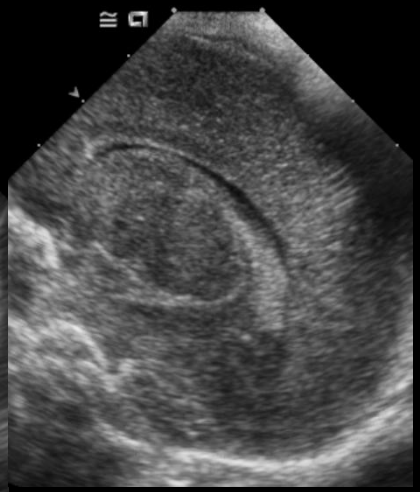
# Selective vulnerability to mild to moderate hypoperfusion in preemie ;PVWM

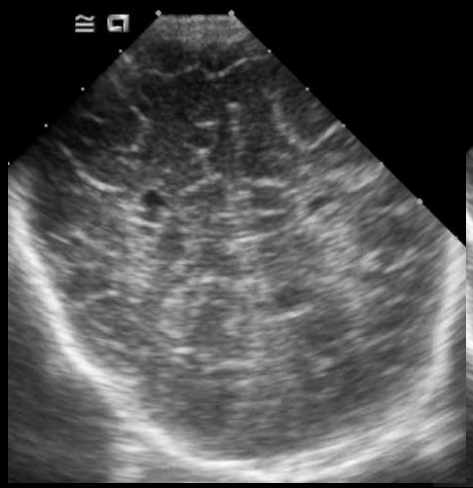


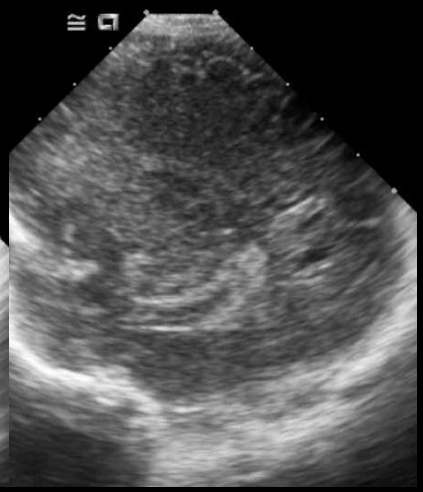
- PVL; echodensity initially & hypoechoic cavitations (2-6 weeks) when necrotic tissue begins to dissolve.

# PVL-US MR images

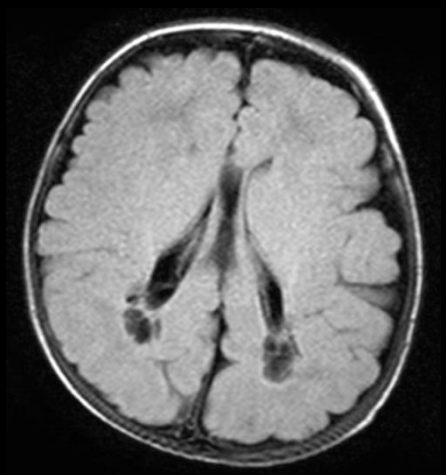


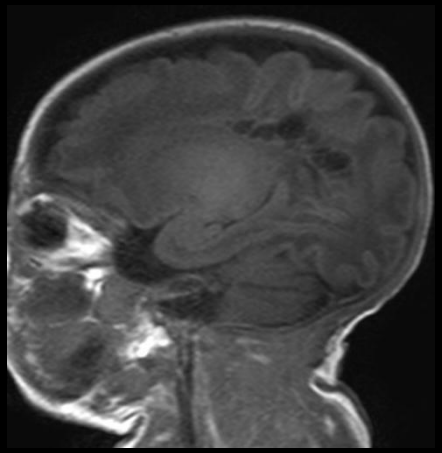


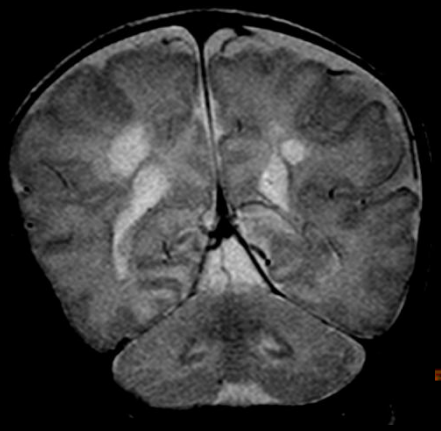




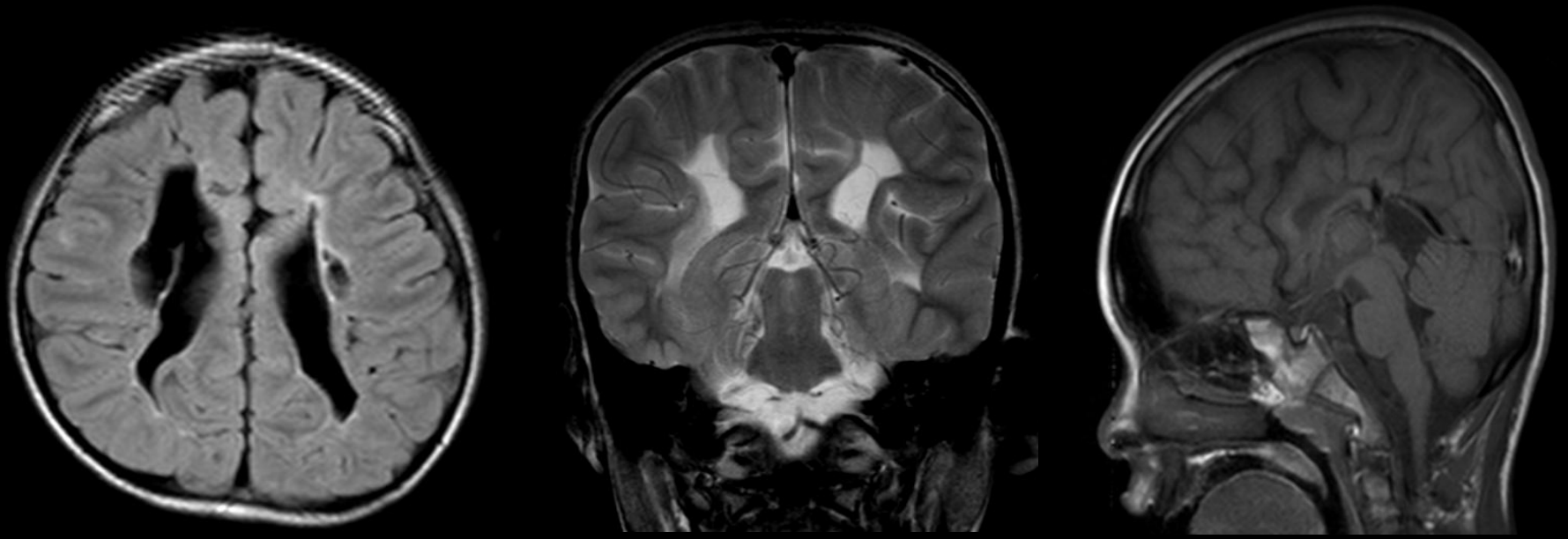
FU 2weeks later







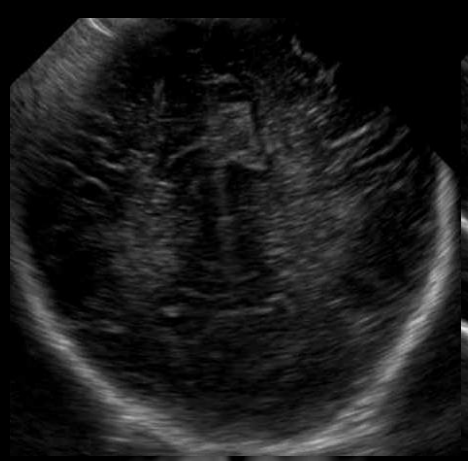
# End-stage PVL

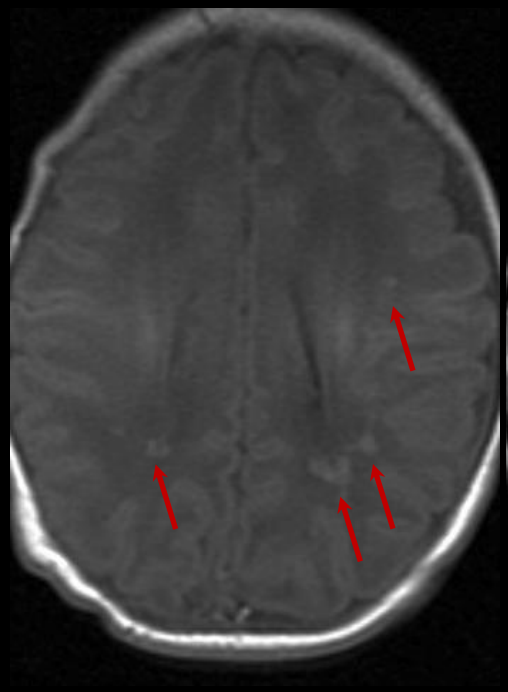


9-year-old girl with cerebral palsy, developmental delay

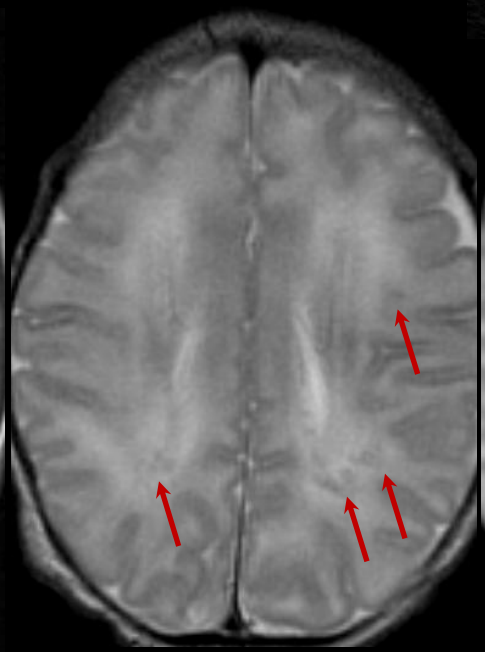
GP 31W+4, 1.4Kg, twin, NICU care for 2 months

# Non-cavitary lesions



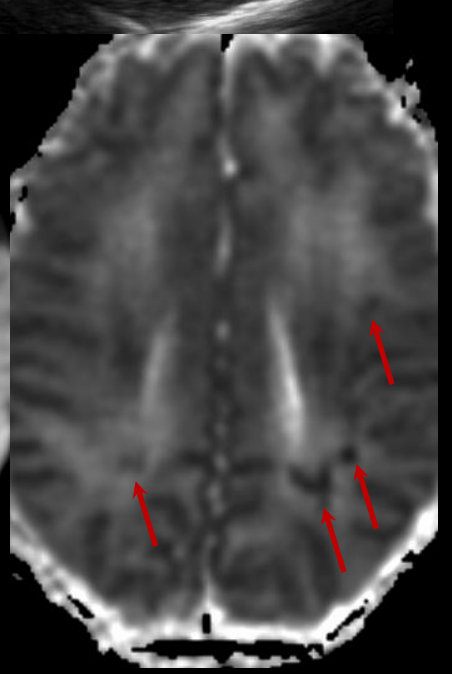


T1WI



T2WI

DWI

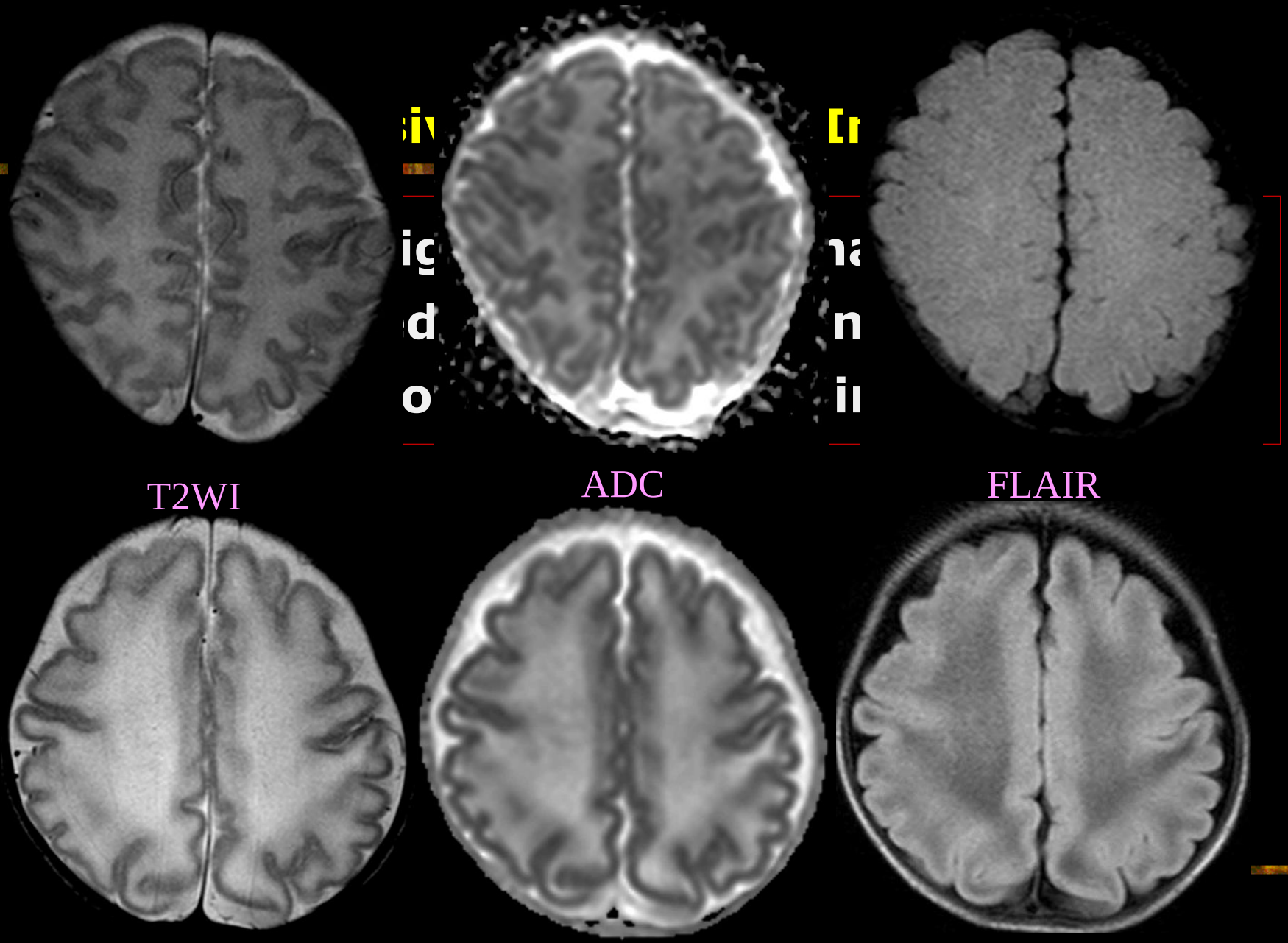


ADC

# US in acute setting

- Relatively poor sensitivity for non-cavitary white matter lesions.
- Up to 70% of hypoxic-ischemic WM lesions are missed in the acute phase on US.

*-Hope PL, et al. Dev Med Child Neurol 1988*


T2WI
ADC
FLAIR

# DEHSI

## Maturation process

- **Serial MR imaging**
  - Less than 30 wks GA scan: DEHSI (-)
  - Near term scan: DEHSI (+)

- **Griffiths Mental Developmental Scales**
  - No correlation between DEHSI and DQs at 18-36 Mo.

*- Dyet et al. Pediatrics 2006*

# DEHSI

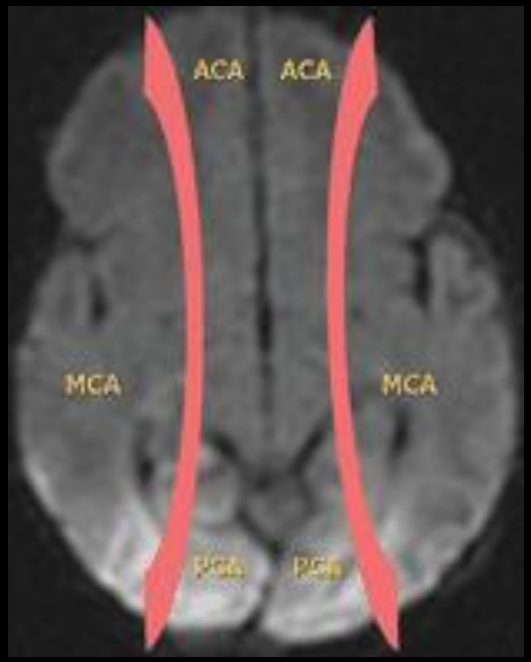
## Diffuse white matter injury

- **Increased ADCs on DWI**
  - **ADC DEHSI > ADC normal WM**
  - **ADC DEHSI = ADC overt WM pathology**
- **Decreased FA on DTI**
  - **Reduction in myelination**
  - **Axonal damage**

- *Counsell et al. Pediatrics 2006*
- *Skiold et al. Acta Paediatr 2010*

# Mild to moderate hypoperfusion in term baby;

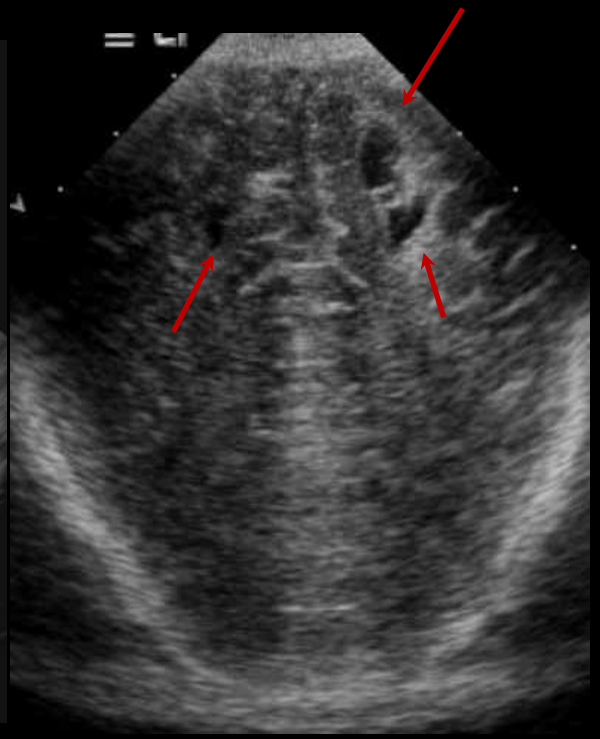
- Parasagittal cortical and subcortical injury



