Structural MRI of the brain in neonates

Universitair
Ziekenhuis
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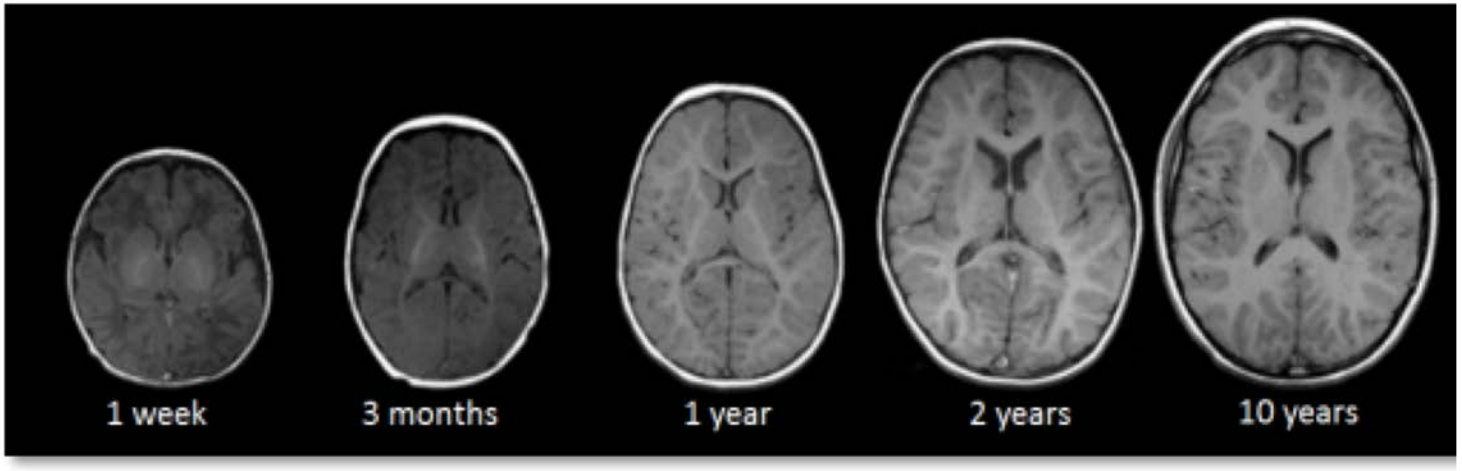
VUB

SIZE MATTERS

http://www.mrineonatalbrain.com/maryrutherfordimaging/downloads/presentations/Neonatal-MR-optimisation.pdf

NEONATAL POPULATION



Small head circumference (only ¼ of adult head)

Rapid maturation in first year of life.

Major changes in water content and myelination: adjusted protocols needed.

Non-cooperative➔ **high probability of motion artifacts**

Patient preparation, materials used and acquisition protocols need to be adapted specifically for neonates.

➔ Using protocols for larger children and adults in neonates is a guarantee of poor images.

PRIMARY CLINICAL INDICATIONS

- Severe prematurity ➔ Born at less than 32 weeks gestational age
  - => PVL = periventricular leukomalacia (white matter disease of prematurity)
  - => Germinal matrix hemorrhage

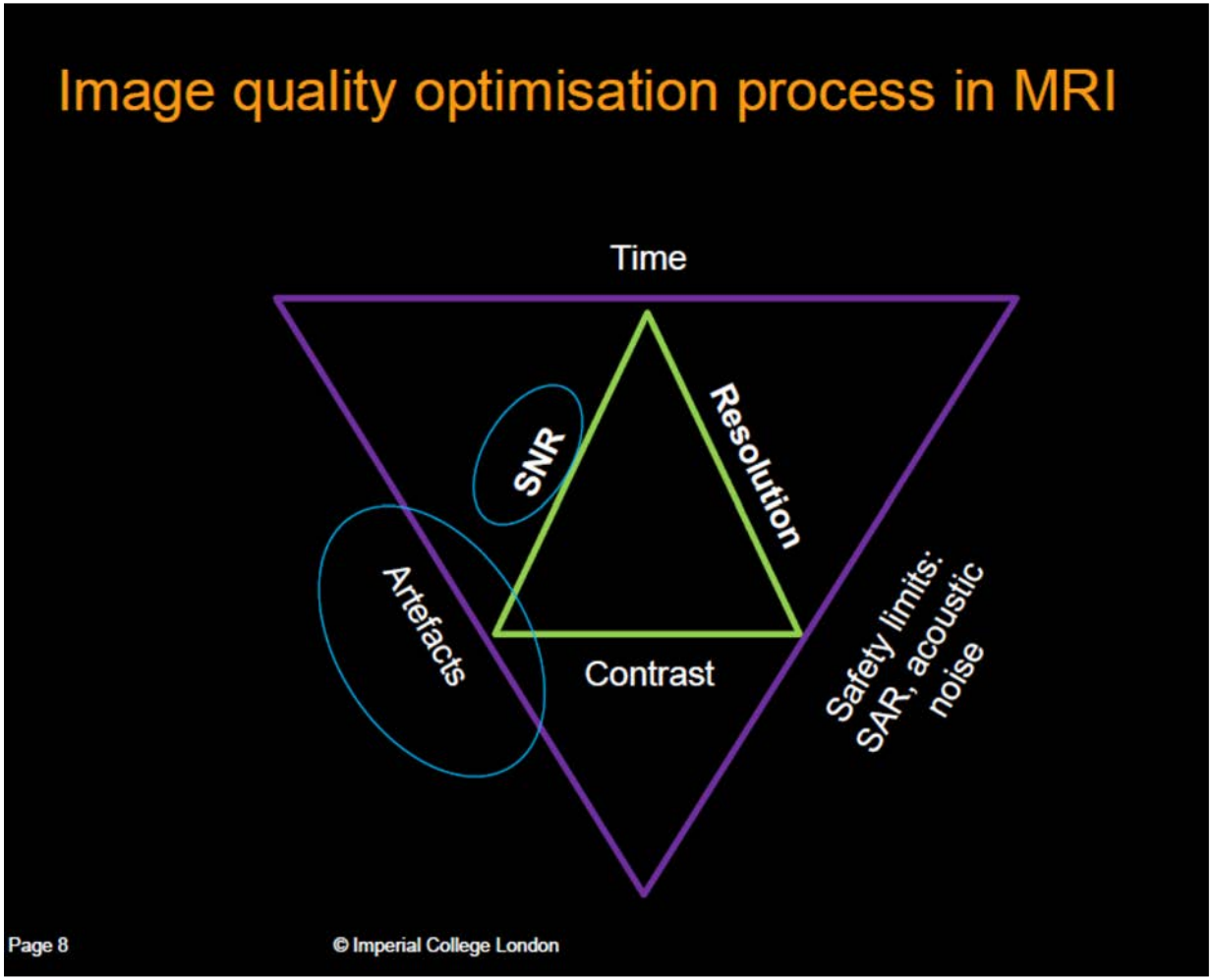
- Asphyxia (= lack of oxygen, usually with difficult birth delivery)
  - ➔ evaluation of brain damage
  - ➔ Prognosis
    - ➔ Clinical managment (supportive, expectant, palliative)