# Serial US of parasagittal injury

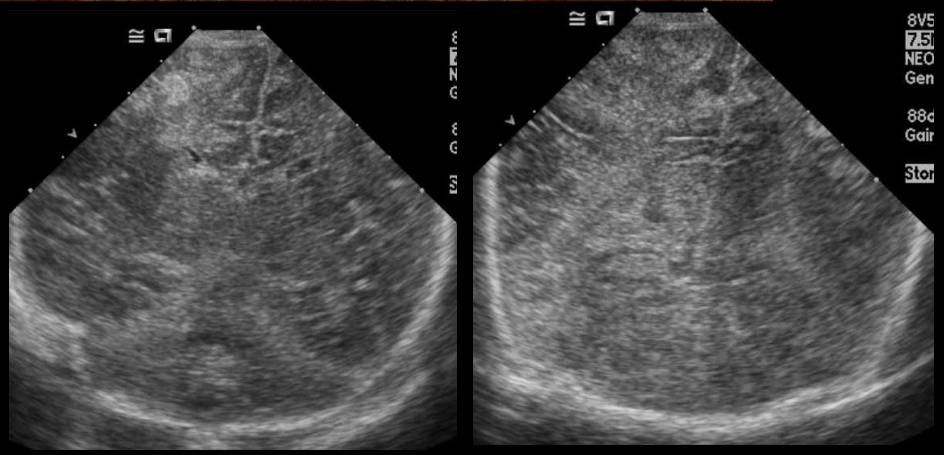
1W

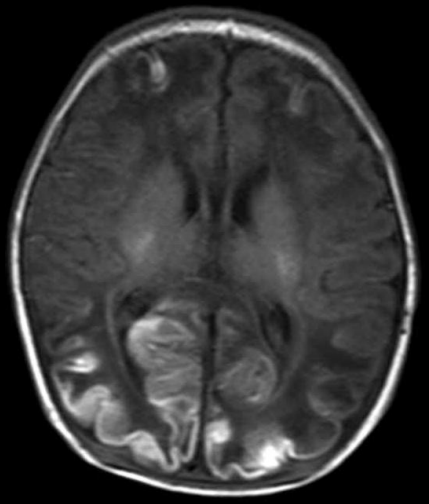
2 W



4 W

# Acute parasagittal injury





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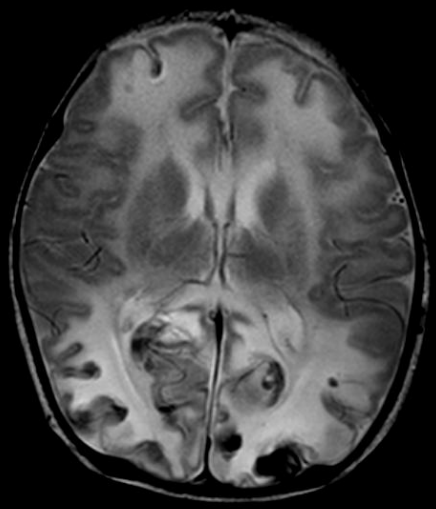
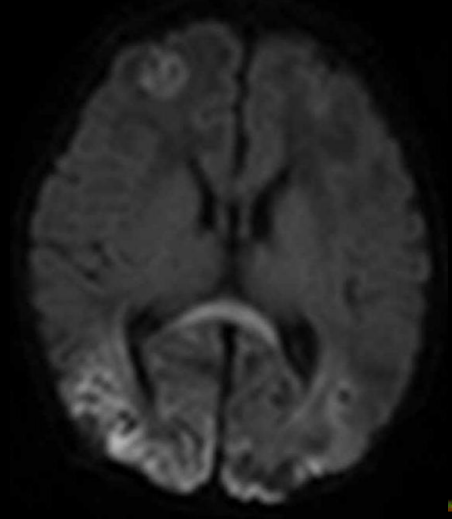
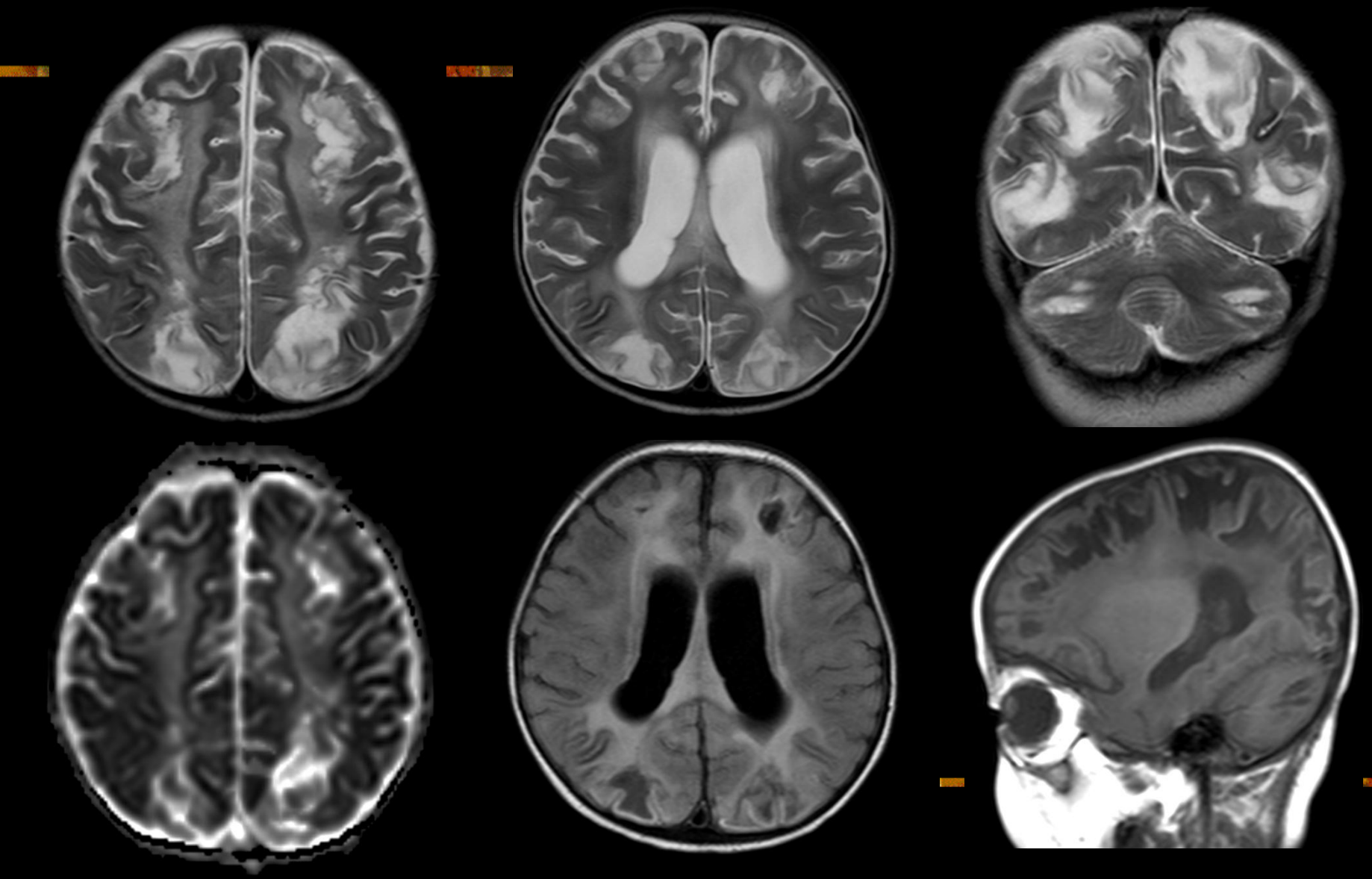


T2WI

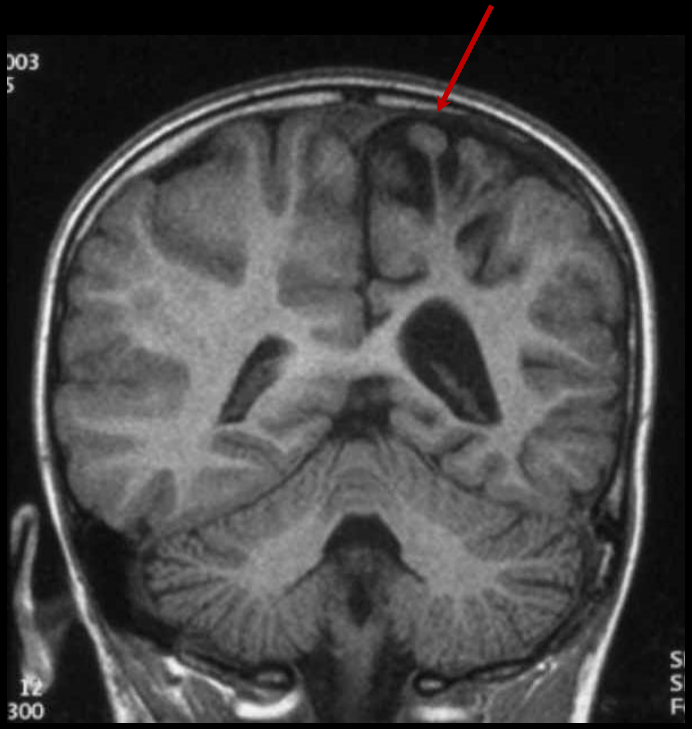


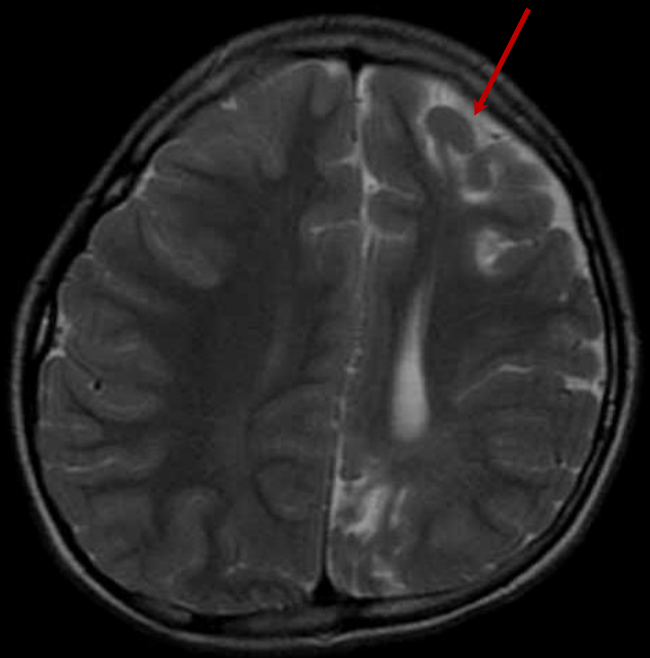
ADC

# Parasagittal injury -evolution



# Ulegyria in late parasagittal injury



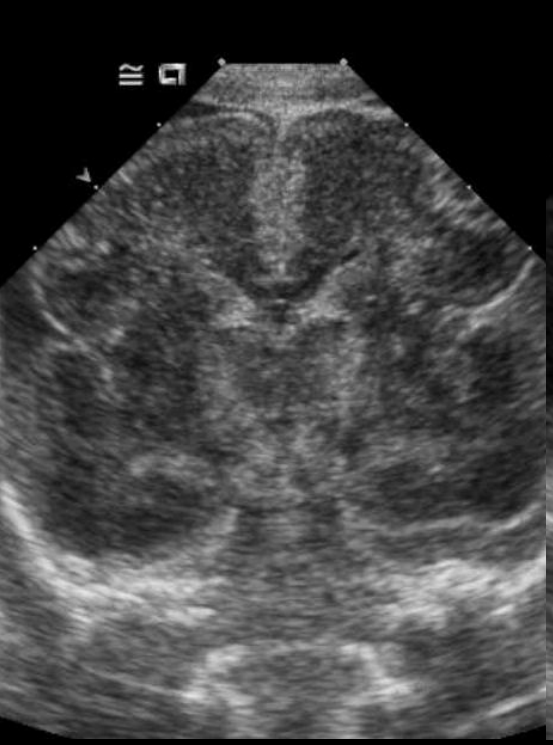


# Severe hypotension, prolonged asphyxia

- Deep gray, myelinated WM (↑ neurotransmitter receptors)

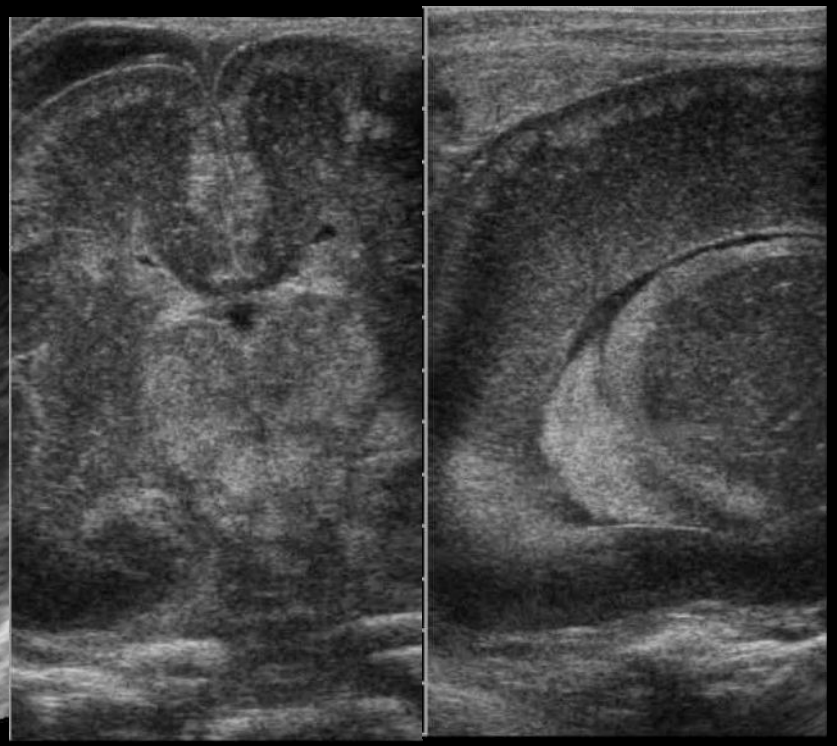
  - Thalami & brainstem in immature brain
  - Lateral thalami, globus pallidus, posterior putamina, hippocampi, brainstem,
    & perirolandic cortex in term infants

# 26w, incarceration during C/S



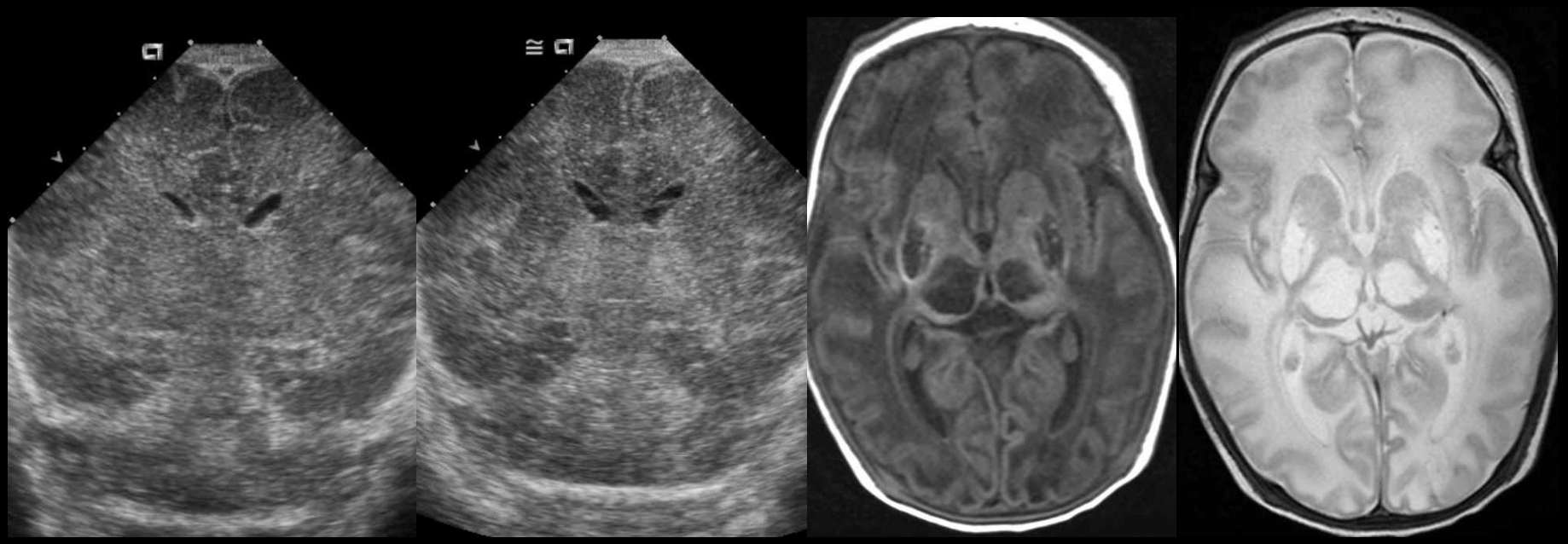
Coronal

Axial



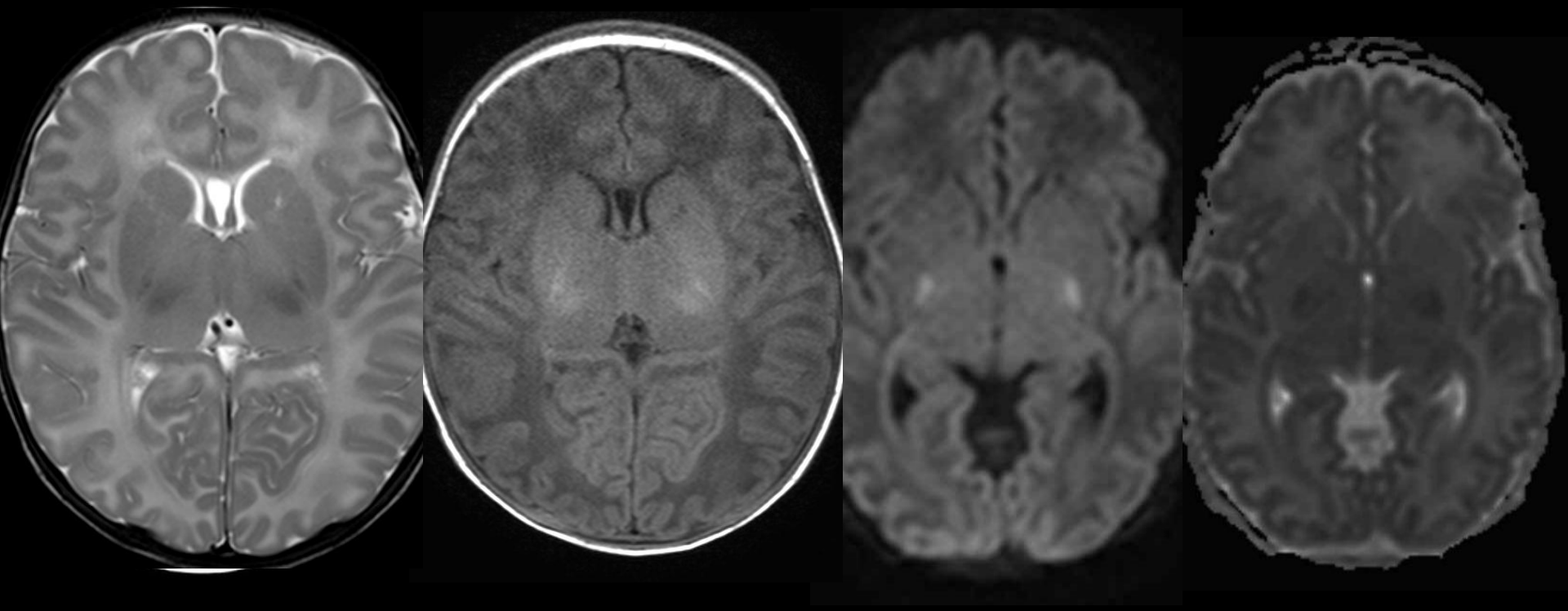
Sagittal

# 36wks 2990g,
# Cardiac arrest, CPR 20 min.



Day 1 Day 8 Day 20

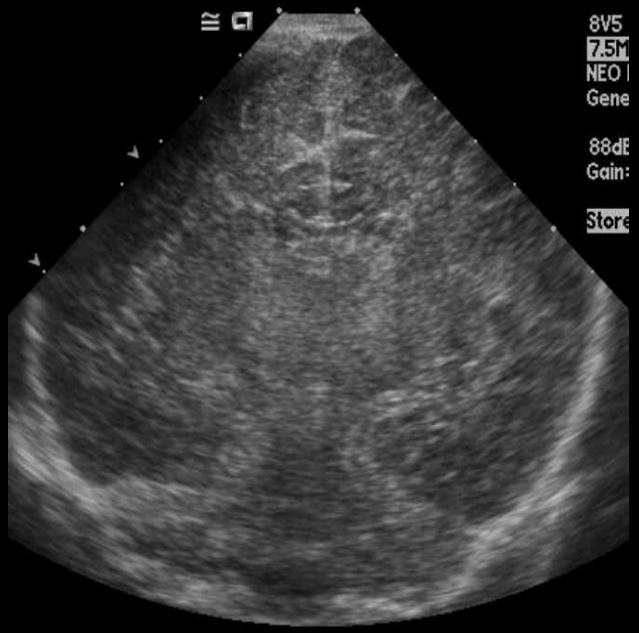
# Term neonate, birth asphyxia



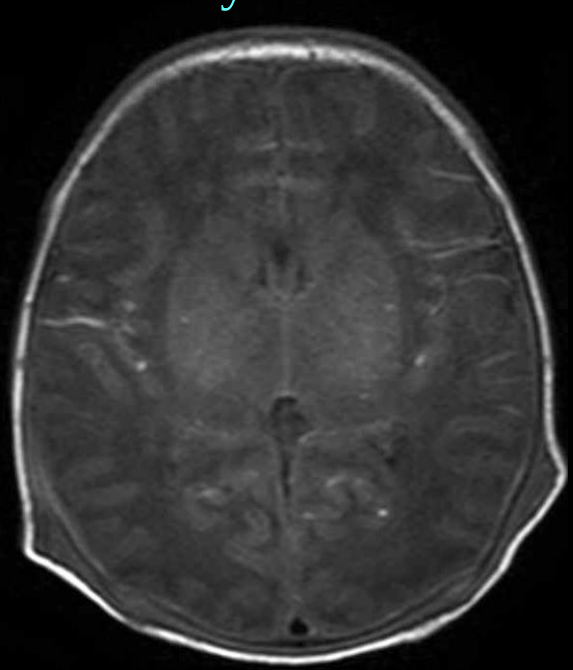
Absent PLIC, Hyperintense BG & thalami, Diffusion restriction