- Dysmorfism and abnormal muscle tone (hypotonia, hypertonia)
  - ➔ Malformations? Abnormal development of the brain
  - ➔ Inborn errors of metabolism (gray and/or white matter disorders). Fault in DNA leads to accumulation of toxic metabolites.
    - ➔ Managment (e.g. removing nutritional substances that are not broken down correctly from diet)
    - ➔ Prognosis (often poor)
    - ➔ Genetic screening/counseling parents/family members (future pregnancies)

- Epielpsy / convulsions / infantile spasms

- Infection (eg. bacterial or tuberculous meningitis)

IMAGE QUALITY OPTIMIZATION



OPTIMIZATION OF IMAGE QUALITY ON 3T

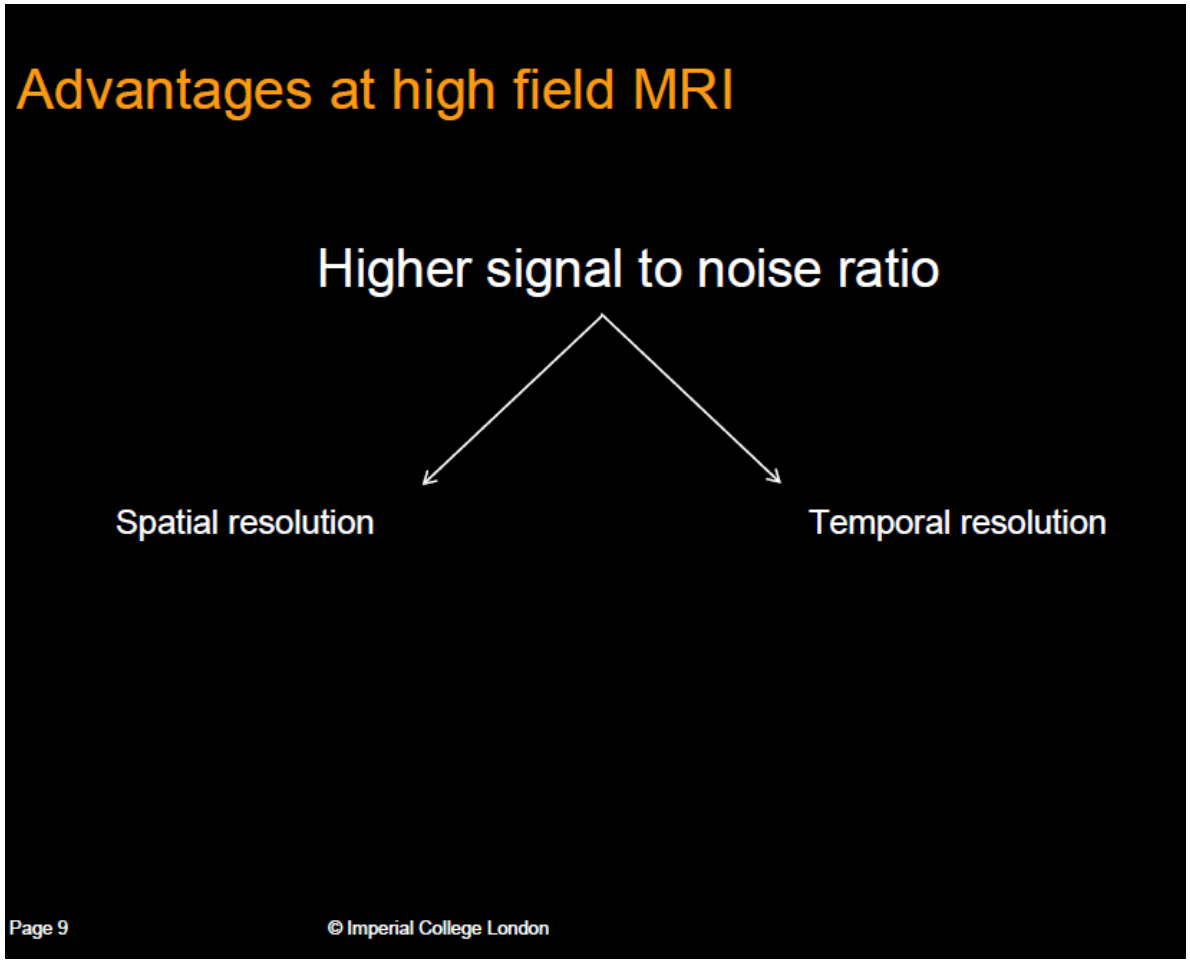
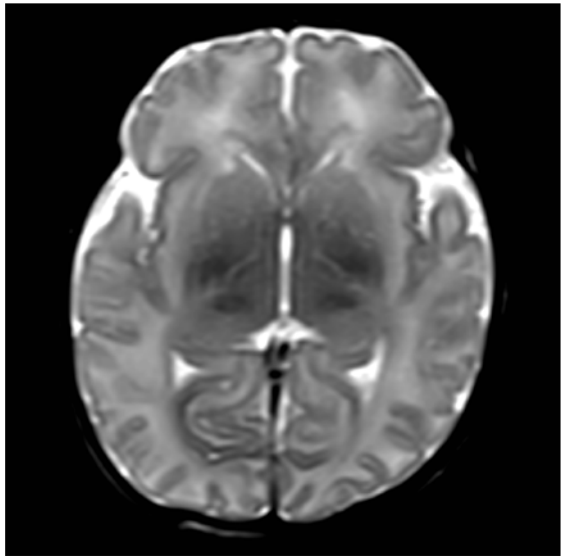
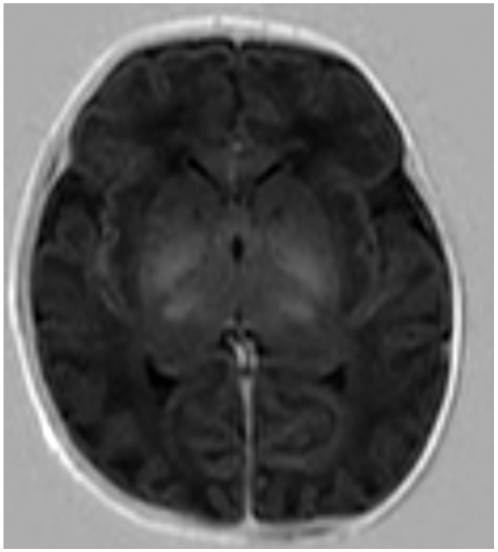
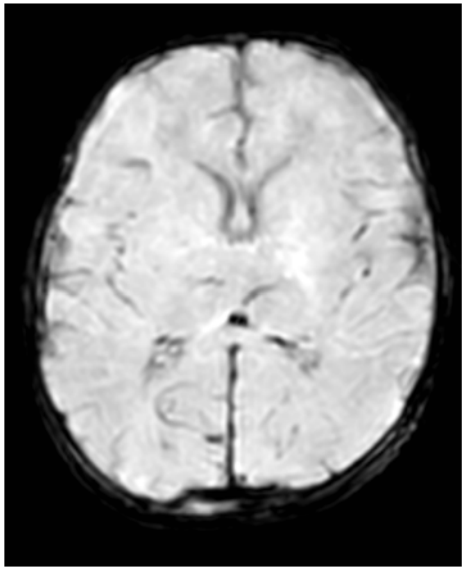


IMAGE QUALITY OF NEONATAL MRI OF THE BRAIN

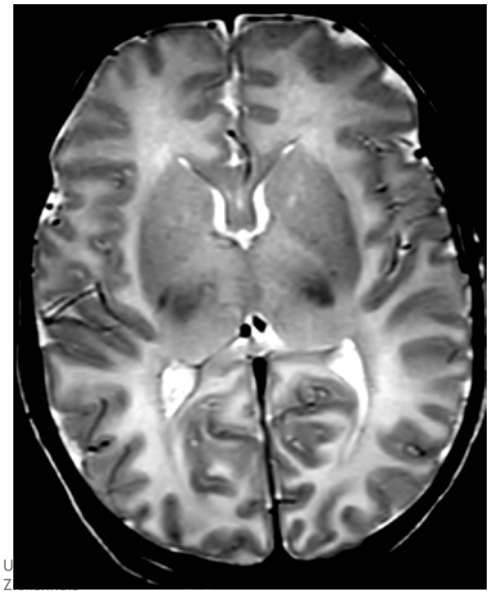
1,5T

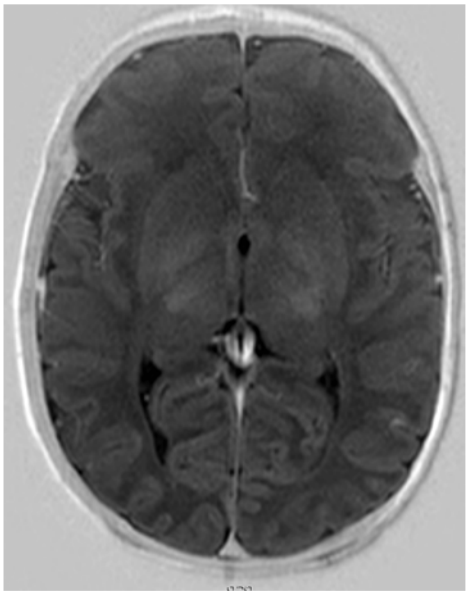


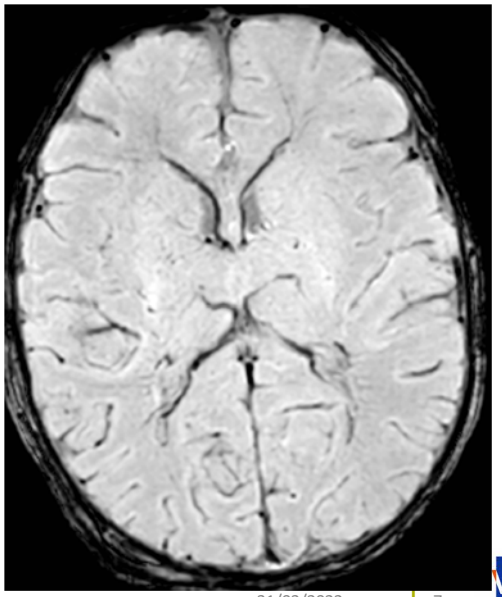




3T







INFANT PREPARATION

Sedation

- Chloral hydrate (syrup)
  - Most used worldwide
  - Readily available
  - Relatively wide margin of safety - oldest and best studied sedative
  - Best taken on an empty stomach
  - Children sleep after 15-30 minutes
  - administration orally (tastes bad), via nasogastric tube (preferred at UZ Brussel) or rectally.
  - Dosage and method of administration are decision of the pediatrician, not of the radiologist!
  - Collaboration with children's daycare hospital
  - MONITORING !

- Feed and sleep
  - Scanning in natural sleep after feeding
  - Works best with children < 6 weeks
  - Requires good coordination/timing
  - Greater chance of non-diagnostic images

  - UZ Brussel :
    - Feed and sleep for infants up to 3 months of age
    - Sedation with chloral hydrate in children up to 12 months of age.
    - Older children under anesthesia (remote team anesthesia) – Propofol (Diprivan)

INFANT PREPARATION

Ear protection – immobilization with vacuum mattress

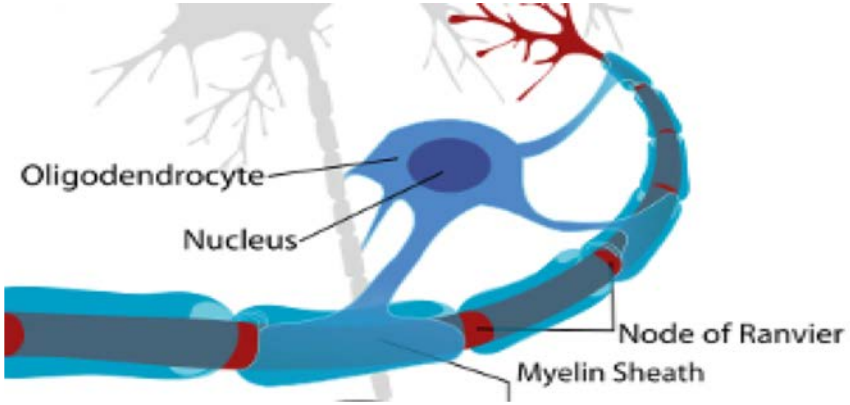
- Mini Muffs; *Natus Medical, San Carlos, California*
- Headphone

Foto : Mathur, A.M., Neil, J.J., McKinstry, R.C. et al. Pediatr Radiol (2008) 38: 260. https://doi.org/10.1007/s00247-007-0705-9

A sedated infant still asleep post MRI within the Med-Vac immobiliser.