# Term baby, birth asphyxia

Day 2




Day 4



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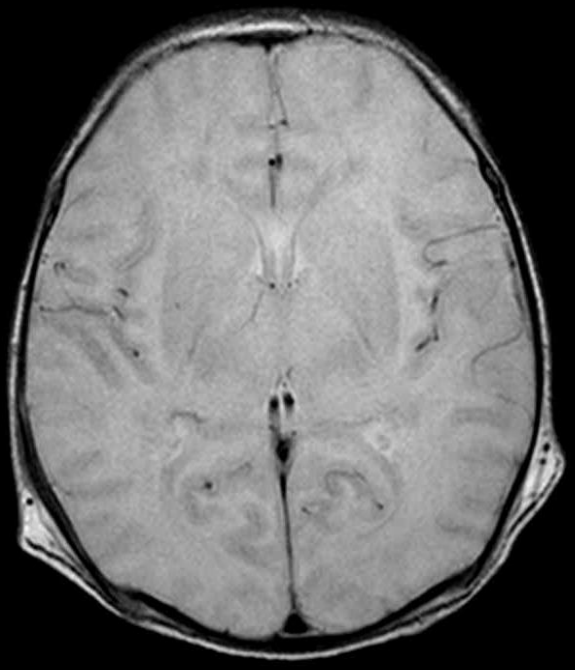
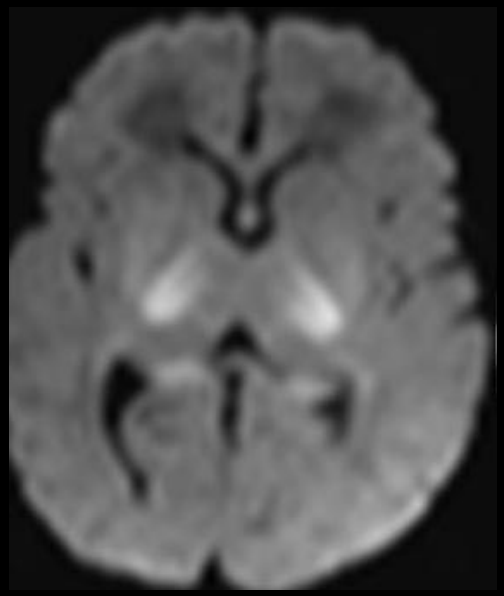
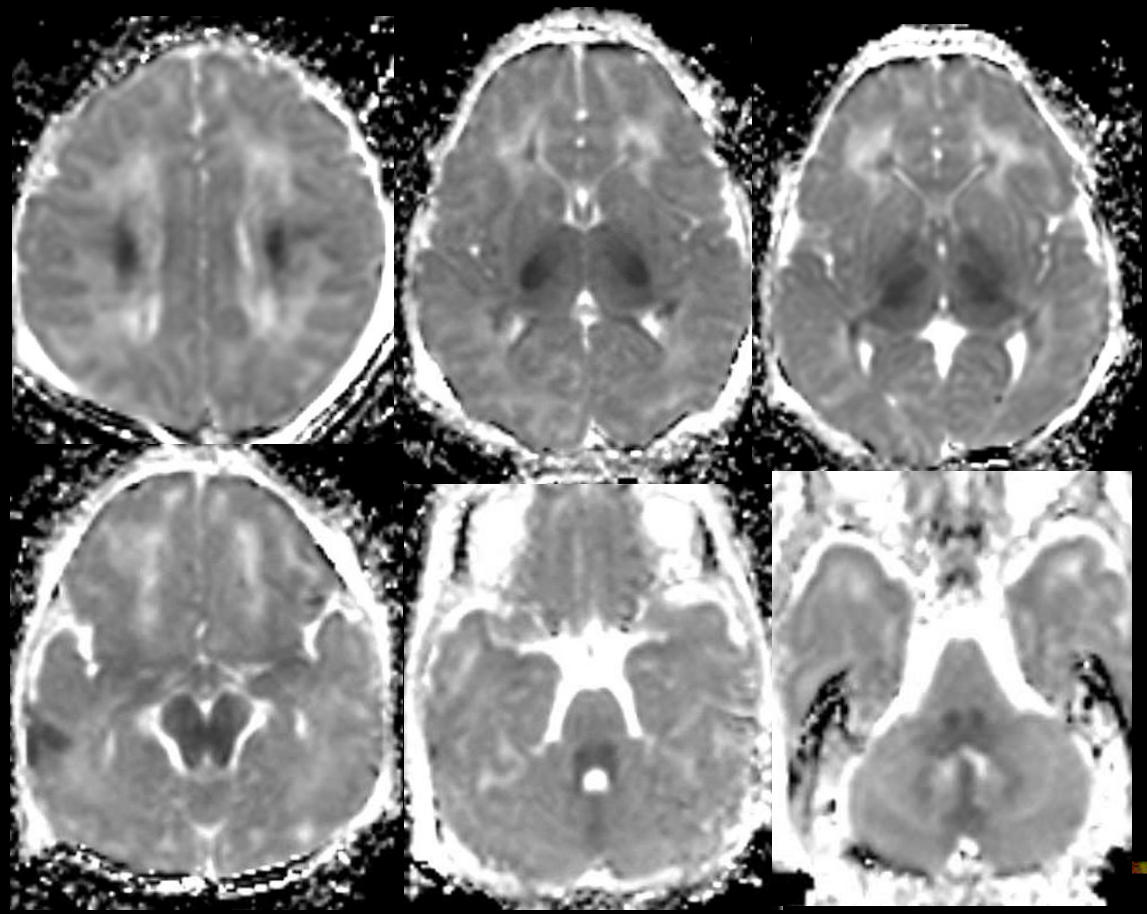


T2WI

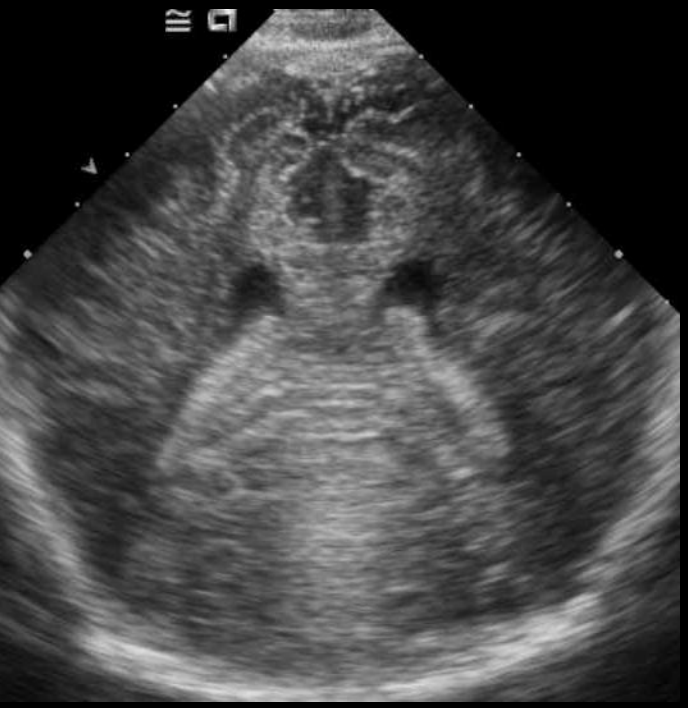
# Acute perinatal injury, DWI-ADC map

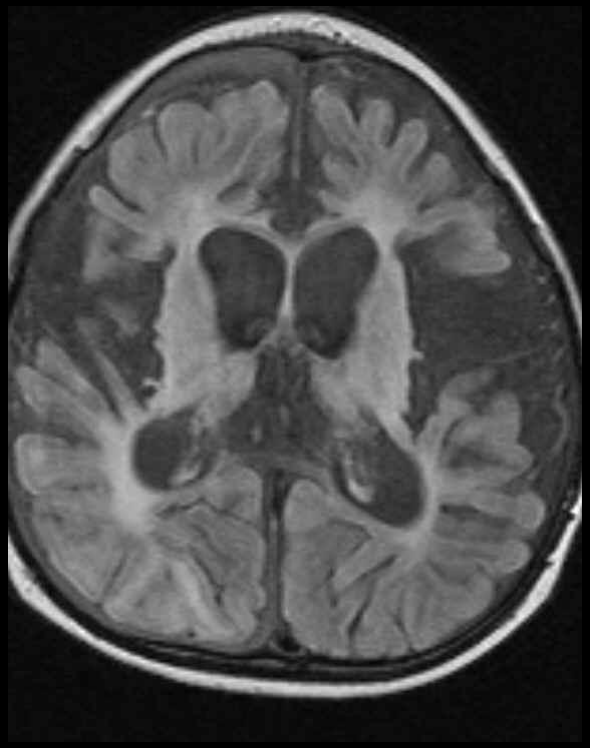


DWI



# F/U images after 2 months





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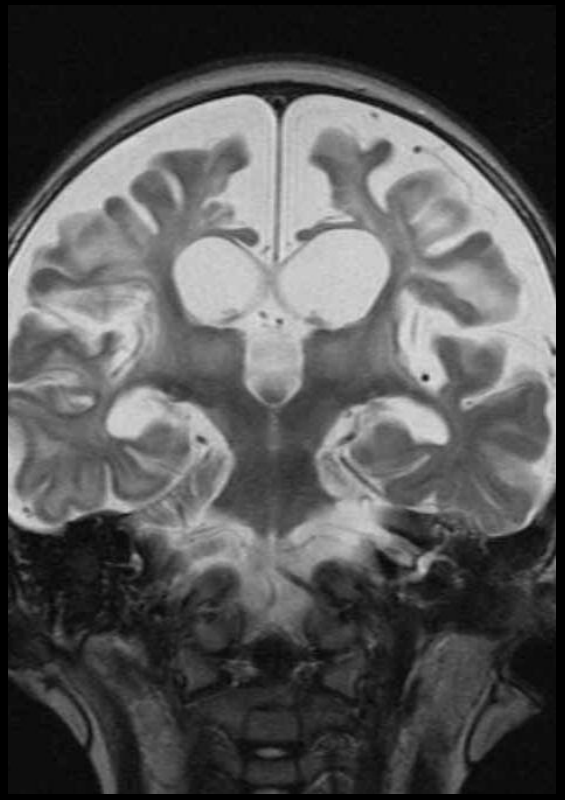
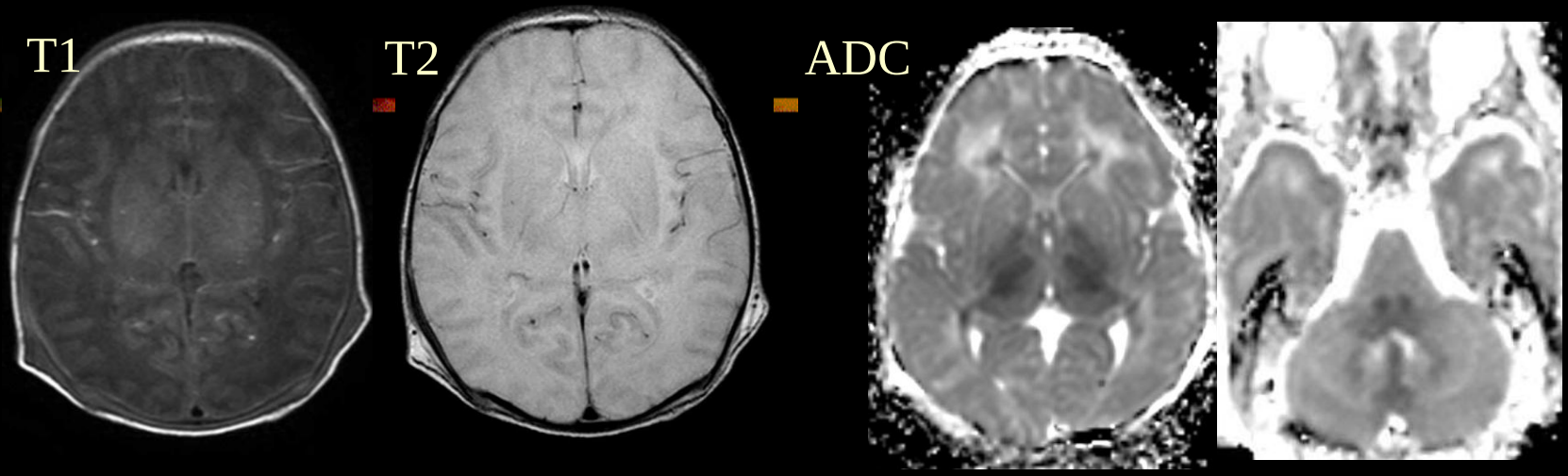
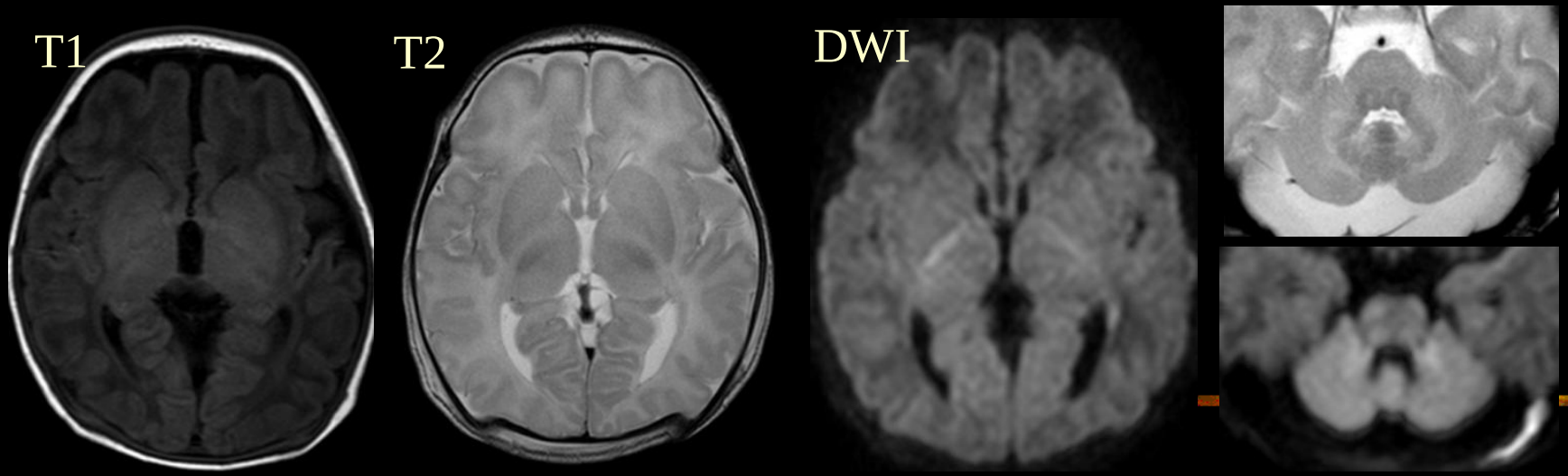