Therese Ibrahim et al. Arch Dis Child Fetal Neonatal Ed 2015;100:F465-F466

MYELINATION



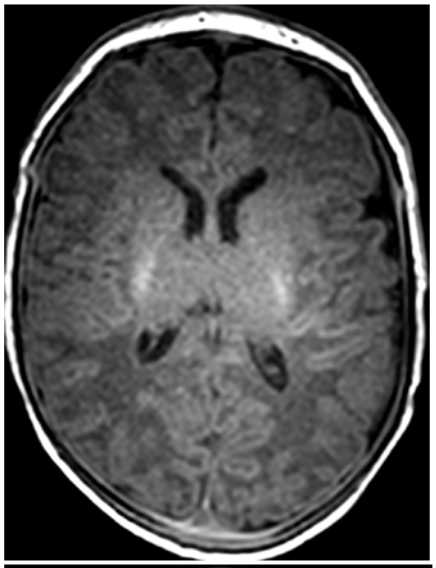
- **Has a major impact on T1 and T2 tissue contrast**
- Myelin shaft is a plasma membrane surrounding axons in the nervous system
- In adults 50-60% of dry weight of the brain
- Forms an insulator => Requires less energy for conduction: up to 5000 times less energy for the same speed at much smaller diameters (Ritchie, 1982)
- Important for normal brain functioning
- In newborns most of the white matter is not yet myelinated.

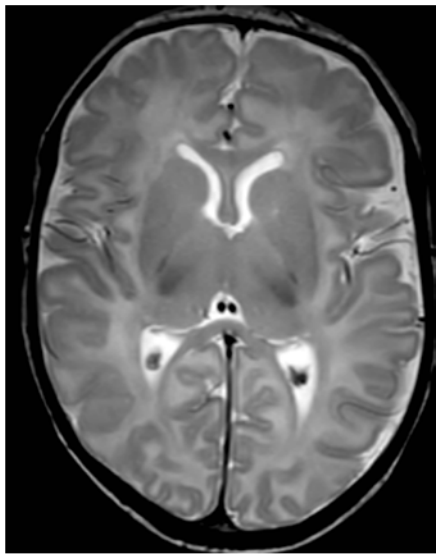
•After one year, the brain is already largely myelinated.

MYELINATION AND TISSUE CONTRAST

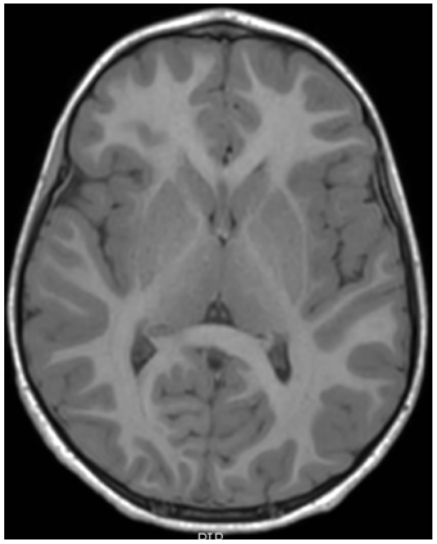
Lack of myelination in neonates: Inverted gray-white contrast on T1 and T2

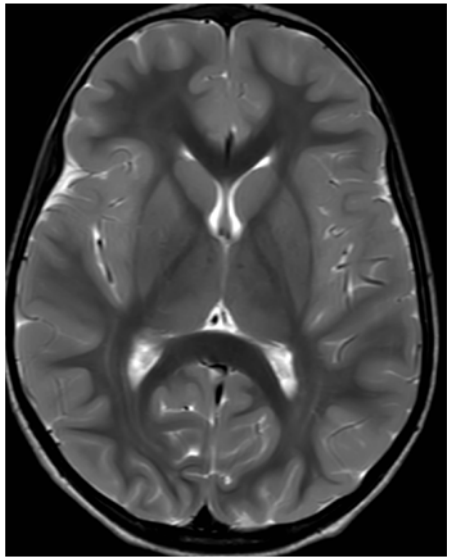
5 days





3 years





EVALUATION OF MYELINATION

T1

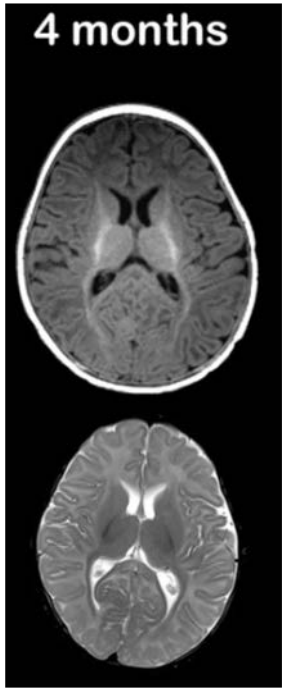
- most sensitive sequence in children <1 year of age
- myelination represented by **T1 <u>hyper</u>intensity**

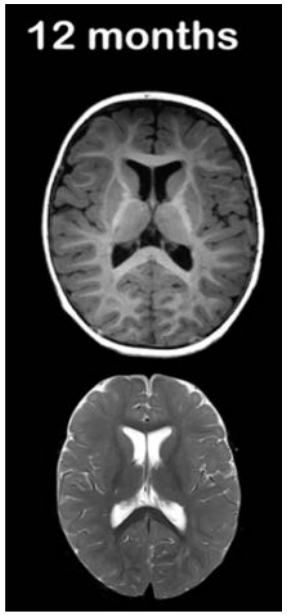
T2

- most sensitive sequence in children between the age of 1 and 2 demonstrating a gradual shift from hyper- to hypo-intense relative to grey matter
- myelination represented by **T1 <u>hypo</u>intensity**

- The only area to remain hyperintense after the age of 2 years, and often for quite some time, is the peritrigonal region [4] which is called terminal zones of myelination

- (Radiopaedia)





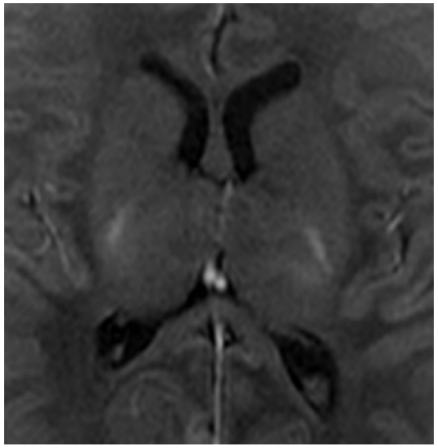
MYELINATION

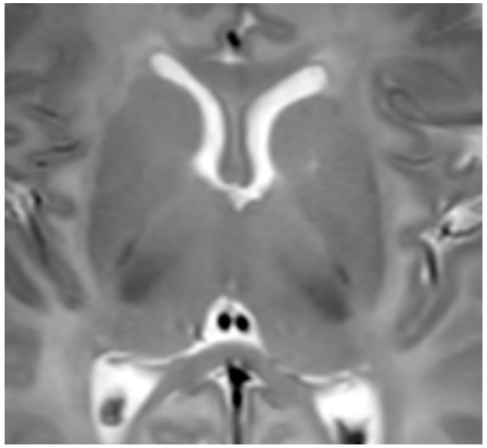
Progression of myelination is predictable and correlates strongly with developmental milestones.