T2

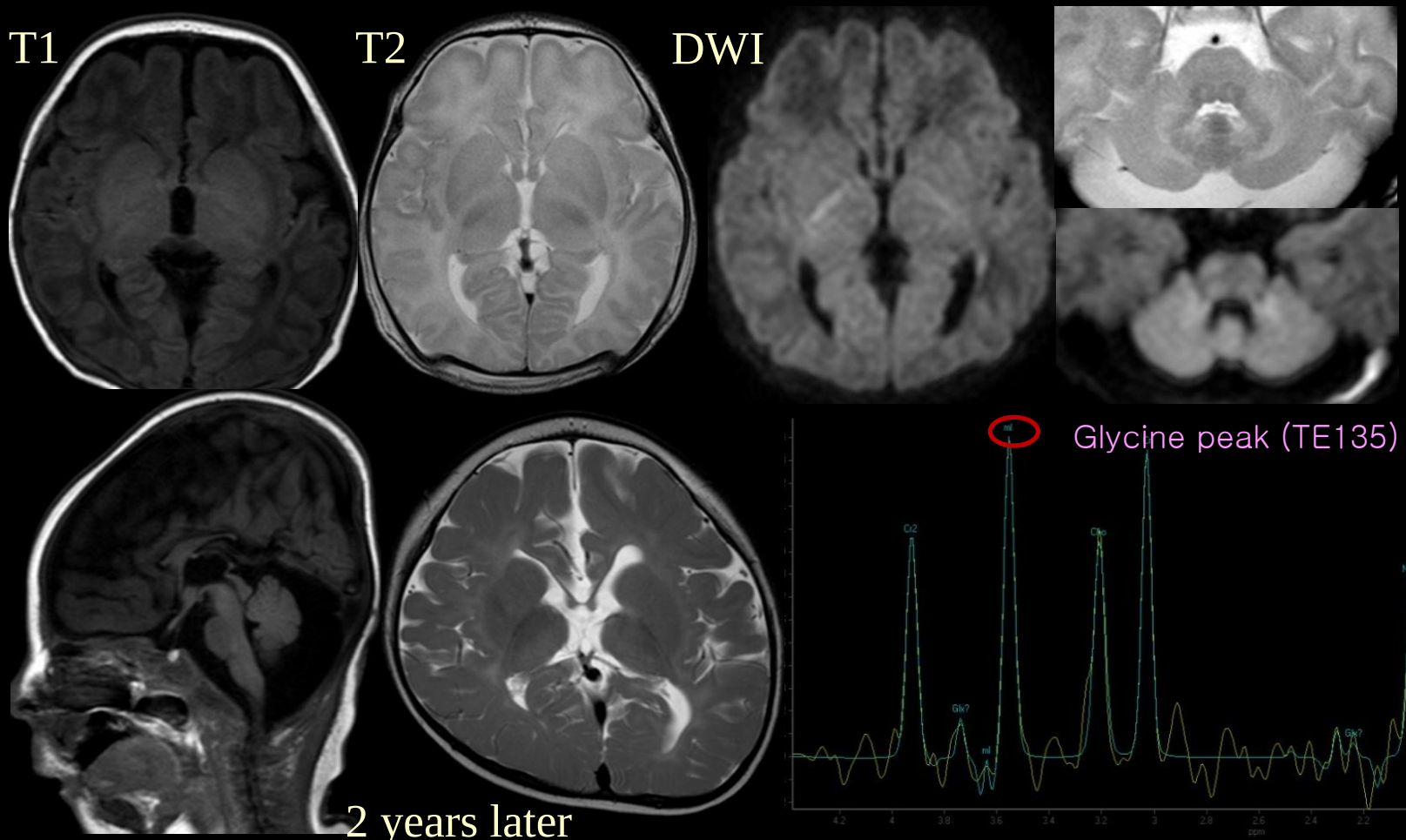
# Hypoxic Ischemic Encephalopathy



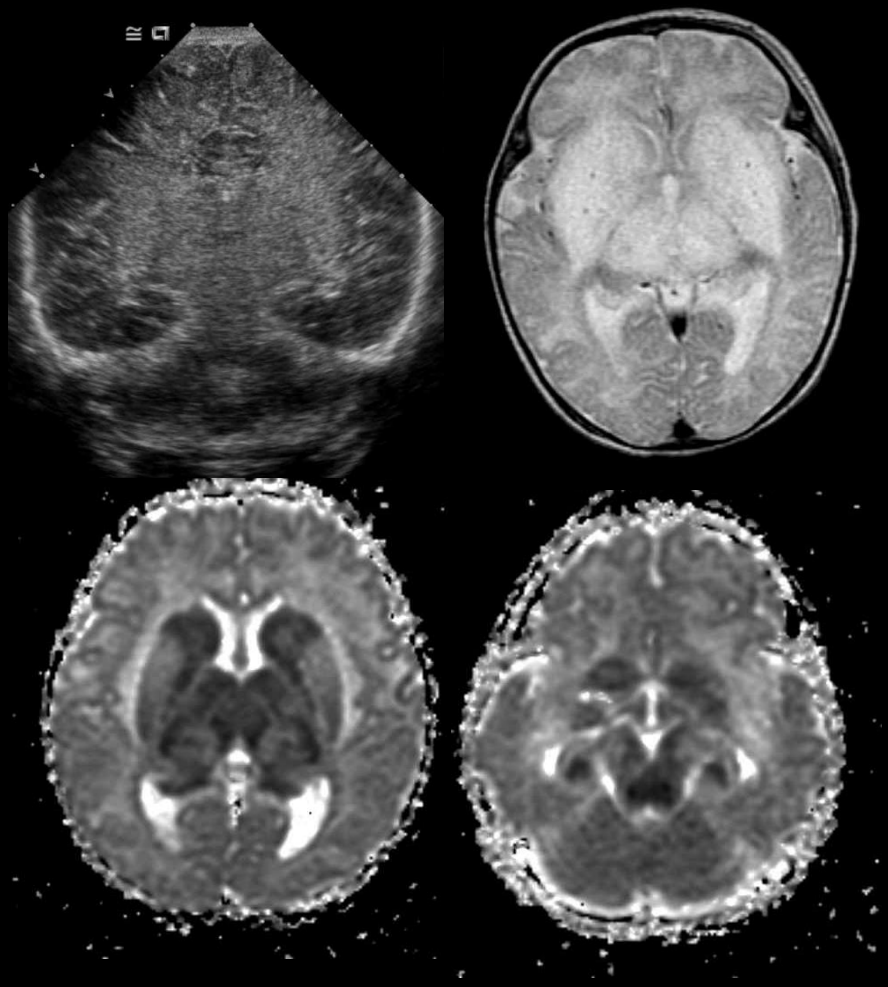

# Nonketotic Hyperglycinemia

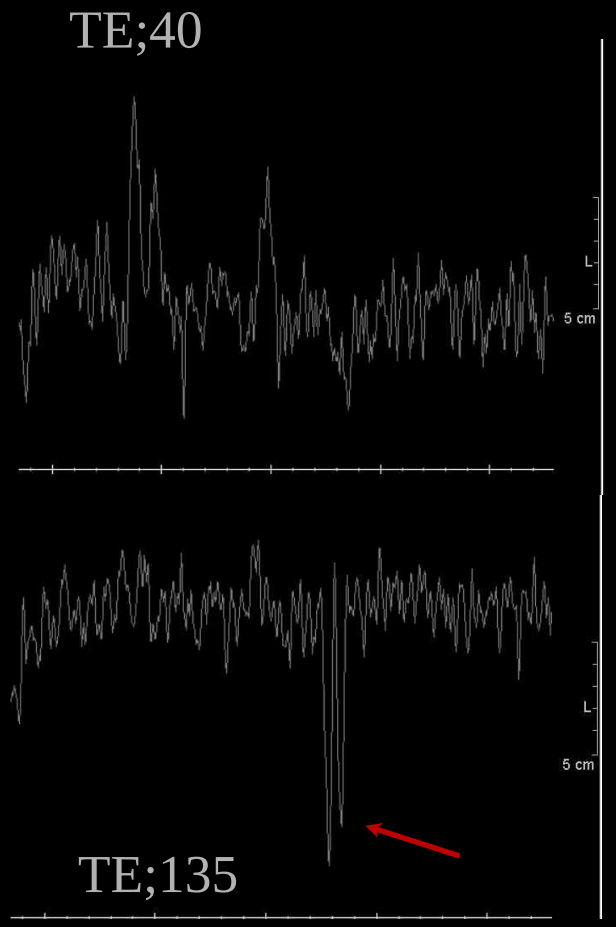


# Nonketotic Hyperglycinemia



# HIE vs. Leigh's syndrome





# Neonatal Disorders Mimicking HIE on MRI

- Neonatal adrenoleukodystrphy
- Primary lactic acidosis
- Urea cycle disorder
- Krabbe disease
- Maple syrup urine disease
- Nonketotic hyperglycinemia

Lack of birth asphyxia, symptom free interval, prolonged or recurrent episode of acute encephalopathy, abnormal lab. findings favor metabolic insult rather than HIE

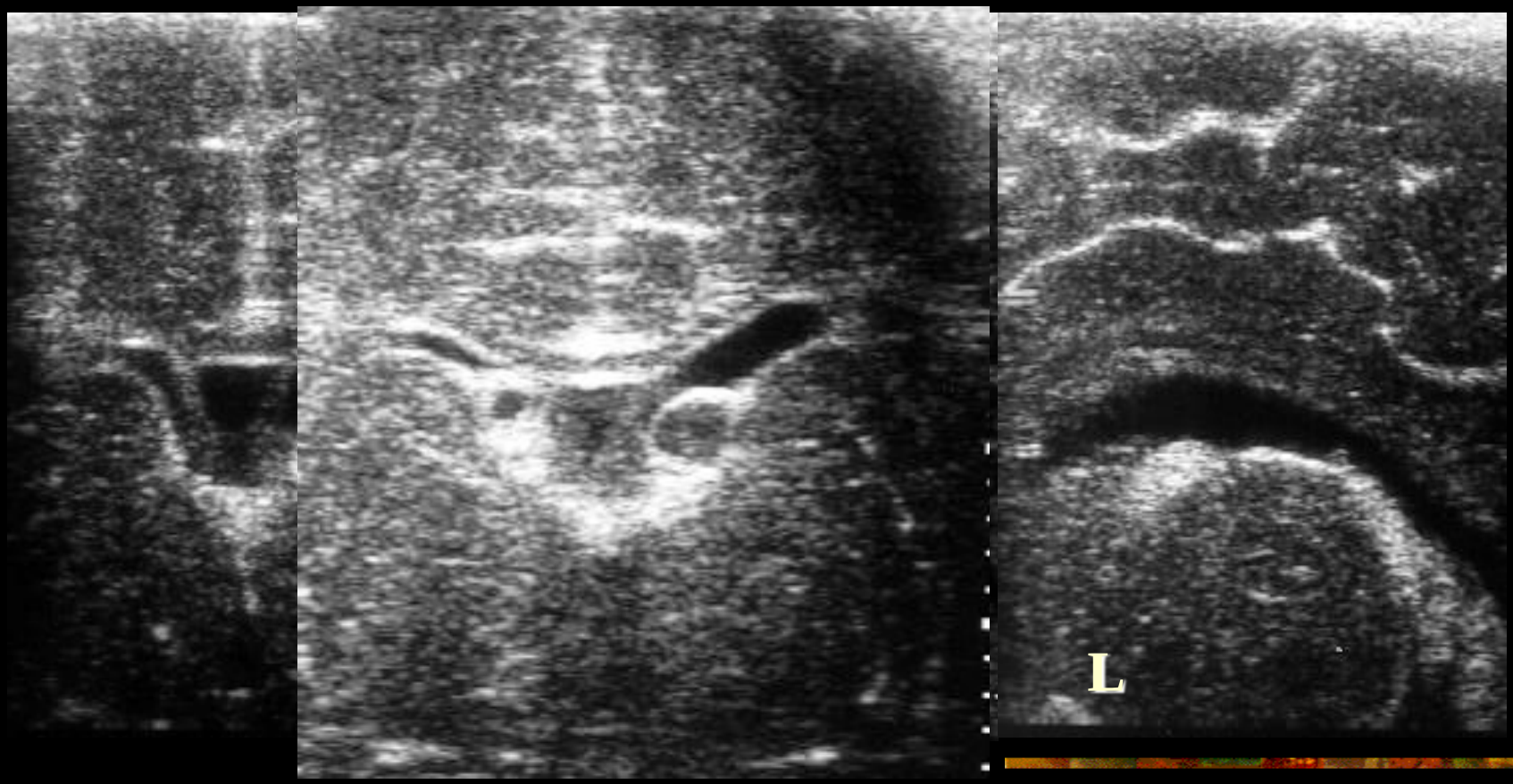
# Intracranial Hemorrhage in Preterm Infants

# GMH/IVH

- Pressure-passive cerebral circulation
- Fluctuations in cerebral blood flow
- Fragile germinal matrix microvasculature
- Derangements of coagulation

*-Roland EH. Neurol Clin 2003*

# Germinal Matrix Hemorrhage



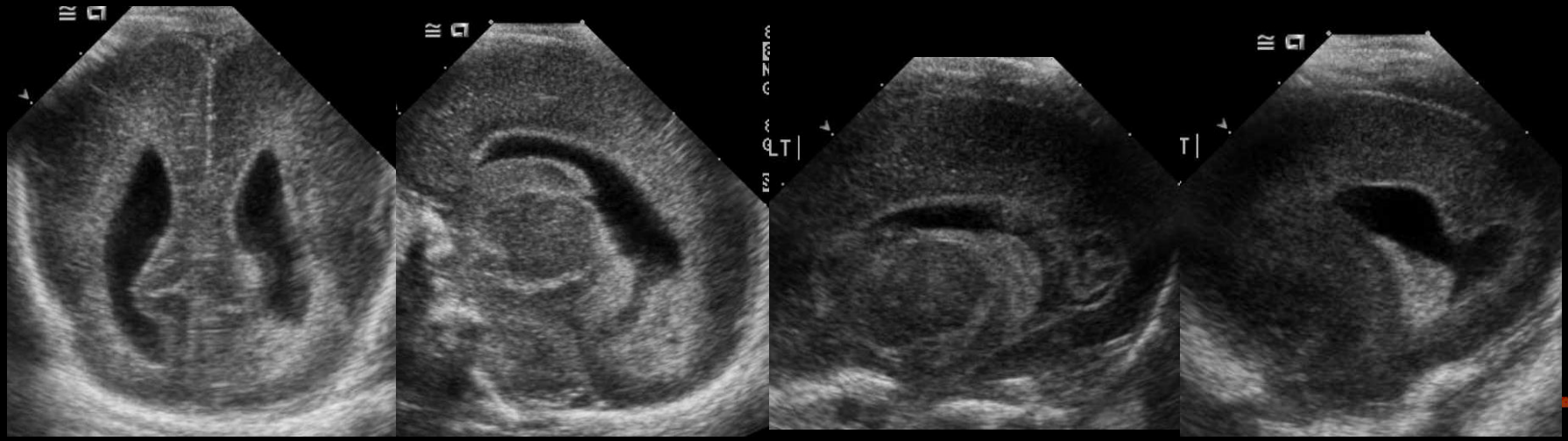
# Timing of GMH-IVH

- Within 1st day of life : 36-50%
- On 2nd day  : 25-30%
- By day 6 : 90%
- After 1 week :5%

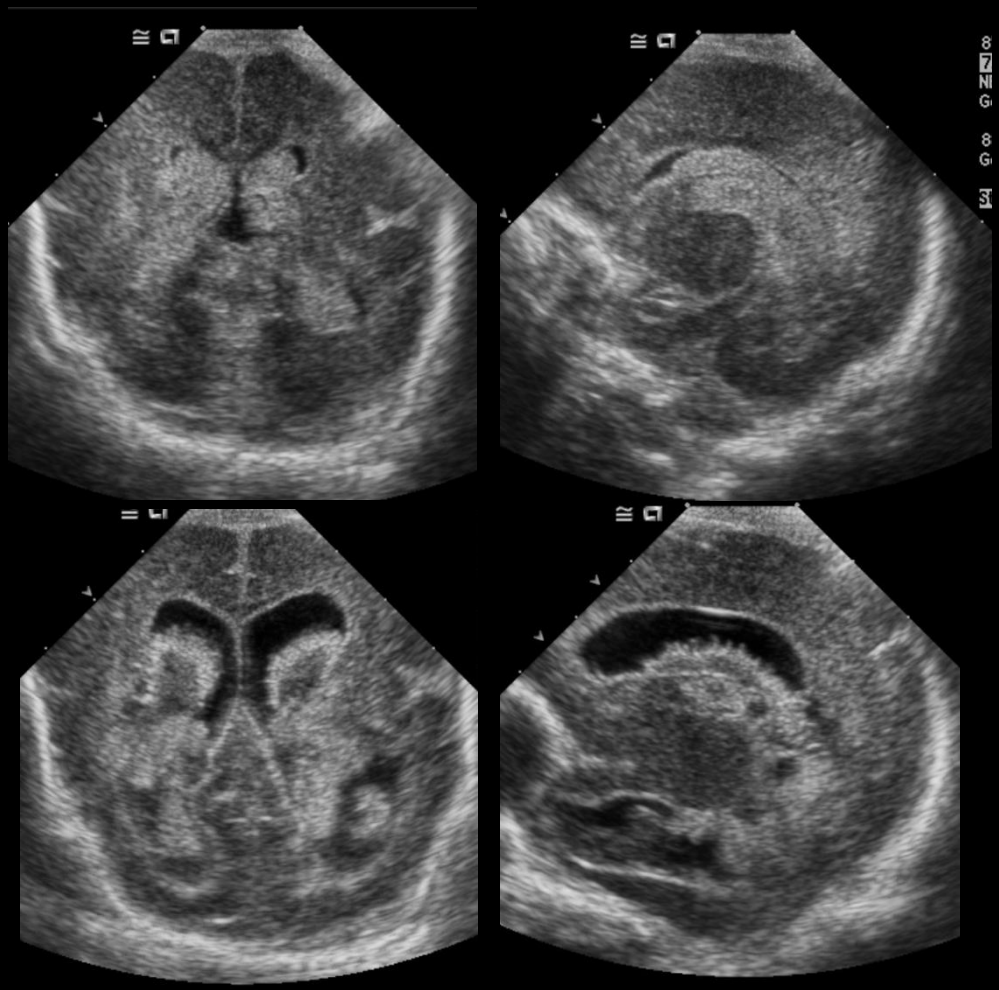
# USG for GMH-IVH

- Routine screening: on 4-7 days
- F/U for IVH : 1wk interval
- Anytime with suspected ICH
- At 3 months for delayed ventriculomegaly

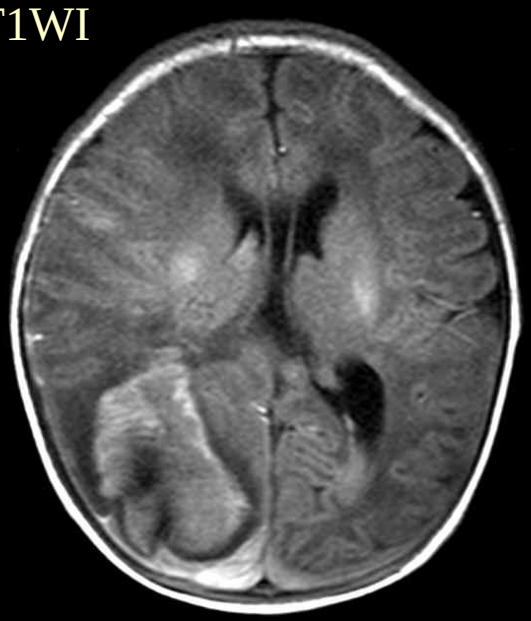
# GMH-IVH, US



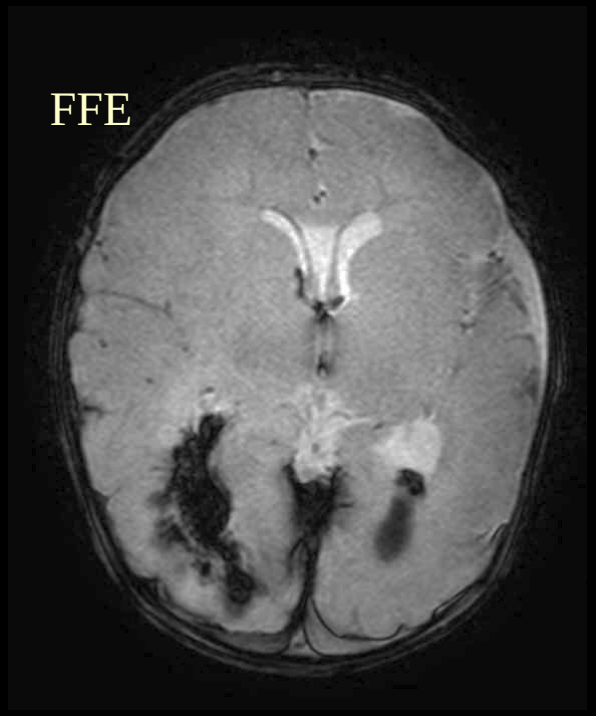
# IVH grade 3



# Periventricular Hemorrhagic Infarction

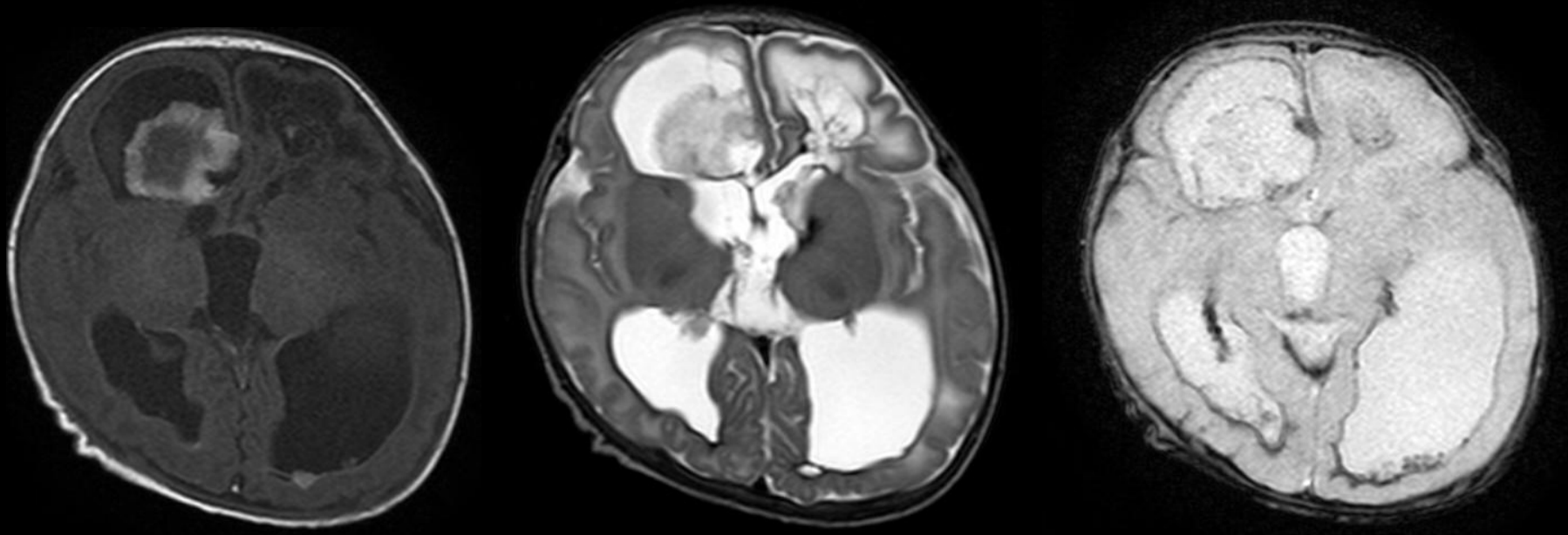







- Venous infarct (WM drained by medullary v. >> v. of GM >> terminal v.)
- Interruption of projection/associated fibers
- Injury of oligodendroglial cells & subplate neurons
- Myelination/ cognitive, attention deficit