1. Central to peripheral
2. Caudal to rostral
3. Dorsal to rostral
4. Sensory before motor

T1: Myeline = hyperintens

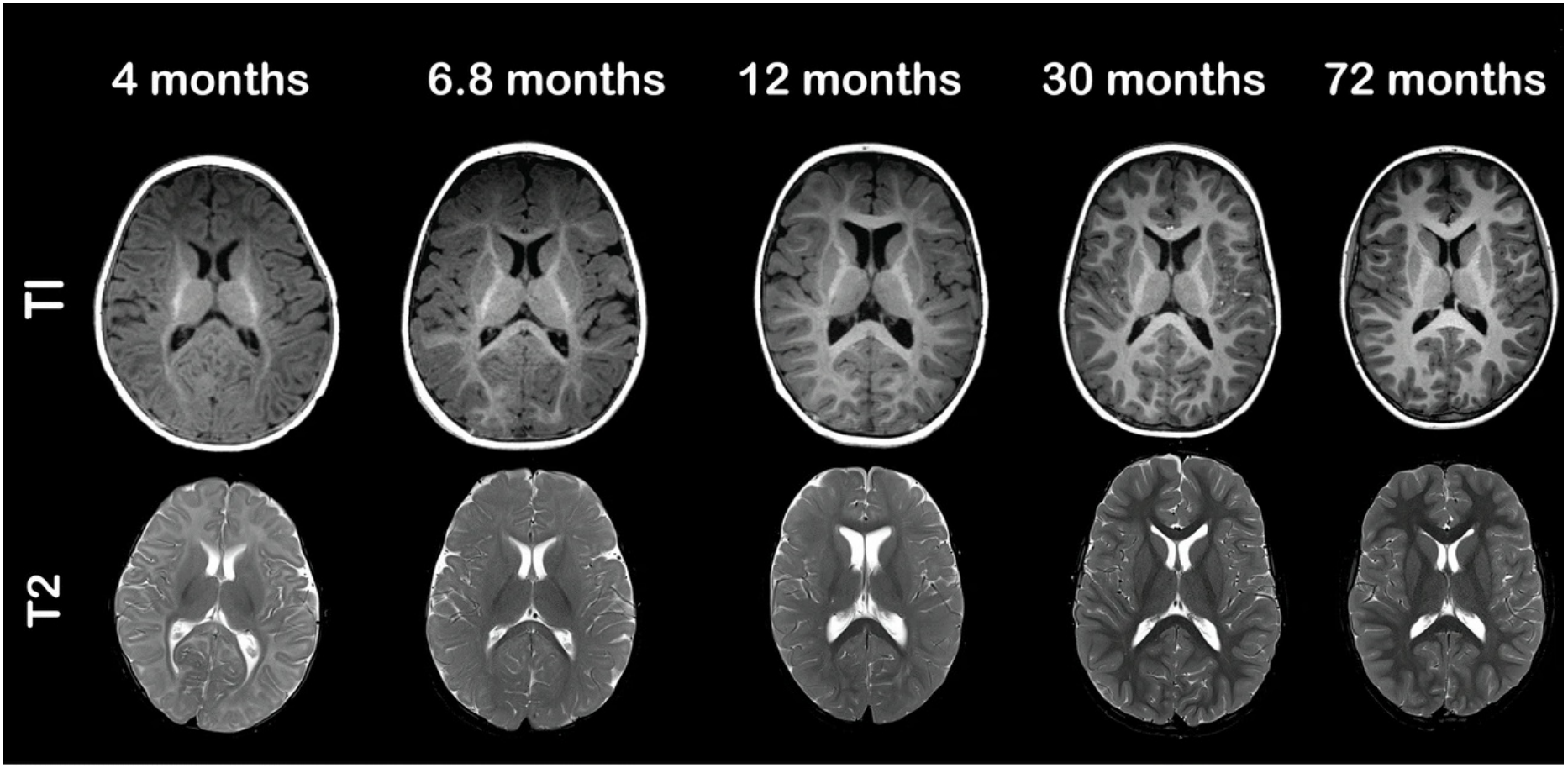
T2: Myeline = hypointens



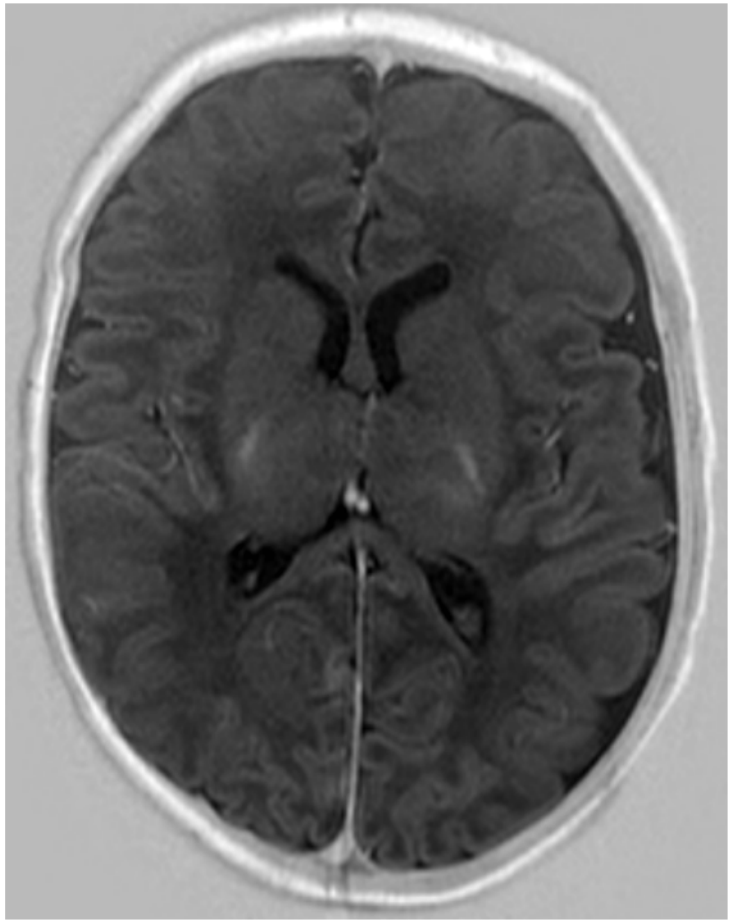


Genetic defects can make myelin formation more difficult or cause degradation of already formed myelin ➔ Leukodystrophy

NORMAL MYELINATION



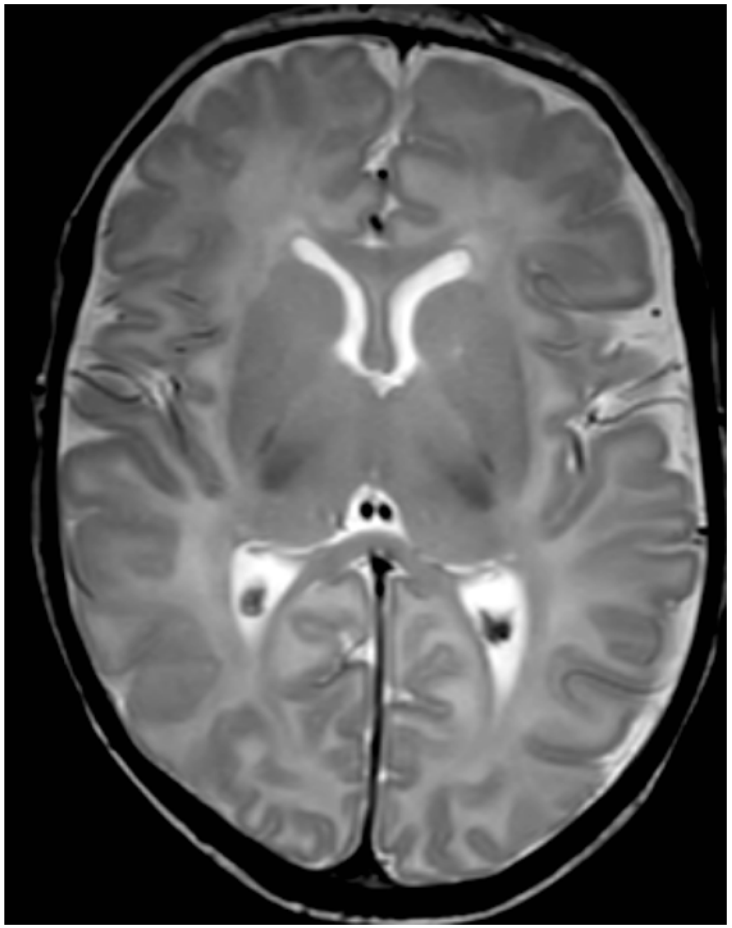
BASIC SEQUENCES



T1 TSE (3 mm)

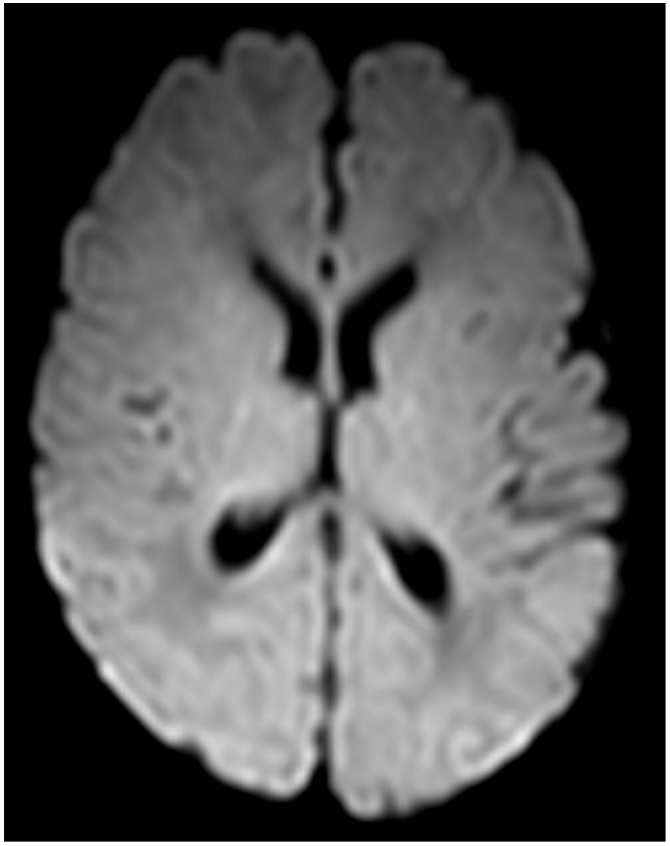
TR 4130

TE 120

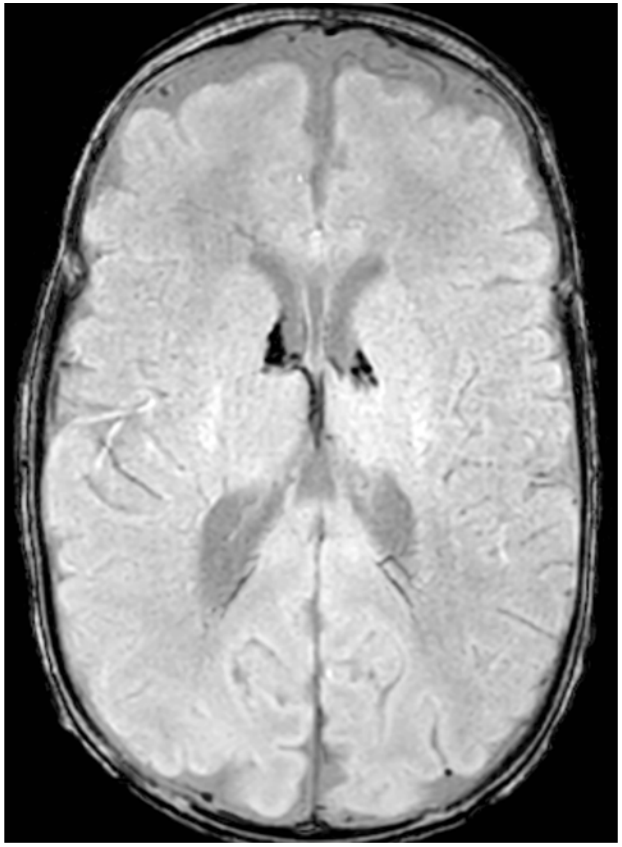


T2 TSE (3.5 mm)

BASIC SEQUENCES

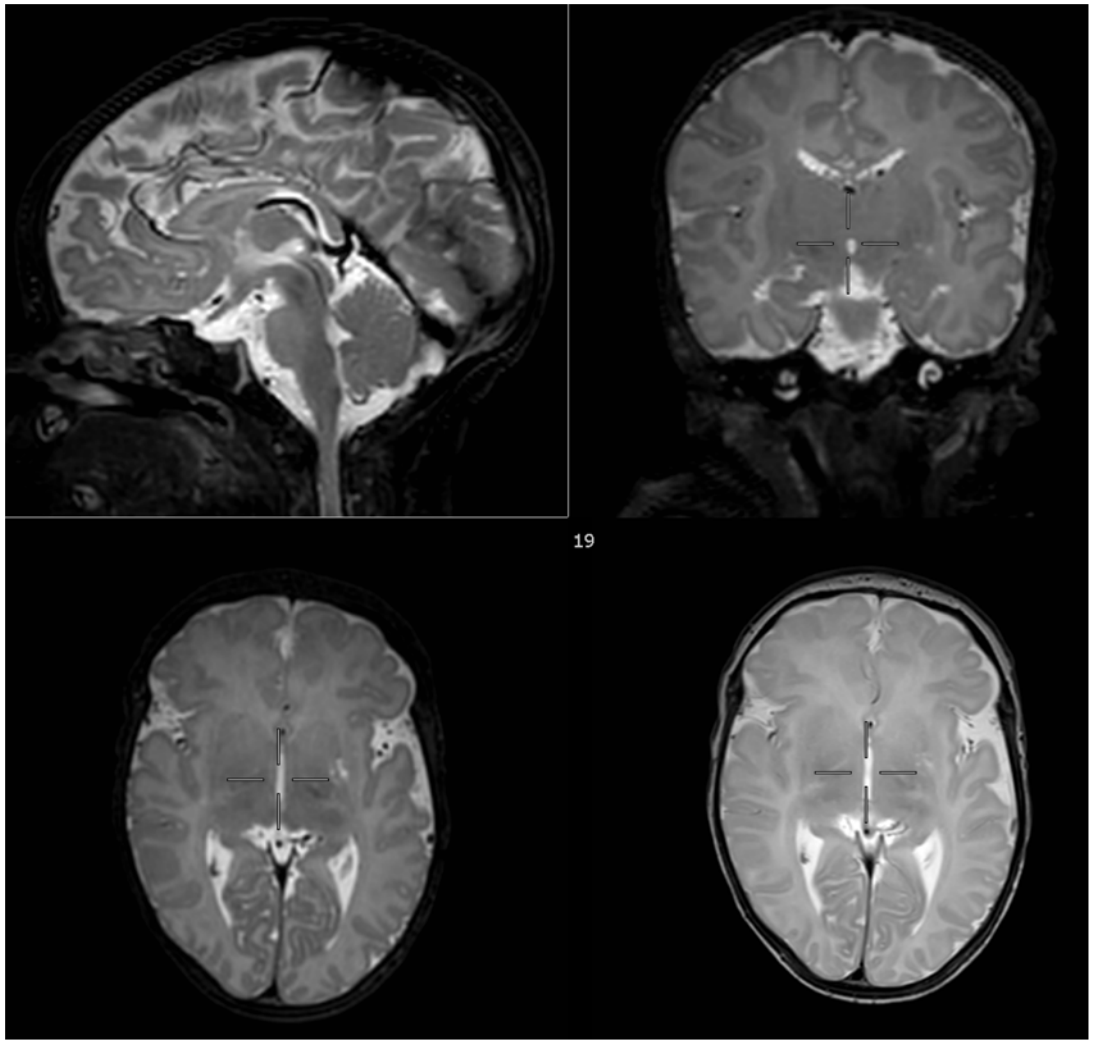


DWI b0-b1000 (4mm)



SWI (3D 2 mm)