# Evolving IVH/PHI



# Grade vs. Prognosis

| Grade | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Mortality rate (%) | 15 | 20 | 40 | 60 |
| Hydrocephalus (%) | 5 | 25 | 55 | 80 |
| Neurologic sequale (%) | 15 | 30 | 40 | 90 |

*-Volpe JJ. Ed. Neurology of the newborn 1987*

- Poor prognosis in prior hypoxic-ischemic insults, hydrocephalus, & periventricular hemorrhagic infarction

*-Volpe JJ. Ed. Ann Neurol.1989*

# Prediction of Neuromotor Outcome in Perinatal Asphyxia: Evaluation of MR Scoring Systems

| Score | Finding |
|---|---|
| **Basal ganglia (BG)** | |
| 0 = | Normal or isolated focal cortical infarct |
| 1 = | Abnormal signal in thalamus |
| 2 = | Abnormal signal in thalamus and lentiform nucleus |
| 3 = | Abnormal signal in thalamus, lentiform nucleus, and perirolandic cortex |
| 4 = | More extensive involvement |
| **Watershed (W)** | |
| 0 = | Normal |
| 1 = | Single focal infarction |
| 2 = | Abnormal signal in anterior or posterior watershed white matter |
| 3 = | Abnormal signal in anterior or posterior watershed cortex and white matter |
| **Basal ganglia/watershed (BG/W)** | |
| 0 = | Normal |
| 1 = | Abnormal signal in basal ganglia or thalamus |
| 2 = | Abnormal signal in cortex |
| 3 = | Abnormal signal in cortex and basal nuclei (basal ganglia or thalami) |
| 4 = | Abnormal signal in entire cortex and basal nuclei |
| **Enhancement (E)** | |
| 0 = | No enhancement |
| 1 = | Enhancement in white matter only |
| 2 = | Enhancement in deep gray matter nuclei |
| 3 = | Enhancement in cerebral cortex |
| 4 = | Enhancement in cortex and deep gray matter or white matter |

- **4 MR scoring systems**
- **51 asphyxiated term neonates**
- **3 MR sequences; T1WI, 1st echo T2WI, 2nd echo T2WI**
- **Neuromotor examinations at 3/12 M, cognitive development at 12 M**

**BG/W score, first-echo T2WI; the most useful for predicting outcome**

**T1WI & first-echo T2WI ; during 1st postnatal week**

**2ND echo T2WI ; during 2nd postnatal week**

*- Barkovich AJ, et al. AJNR 1998*

# Neonatal MRI to Predict Neurodevelopmental Outcomes in Preterm Infants

- 167 preterms (gestational age < 30 weeks)
- White-matter (WM) & gray-matter (GM) abnormalities on MRI at term equivalent
- Risks of severe cognitive delay, severe psychomotor delay, cerebral palsy, neurosensory impairment at 2 years of corrected age
- Moderate- to-severe WM abnormalities on MRI were significant predictors of severe motor delay & cerebral palsy

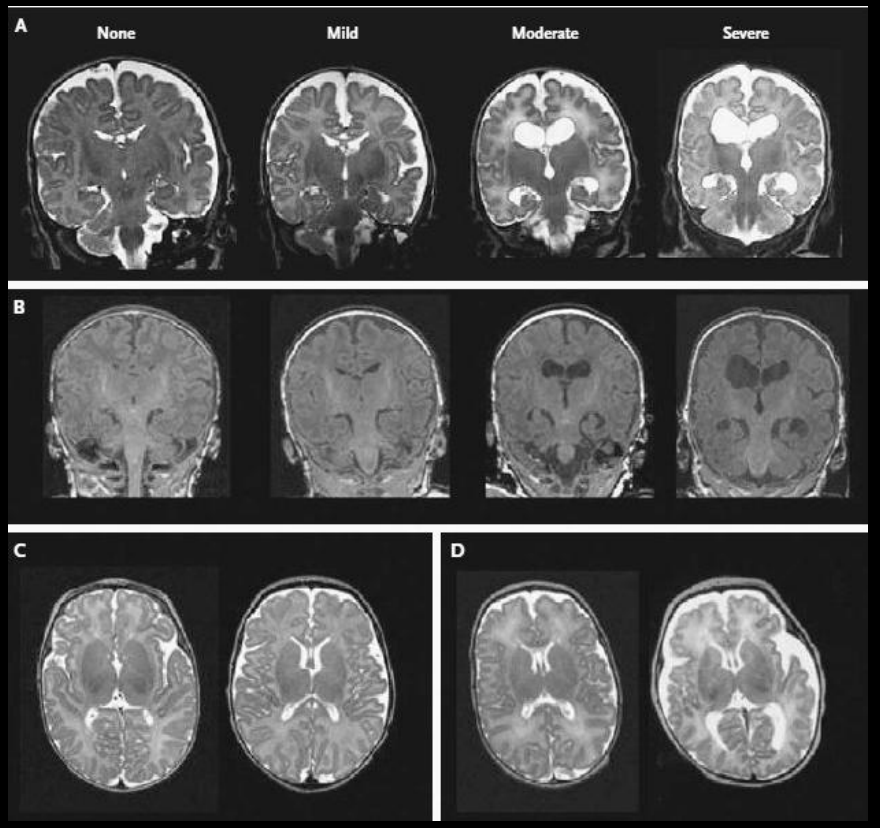
*-Woodward LJ, et al N Engl J Med 2006*

# Standardized scoring system (3-point scales)

- WM abnormality; signal abnormality, volume loss, cystic abnormalities, ventricular dilatation, thinning of corpus callosum
- GM abnormality; signal abnormality, gyral maturation, size of subarachnoid space
- Categorize according to composite scores

-WM; none(5-6), mild(7-9), moderate(10-12), severe(13-15)

-GM;normal(3-5), abnormal(6-9)

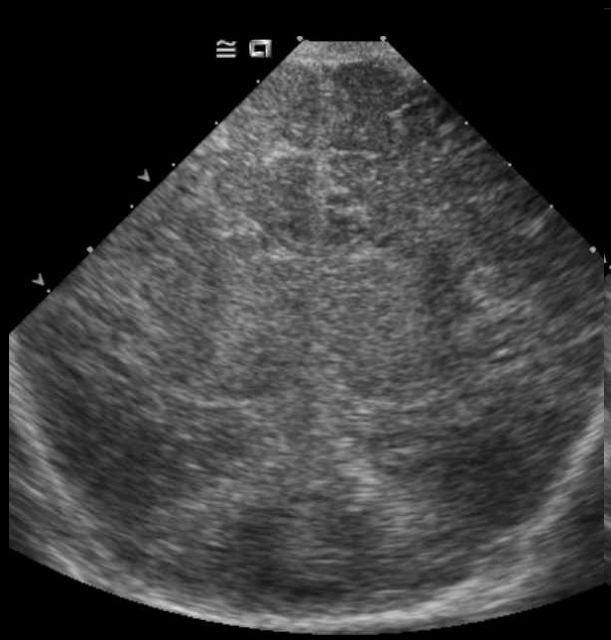



*-Woodward LJ, et al. N Engl J Med 2006*

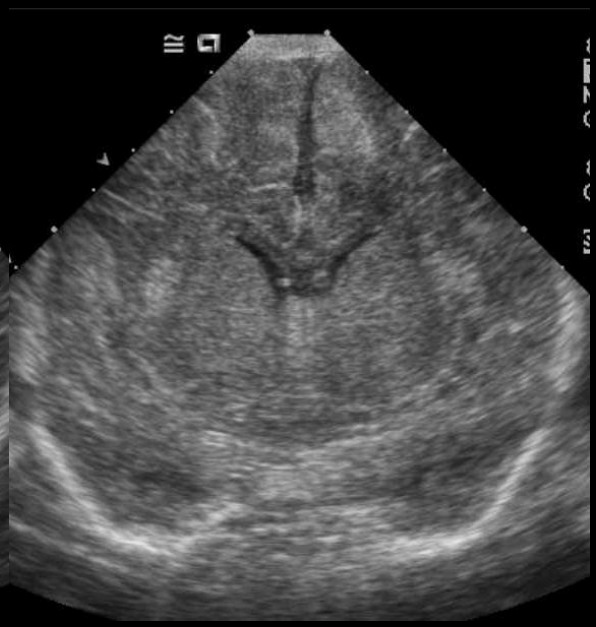
# Timing of imaging for neonatal encephalopathy

- Early diagnosis
  - US screening & F/U vs. MRI
- Screening MRI before discharge
- Late MRI
  - Evolution of lesions & additional detection
  - Prediction of patient outcome

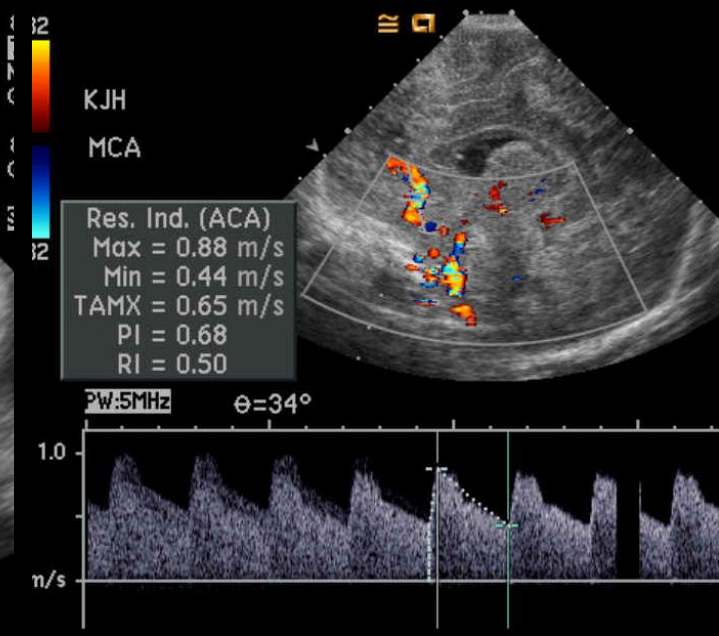
# 39W, meconium aspiration



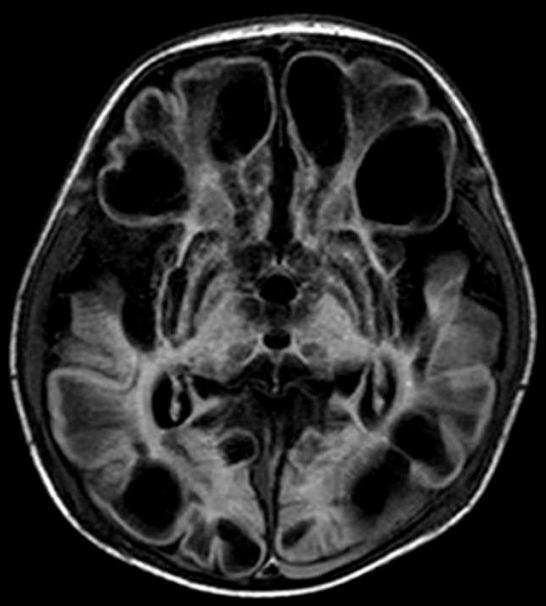
Day 1

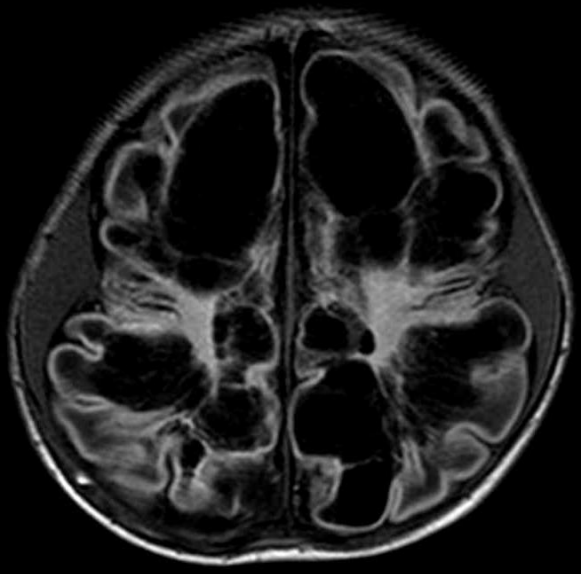


Day 6

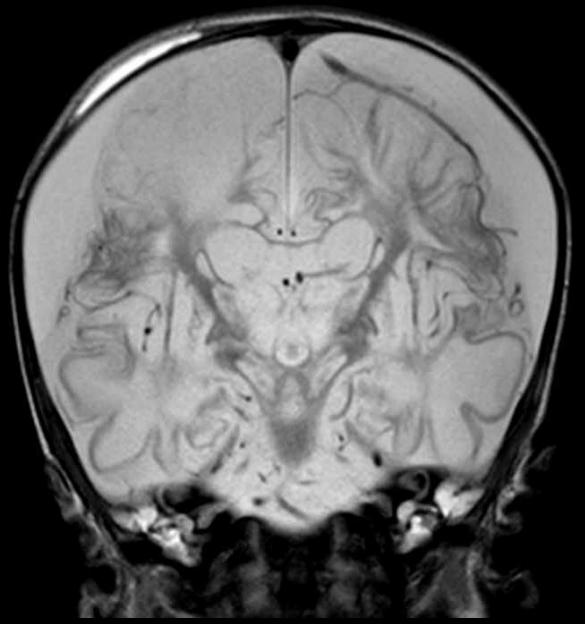


# MR images after 2months





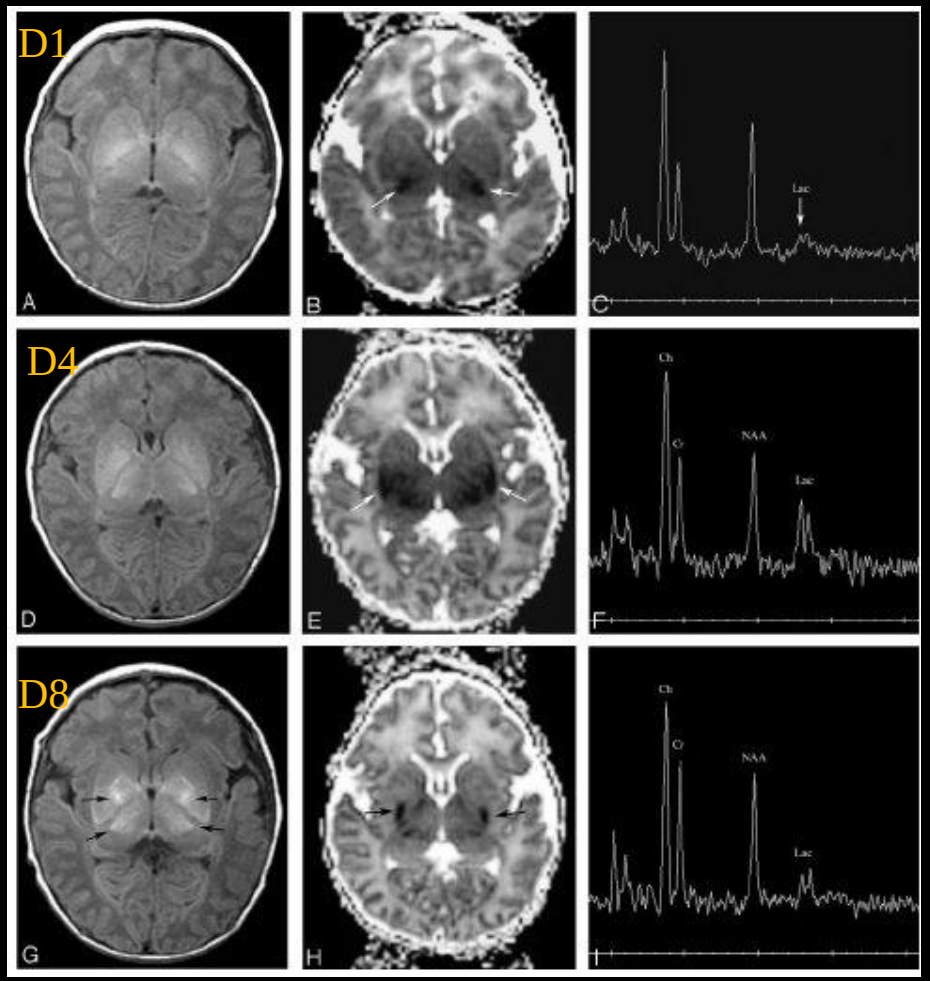
FLAIR



T2WI

# MRI obtained during early postnatal period

# Sequential MR imaging in neonatal encephalopathy in first 2 weeks of life




T1WI ADC MRS

- Dav, FA, 3eigenvalues of diffusion tensor, metabolite ratio at different locations
- None/subtle changes on T1WI
- Diffusion/MRS changes until day 5 & normalized
- Simultaneous appearance of diffusion restriction & pseudonormalization

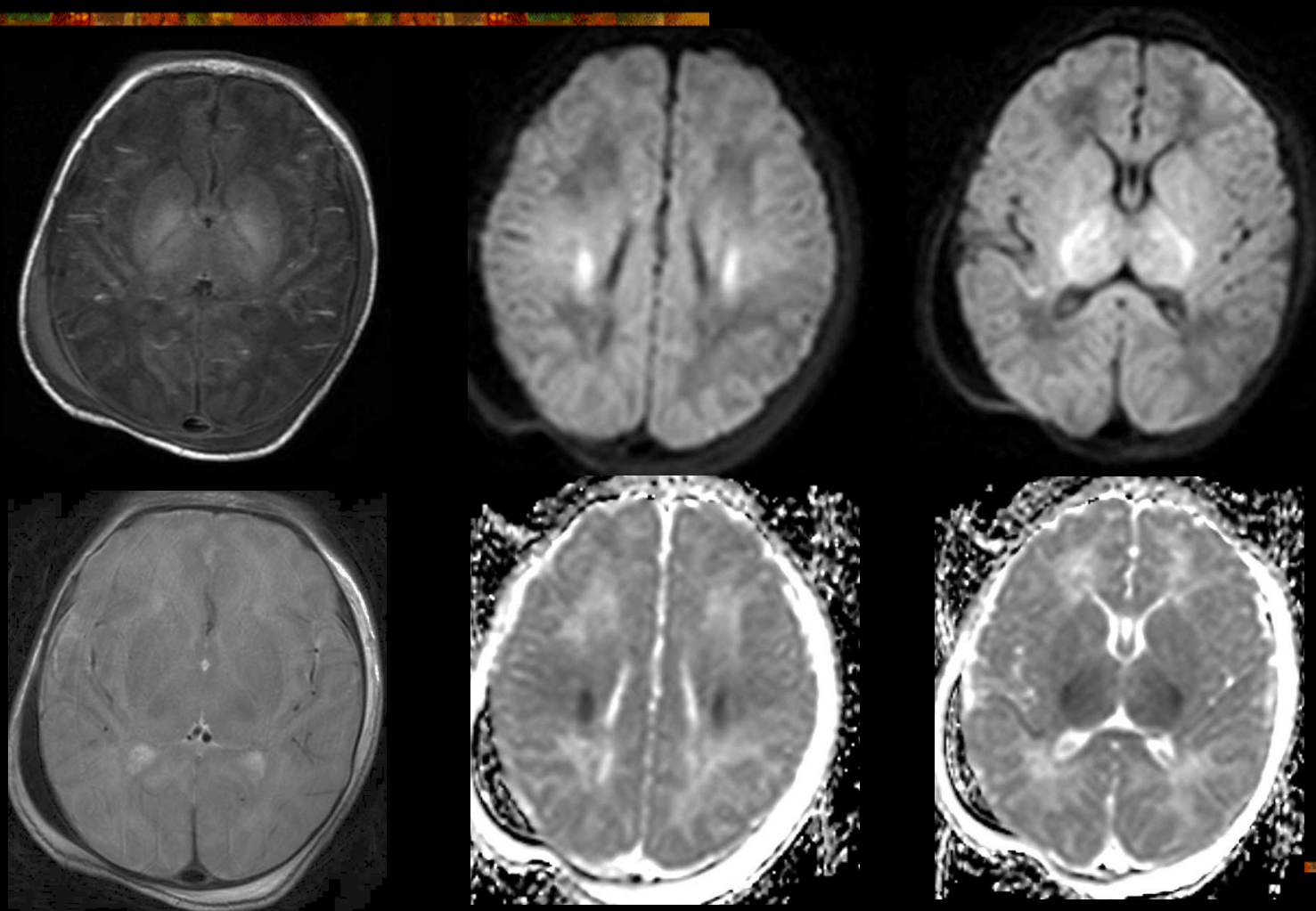
*-Barkovich AJ, et al. AJNR 2006*

# Hypoxic ischemic injury

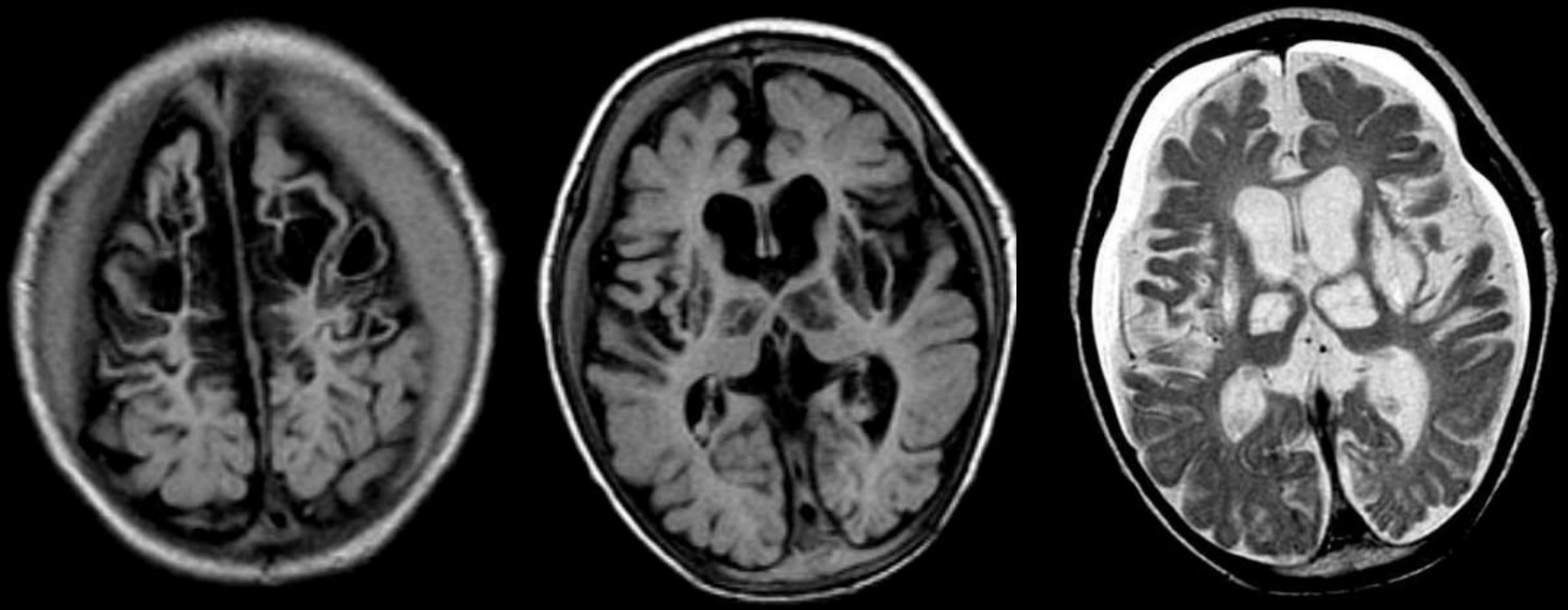
Anaerobic metabolism, failure of ion pumps, release of excitory neurotransmitters

| | Tissue changes | | MR Imaging |
|---|---|---|---|
| 0-2 hrs | Accumulation of intracellular lactate | Elevated lactate | MRS |
| 2-6 hrs | Accumulation of intracellular $Na^+$, $Ca^{++}$, $H_2O$ | Cytotoxic edema | DWI |
| 6-48 hrs | Free radical injury (free fatty acids, NO, Xanthine, iron) | Necrosis/ apoptosis | DWI, T1, T2 |
| Delayed | Secondary energy failure, reperfusion, inflammation | Further necrosis, hemorrhage | + GRE |
| | Gliosis, scarring, neurogenesis | Plasticity, reorganization | + DTI, fMRI |

# Term infant at 2nd day of life



# Encephalomalacia after asphyxia



# Screening MRI at term equivalent

# High Risk Preterm Screening MRI

## Indications in SMC NICU

High risk preemie (< 32 wks or < 1500g)

- corrected GA>35WK
- before discharge

Any suspected brain lesion

- HIE, metabolic brain disease, infection, etc.

# Comparison of US and MR

- 121 Neonates with brain US and MRI

| | Number (M:F) | Median GA | Range | Weight |
|---|---|---|---|---|
| Preterm | 105 (53:52) | 28+3 | $23^{+0}$~$36^{+5}$ | 1172 ± 520g |
| Term | 16 (10:6) | 39+1 | $37^{+1}$~$41^{+2}$ | 2496 ± 731g |

- Retrospective review by 2 radiologists
  1) Hemorrhage
     GMH/IVH ; Presence, grade, pattern
     Other sites

  2) Parenchymal lesions

*- Kim JH. KJMRI 2009*

# GMH/IVH

Number of lateral ventricles with hemorrhage (Total N=242)

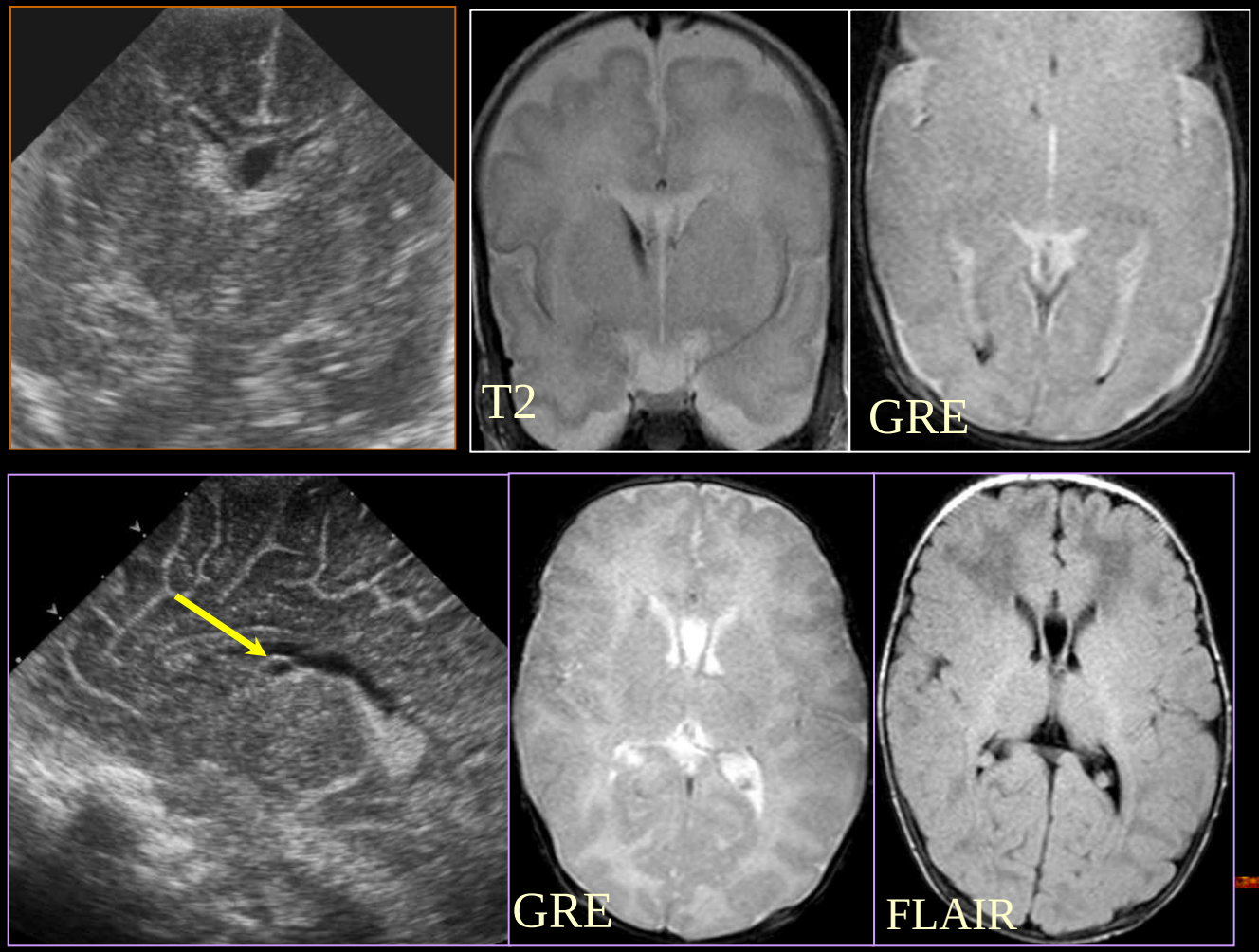
| | US | MR | Both | Total |
|---|---|---|---|---|
| GMH | 30 | 7 | 12 | 49 (20%) |
| IVH | 4 | 46 | 17 | 67 (28%) |

- Sensitivity of US detection for IVH seen on MRI; 26%
- Sensitivity of MR detection for GMH seen on US; 29%

Grade

| | I | II | III | IV | Total |
|---|---|---|---|---|---|
| US | 24 | 8 | 13 | 0 | 45 |
| MR | 3 | 49 | 10 | 2 | 64 |

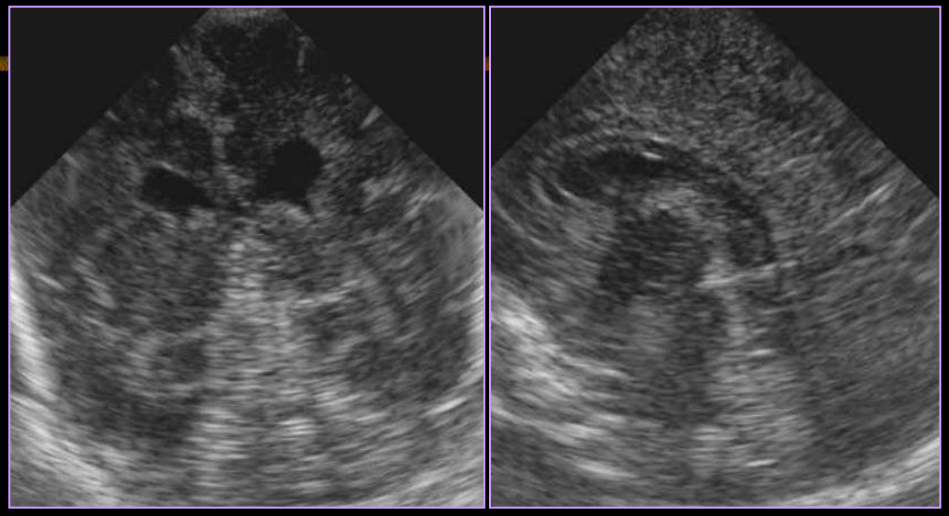
# GMH/IVH

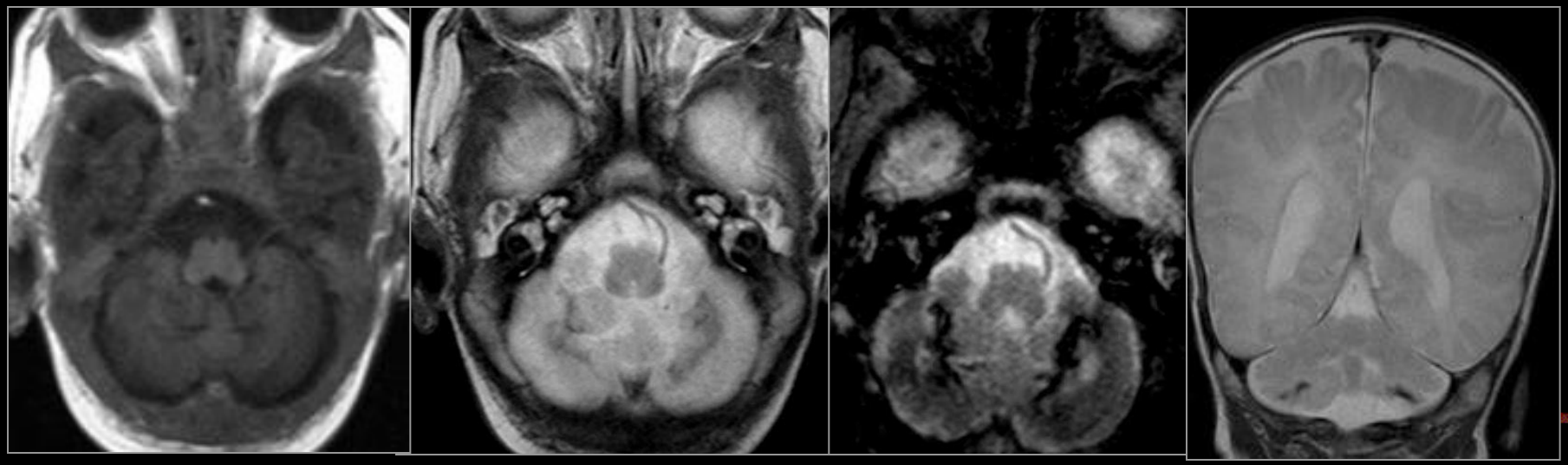


# Hemorrhage other than GMH/IVH

| | MR | US |
|---|---|---|
| Cerebral hemorrhage | **8** | **4** |
| Cerebellar hemorrhage | **6** | **2** |
| SDH | **8** | **1** |
| SAH | **1** | **0** |

# Cerebellar Hemorrhage





T1 T2 GRE T2

# Cerebellar Hemorrhage

- Traumatic birth, tight ventilator mask, supratentorial hemorrhage, germinal matrix hemorrhage
- 10-25% of VLBW preterm at postmortem exam
- 3% of preterm (<1500g) on US
- 8% of preterm (< GA 32W) on MRI
- Neurologic signs due to co-occurring lesions? cognitive function?

*- Counsell et al. Arch Dis Child Fetal Neonatal Ed 2003*

# Parenchymal Lesions

| | MR | US |
|---|---|---|
| DEHSI | 72 | 14 |
| Non-cavitary lesion | 7 | 3 |
| Deep GM injury | 2 | 3 |
| Encephalomalacia (PVL) | 7(5) | 5(3) |
| Ventriculomegaly | 16 | 11 |
| Cysts (PV/pineal/V3/choroidal) | 5/2/1/1 | 5/2/1/3 |
| Callosal dysgenesys | 1 | 1 |
| Chiari malformation | 1 | 1 |

# Neurodevelopmental Outcomes in Preterm Infants with DEHSI Seen on MR images at Near Term-equivalent Age

Tae Yeon Jeon[1], Ji Hye Kim[1], So-Young Yoo[1], Hong Eo[1], Jeong-yi Kwon[2], Jee Hun Lee[3], Mun Hyang Lee[3], Yun-sil Jang[3], Won Soon Park[3]

Department of Radiology and Center for Imaging Science[1], Department of Rehabilitation[2] and Department of Pediatrics[3], Samsung Medical Center
Seoul, Korea

# 126 High risk preterm infants

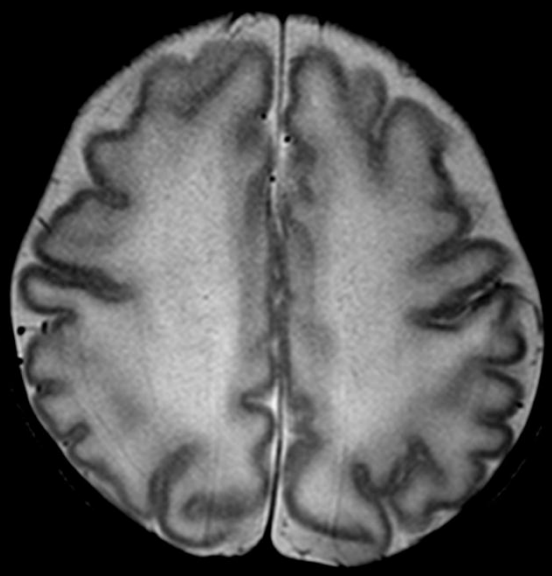
- GP < 32 W or birth weight < 1500g
- Screening Brain MRI at mean CGA 36.6±1.9W
- Neurodevelopmental assessment at CGA 18-24 M
- M:F = 59:67 (GP23-36W, mean 27.5)

- Exclusion criteria
  - Metabolic disorders
  - Congenital malformations
  - Infections

# MR Analysis

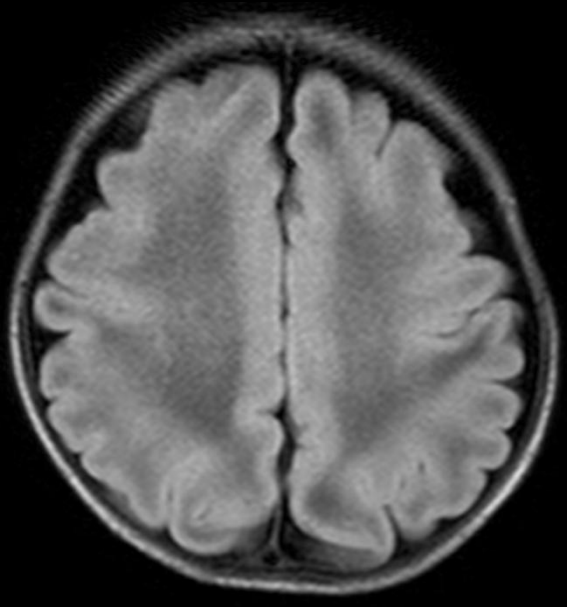
## DEHSI

**: Visually apparent high signal intensity of WM at centrum semiovale on T2WI/ADC map, low SI on T1WI/FLAIR**



T2WI

ADC



FLAIR

# MR Analysis

- Other WM lesions
  - Punctate noncavitary lesions
  - Cystic encephalomalacia
  - Ventricular undulation
  - Ventricular dilatation
  - Myelination delay
- Gray matter lesions
  - Gray matter SI change
  - Gyral maturation
  - Widening of the sulci
- GMH/IVH grades I~IV

* Follow-up MRI (n=8, 6%)  CGA 6~48 M (median, 10M)

# Neurodevelopmental assessment

- At 18-24 M of age
- Bayley Scale of Infant Development-II
  - Mental developmental index (MDI) : Cognitive delay
  - Psychomotor developmental index (PDI) : Motor delay
- Cerebral palsy
- Neurosensory impairment
  - Vision impairment
  - Hearing defect

# Results

**DEHSI (+) : 95 (75%), DEHSI (-) : 31 (25%)**

| Clinical factors | DEHSI (+) | DEHSI (−) | *P* |
|---|---|---|---|
| GA (wk)* | 27.8 ± 2.7 | 26.6 ± 2.9 | 0.011 |
| Birth weight (g)* | 1036 ± 270 | 922 ± 268 | 0.042 |
| Corrected GA at MRI (wk)* | 36.6 ± 2.1 | 36.7 ± 1.8 | 0.747 |
| Small size for GA (%) | 23 (24%) | 6 (19%) | 0.577 |
| Male (%) | 46 (48%) | 13 (42%) | 0.530 |
| Singleton (%) | 72 (76%) | 23 (74%) | 0.858 |

* Means ± SD

# Results

| Outcome | DEHSI (+) | DEHSI (−) | *P* |
|---|---|---|---|
| MDI score* | 97 [105, 86] | 97 [104, 85] | 0.749 |
| Severe cognitive delay | 9 | 1 | 0.483 |
| PDI score* | 93 [103, 84] | 97 [103, 85] | 0.655 |
| Severe motor delay | 11 | 2 | 0.517 |
| Cerebral palsy | 7 | 2 | 1 |
| Neurosensory impairment | 11 | 9 | 0.054 |

***Medians [75$^{th}$ percentile, 25$^{th}$ percentile]**

# Results

| Outcome | DEHSI (+) | | DEHSI (−) | | *P* |
|---|---|---|---|---|---|
| | Other WM lesion | | Other WM lesion | | |
| | (+) | (−) | (+) | (−) | |
| MDI score* | 97 [106,76] | 97.5 [105,90] | 96 [97,81] | 99.5 [105,90] | 0.392 |
| Severe cognitive delay | 5 | 4 | 0 | 1 | 0.076 |
| PDI score* | 84 [101,61] | 93 [104,86] | 88 [101,73] | 99.5 [106,86] | 0.035 |
| Severe motor delay | 8 | 3 | 1 | 1 | 0.001 |
| Cerebral palsy | 7 | 0 | 2 | 0 | <.0001 |
| Neurosensory impairment | 3 | 8 | 2 | 7 | 0.102 |

***Medians [75$^{th}$ percentile, 25$^{th}$ percentile]**

# Results

| Outcome | DEHSI (+) | | DEHSI (−) | | *P* |
|---|---|---|---|---|---|
| | Other WM lesion | | Other WM lesion | | |
| | (+) | (−) | (+) | (−) | |
| MDI score* | 97 [106,76] | 97.5 [105,90] | 96 [97,81] | 99.5 [105,90] | 0.392 |
| Severe cognitive delay | 5 | 4 | 0 | 1 | 0.076 |
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| Severe motor delay | 8 | 3 | 1 | 1 | 0.001 |
| Cerebral palsy | 7 | 0 | 2 | 0 | <.0001 |
| Neurosensory impairment | 3 | 8 | 2 | 7 | 0.102 |

*Medians [75$^{th}$ percentile, 25$^{th}$ percentile]

# Results

| Outcome | DEHSI (+) | | DEHSI (−) | | *P* |
|---|---|---|---|---|---|
| | Other WM lesion | | Other WM lesion | | |
| | (+) | (−) | (+) | (−) | |
| MDI score* | 97 [106,76] | 97.5 [105,90] | 96 [97,81] | 99.5 [105,90] | 0.392 |
| Severe cognitive delay | 5 | 4 | 0 | 1 | 0.076 |
| PDI score* | 84 [101,61] | 93 [104,86] | 88 [101,73] | 99.5 [106,86] | 0.035 |
| Severe motor delay | 8 | 3 | 1 | 1 | 0.001 |
| Cerebral palsy | 7 | 0 | 2 | 0 | <.0001 |
| Neurosensory impairment | 3 | 8 | 2 | 7 | 0.102 |

**DEHSI only** **Normal WM**

# Univariate Analysis for Associations between MR findings and Outcomes

| | No. | Severe cognitive delay | Severe motor delay | Cerebral palsy | Neurosensory impairment |
|---|---|---|---|---|---|
| *MR findings* | | | | | |
| DEHSI | 95 | 3.1 (0.4–142.9) | 1.9 (0.4–18.5) | 1.2 (0.2–12) | 0.3 (0.1–1) |
| Other WM lesion | 32 | 3.3 (0.7–15.4) | 8.6 (2.2–41.7) | NA | 1 (0.3–3.2) |
| Cystic encephalomalacia | 7 | 5.4 (0.5–40) | 8 (1–55.6) | 13.3 (1.6–100) | 2.2 (0.2–14.9) |
| Punctate lesion | 9 | 3.8 (0.3–25.6) | 9.3 (1.6–52.6) | 32.3 (5–250) | 0.7 (0.1–5.3) |
| GM lesion | 44 | 3 (0.7–15.6) | 3.4 (0.9–14.1) | 4.1 (0.8–27) | 2.1 (0.7–6.3) |
| GMH (Grade 3–4) | 6 | 2.5 (0.5–11.6) | 2.4 (0.6–9.4) | 3.1 (0.6–15.4) | 2.2 (0.7–6.8) |

**Odds ratio (95% CI)**

# Univariate Analysis for Associations between MR findings and Outcomes

| | No. | Severe cognitive delay | Severe motor delay | Cerebral palsy | Neurosensory impairment |
|---|---|---|---|---|---|
| *MR findings* | | | | | |
| DEHSI | 95 | 3.1 (0.4–142.9) | 1.9 (0.4–18.5) | 1.2 (0.2–12) | 0.3 (0.1–1) |
| Other WM lesion | 32 | 3.3 (0.7–15.4) | 8.6 (2.2–41.7) | NA | 1 (0.3–3.2) |
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| Punctate lesion | 9 | 3.8 (0.3–25.6) | 9.3 (1.6–52.6) | 32.3 (5–250) | 0.7 (0.1–5.3) |
| GM lesion | 44 | 3 (0.7–15.6) | 3.4 (0.9–14.1) | 4.1 (0.8–27) | 2.1 (0.7–6.3) |
| GMH (Grade 3–4) | 6 | 2.5 (0.5–11.6) | 2.4 (0.6–9.4) | 3.1 (0.6–15.4) | 2.2 (0.7–6.8) |

**Odds ratio (95% CI)**

# Multivariate Analysis for Associations between MR findings and Outcomes

* Covariate factors : GA < 28W, weight < 1000g, low Apgar score, male, multiple birth

| | No. | Severe cognitive delay | Severe motor delay | Cerebral palsy | Neurosensory impairment |
|---|---|---|---|---|---|
| *Adjusted MR findings** | | | | | |
| DEHSI | 95 | 5.9 (0.6–58.8) | 3.2 (0.5–21.3) | 0.6 (0–7.5) | 0.3 (0.1–1.1) |
| Other WM lesion | 32 | 0.7 (0.1–6.5) | 3.9 (0.6–25) | NA | 0.5 (0.1–2.5) |
| Cystic encephalomalacia | 7 | 6.2 (0.4–100) | 3.8 (0.4–41.7) | 19.6 (1.3–333.3) | 4.4 (0.4–45.5) |
| Punctate lesion | 9 | 3.4 (0.2–50) | 3.3 (0.4–29.4) | 90.9 (6.4– 1000) | 0.8 (0.1–11.5) |
| GM lesion | 44 | 2.6 (0.5–13) | 2.5 (0.6–10.5) | 11.6 (0.8–166.7) | 2.1 (0.7–6.4) |
| GMH (Grade 3–4) | 6 | 1.7 (0.3–9.9) | 1.0 (0.2–4.9) | 1.5 (0.2–13.7) | 1.5 (0.4–5.5) |

**Odds ratio (95% CI)**

# DEHSI in Preterm Infants

- **Most common MR findings at near term (75%, 95/126 infants)**

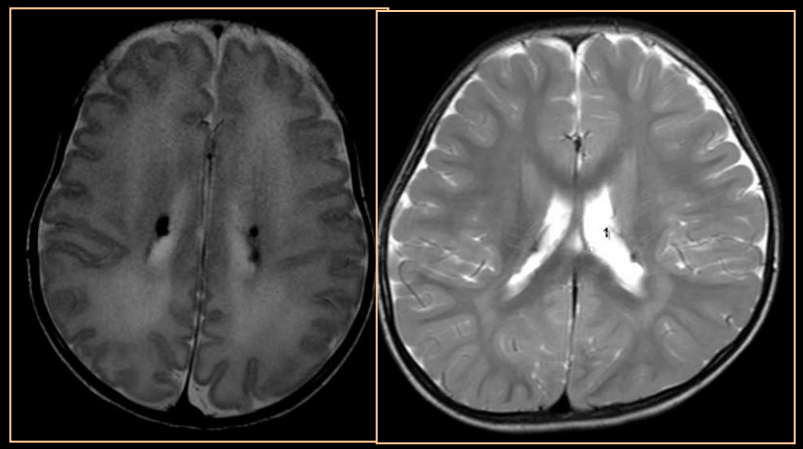
- **Did not associated with more adverse outcomes compared with infants without DEHSI**

- **Significant predictors for outcomes;**
  - **Cystic encephalomalacia**
  - **Noncavitary punctate WM lesions**

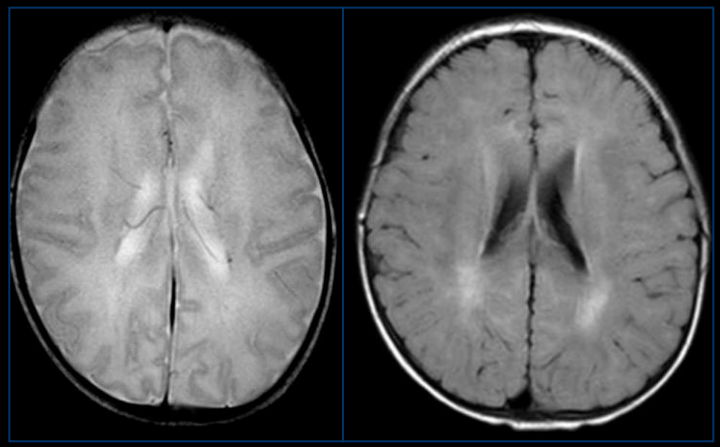
*-Jeon TY, Kim JH, Yoo SY et al. Radiology 2012*

# Late MRI

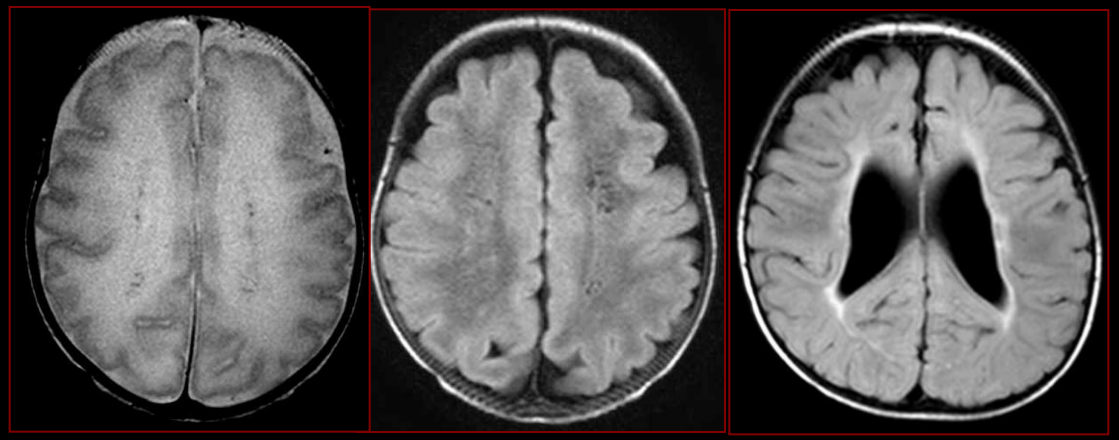
# Evolution of DEHSI



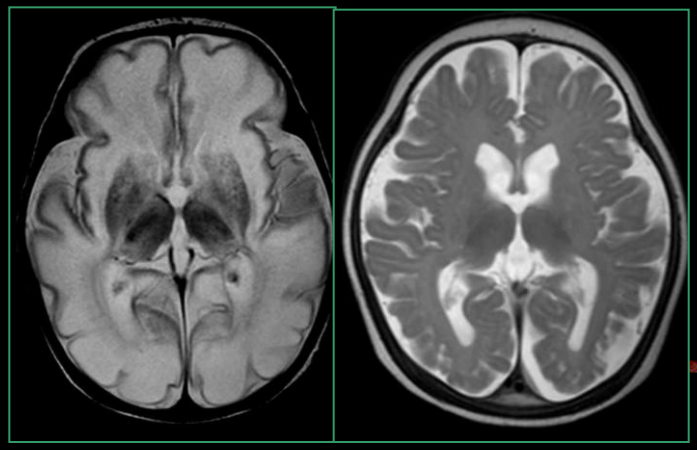
T2 2Y later



T2 FLAIR, 6m later



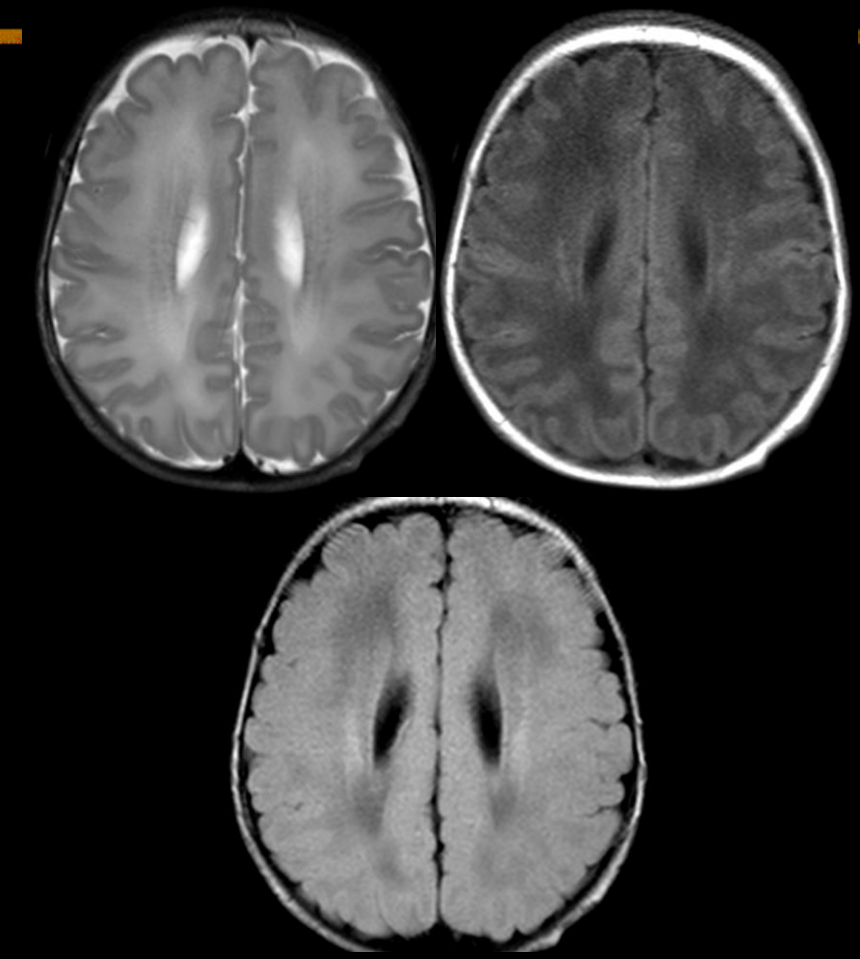
T2 FLAIR FLAIR, 1Y later



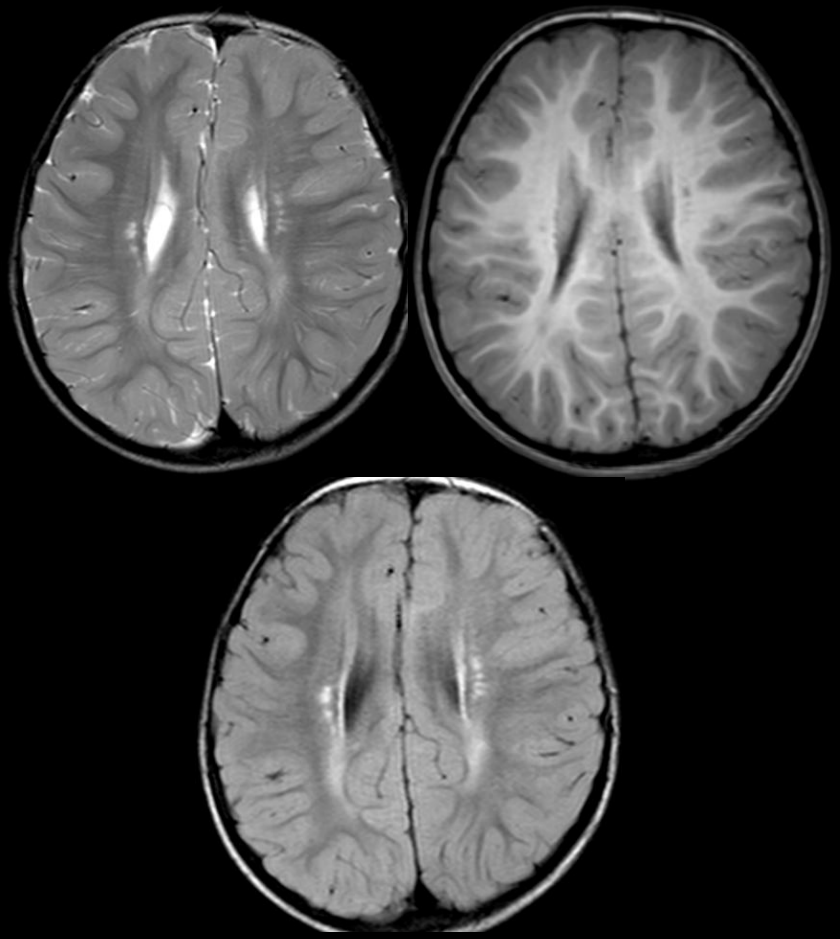
## On-going study

- Serial MR Imaging and Clinical Outcome in High Risk Premature Infants at Term-equivalent and 2 Years of Age.

# Punctate lesion→ PVL

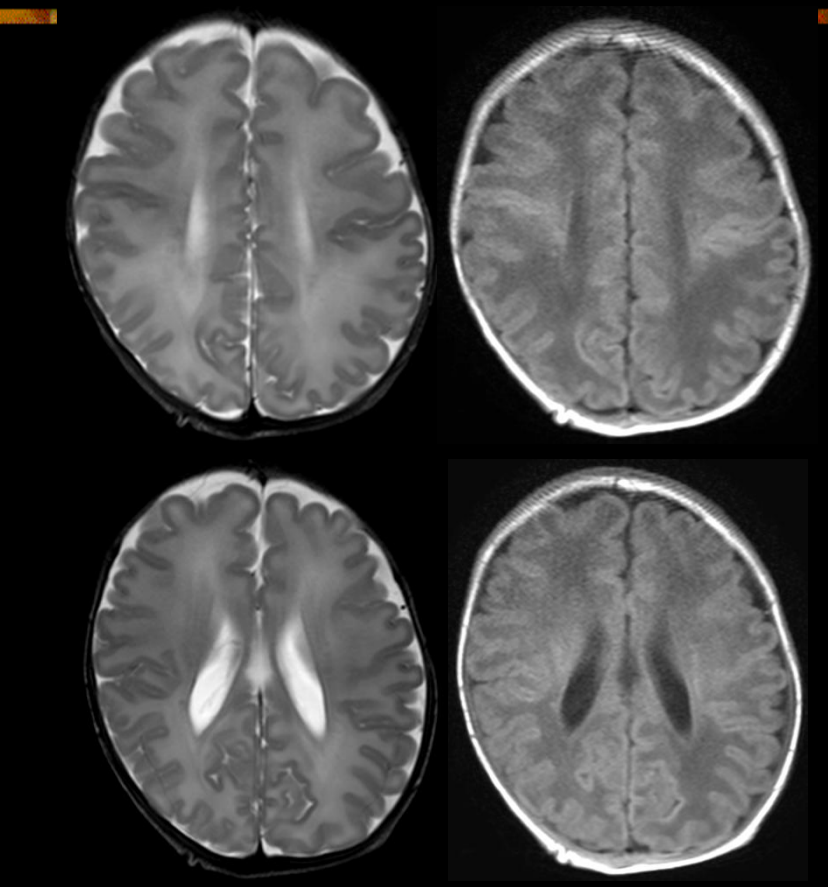


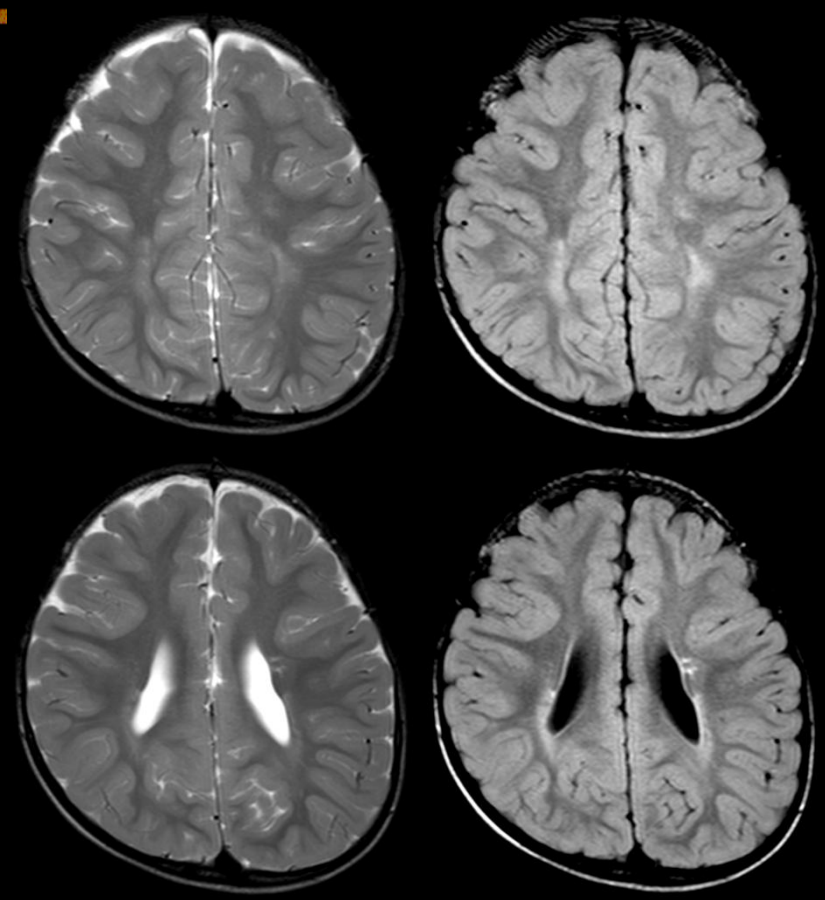
cGA 38 wk



cGA 24mo

# Punctate lesion→ PVL

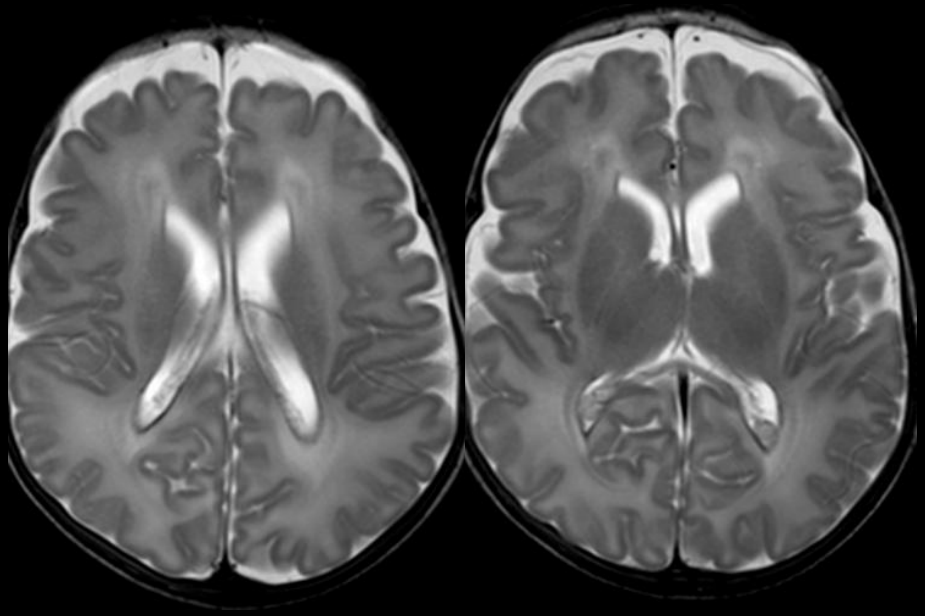




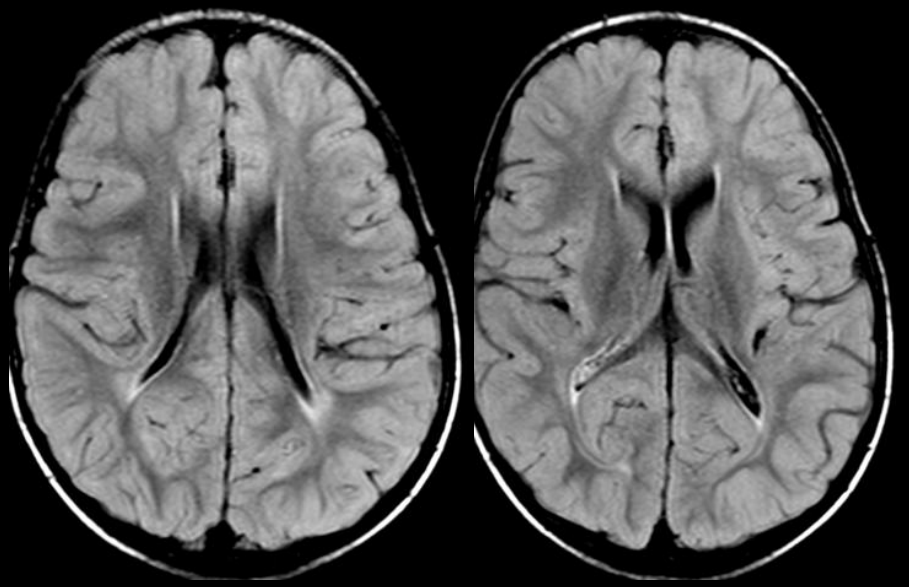
cGA 37 wk

cGA 25mo

# IVH G2 → PVL

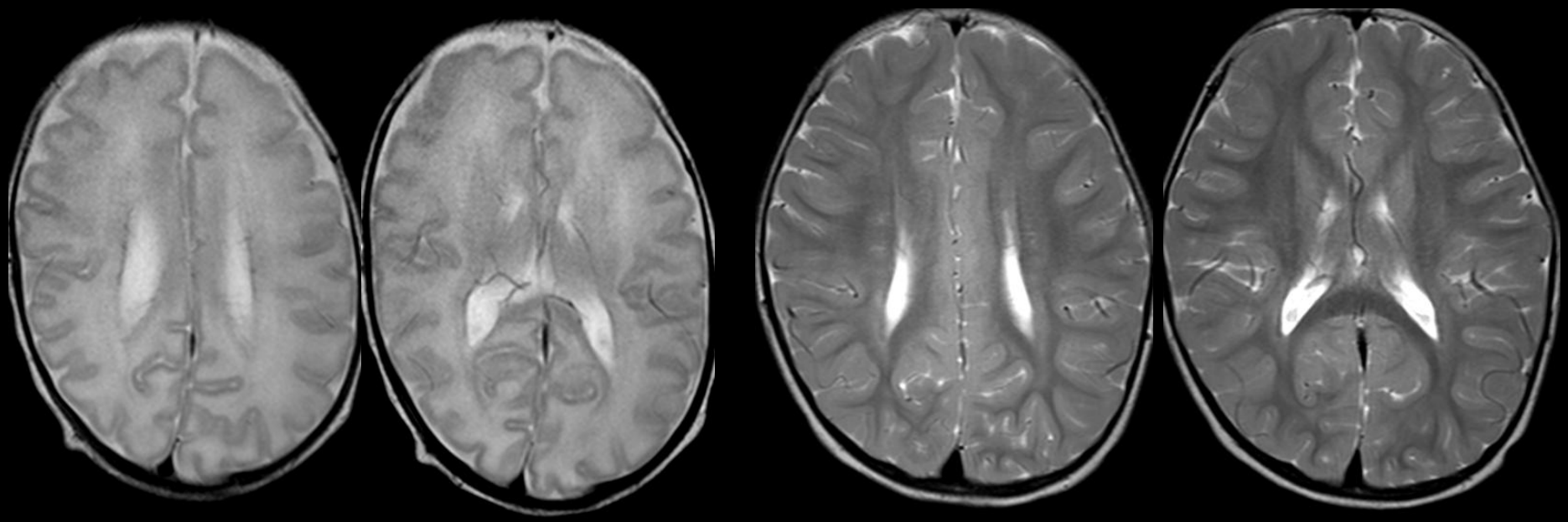


cGA 39 wk



cGA 24mo

# Normal → PVL

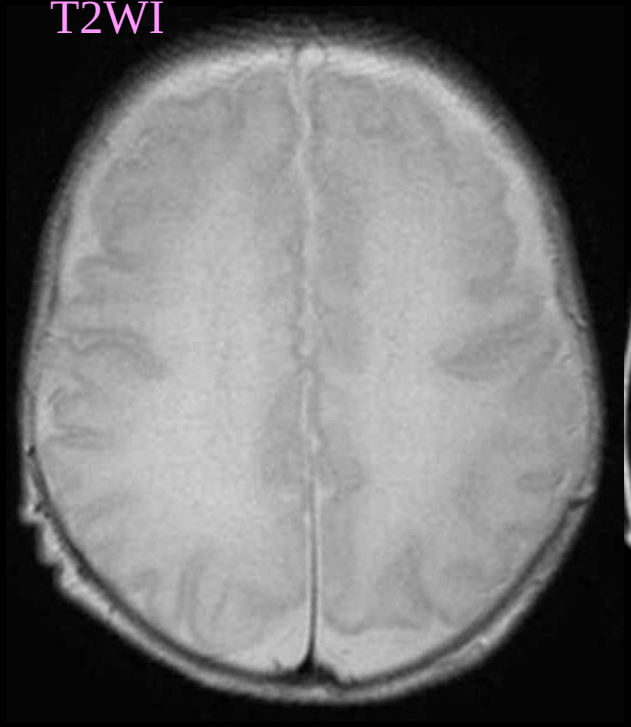


cGA 35 wk

cGA 24mo

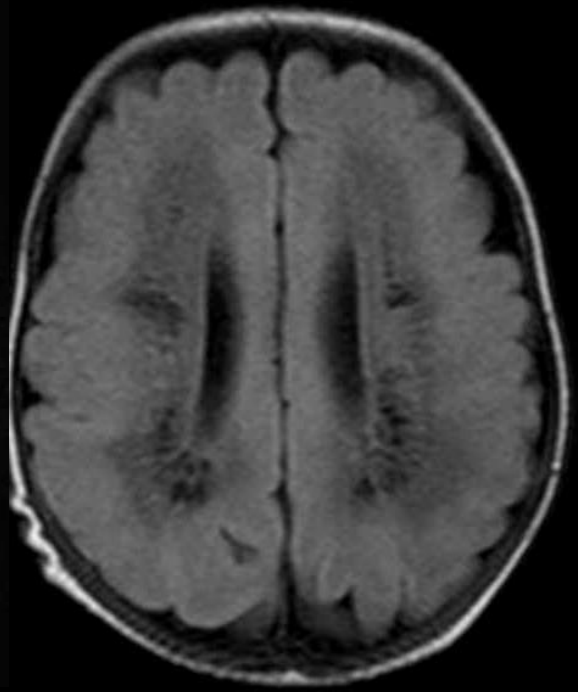
# Evolution of PVL on MRI

T2WI

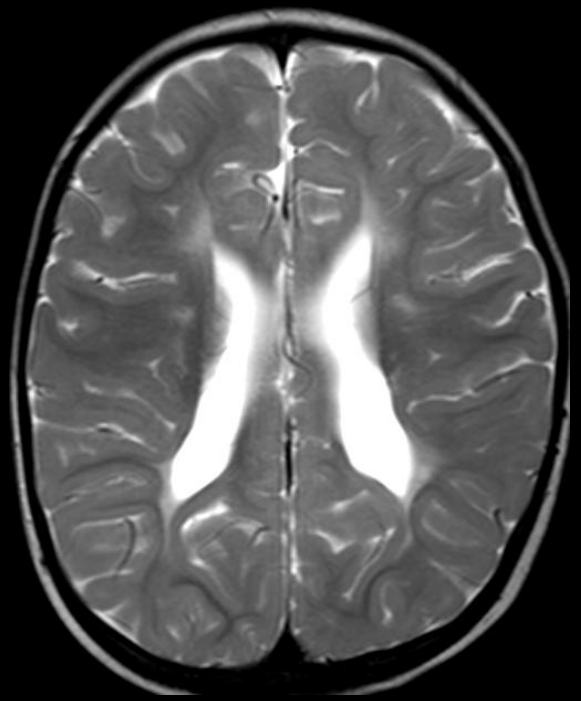


Day 21

FLAIR

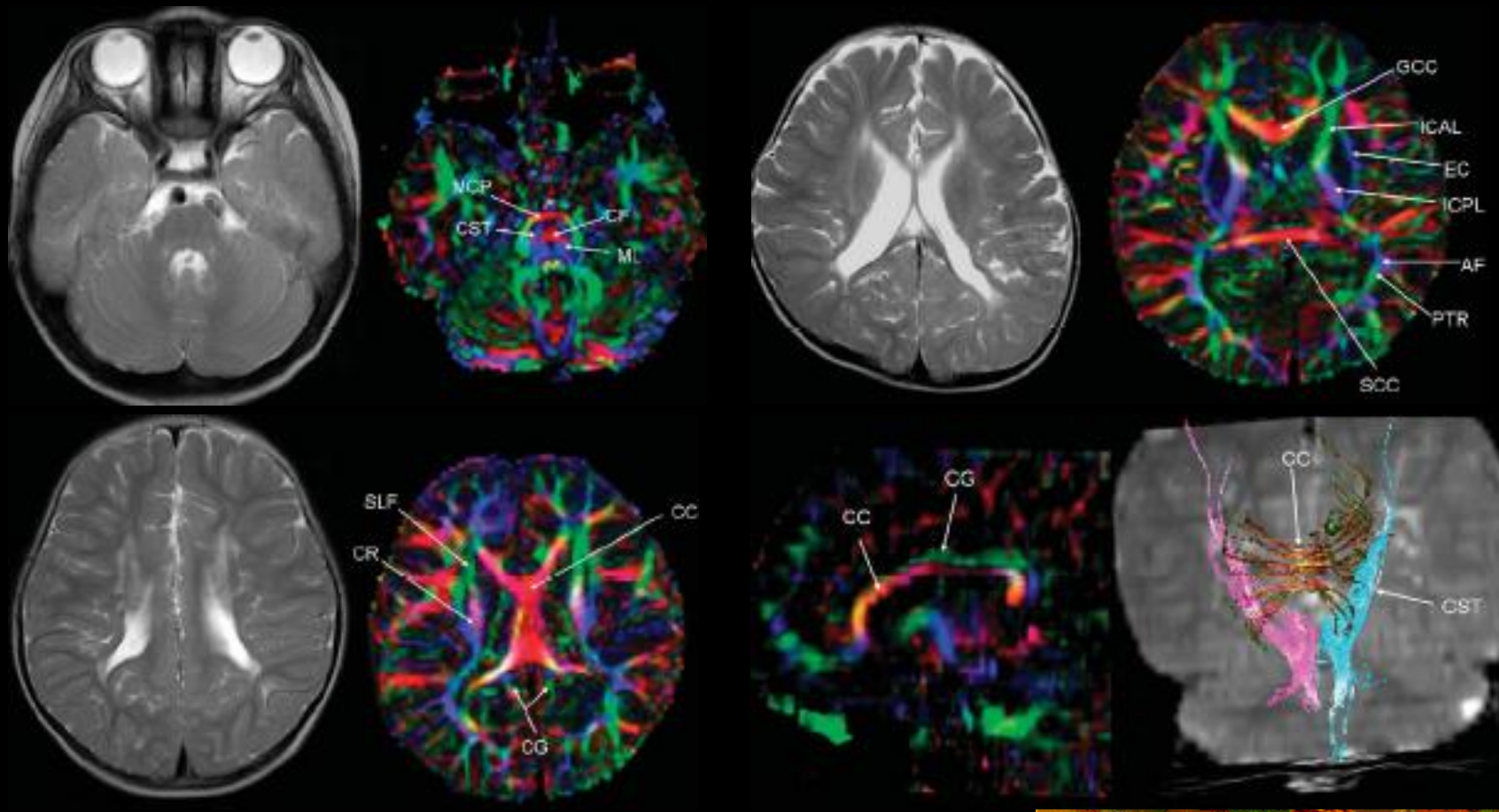


T2WI



2 Years of age

# DTI in Assessment of PVL

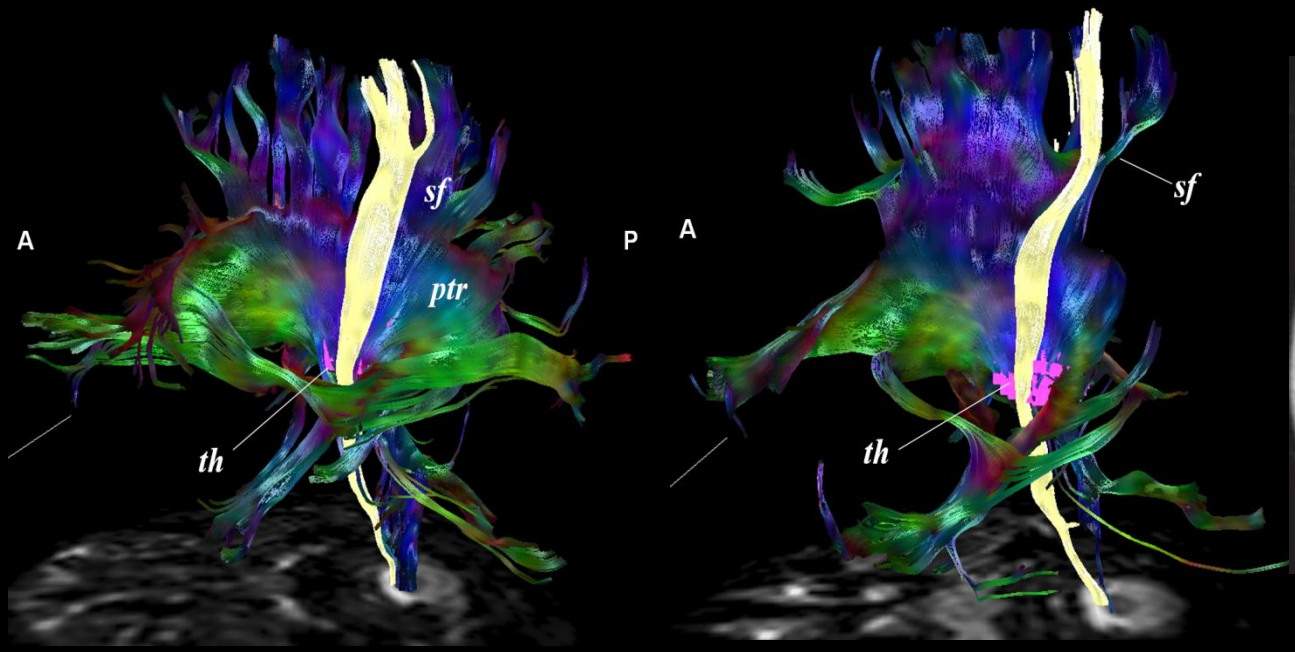


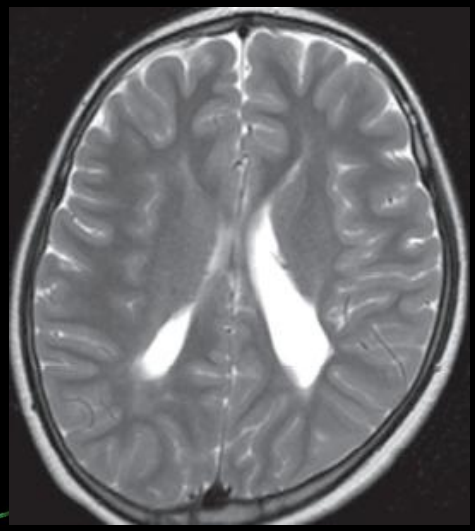

*- Fan GG et al. Clinical Radial 2006*

# DTI in Assessment of PVL

- Decreased FA in damaged area
  -Impaired myelination
  -Axonal damage
- Attenuated size of CST, PTR, AF, SLF, CR
  -Abnormal tone/movement
  -Aphasia
  -Interconnection of somatomotor/sensory
  -Visual disorder

# Spastic motor dysfunction in PVL



Normal Control

PVL

**Corticospinal tract (CST) injury vs. Impaired sensory inhibition by thalamus**

*- Lee JD et al J Nucl Med 1998, -Hoon AH et al. Neurology 2002, Lee SK et al. Radiographics 2005*

# Brain imaging for perinatal brain injury

- Selective injury according to brain maturity & severity of hypoperfusion
- Evolving white matter injury in preterm infants
- Diverse spectrum of intracranial hemorrhage
- Complementary role of US and MRI
- Prediction of patient outcome