BASIC SEQUENCES



3D T2 TSE

Multiplanar reconstructions

•Less ontrast in white matter

• Lower in plane resolutiun

•Better delinieation of the cortex

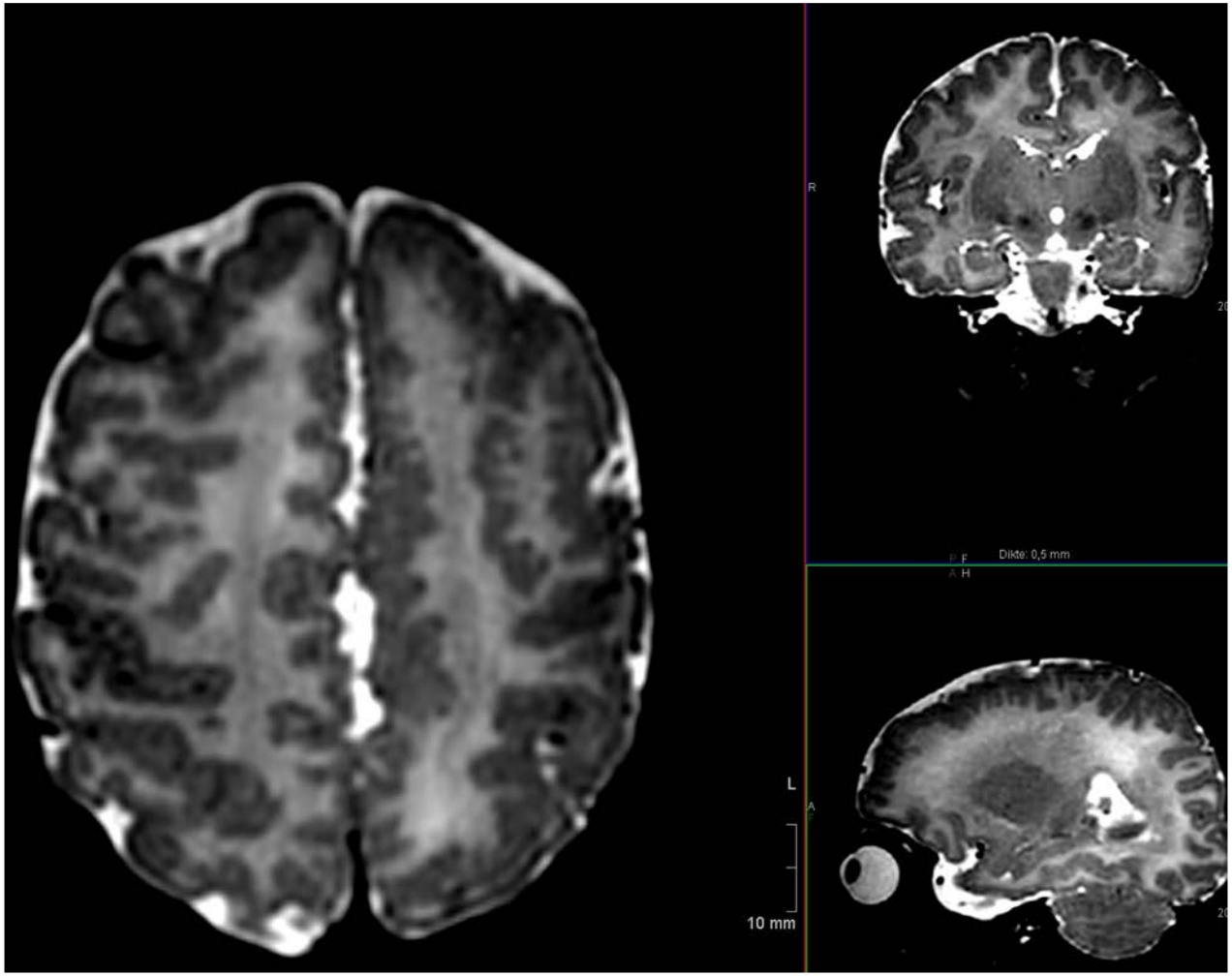
➔ detection of subtle cortical malformations

• Flow void trough aquaduct

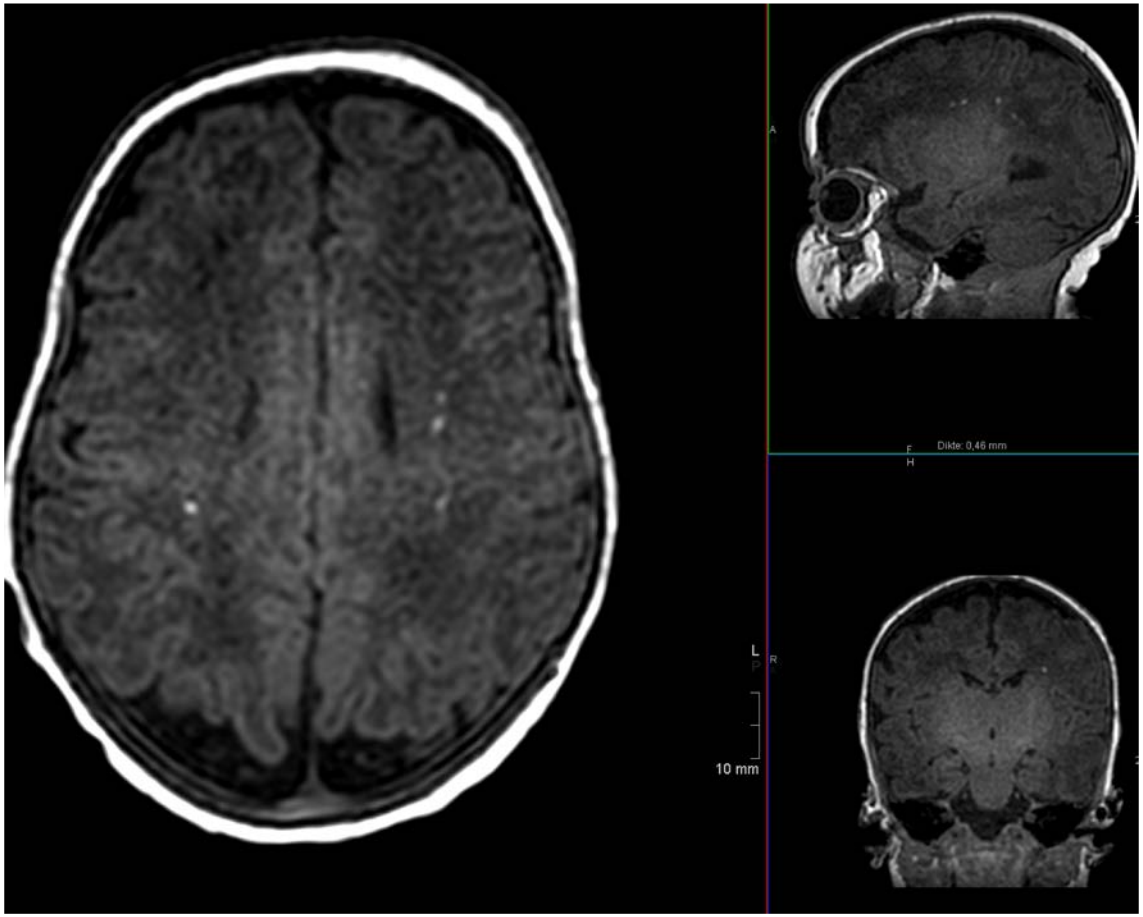
TR:2500
TE:330
FOV 190

BASIC SEQUENCES

3D T2 + MPR: polymicrogyria (PMG)



BASIC SEQUENCES



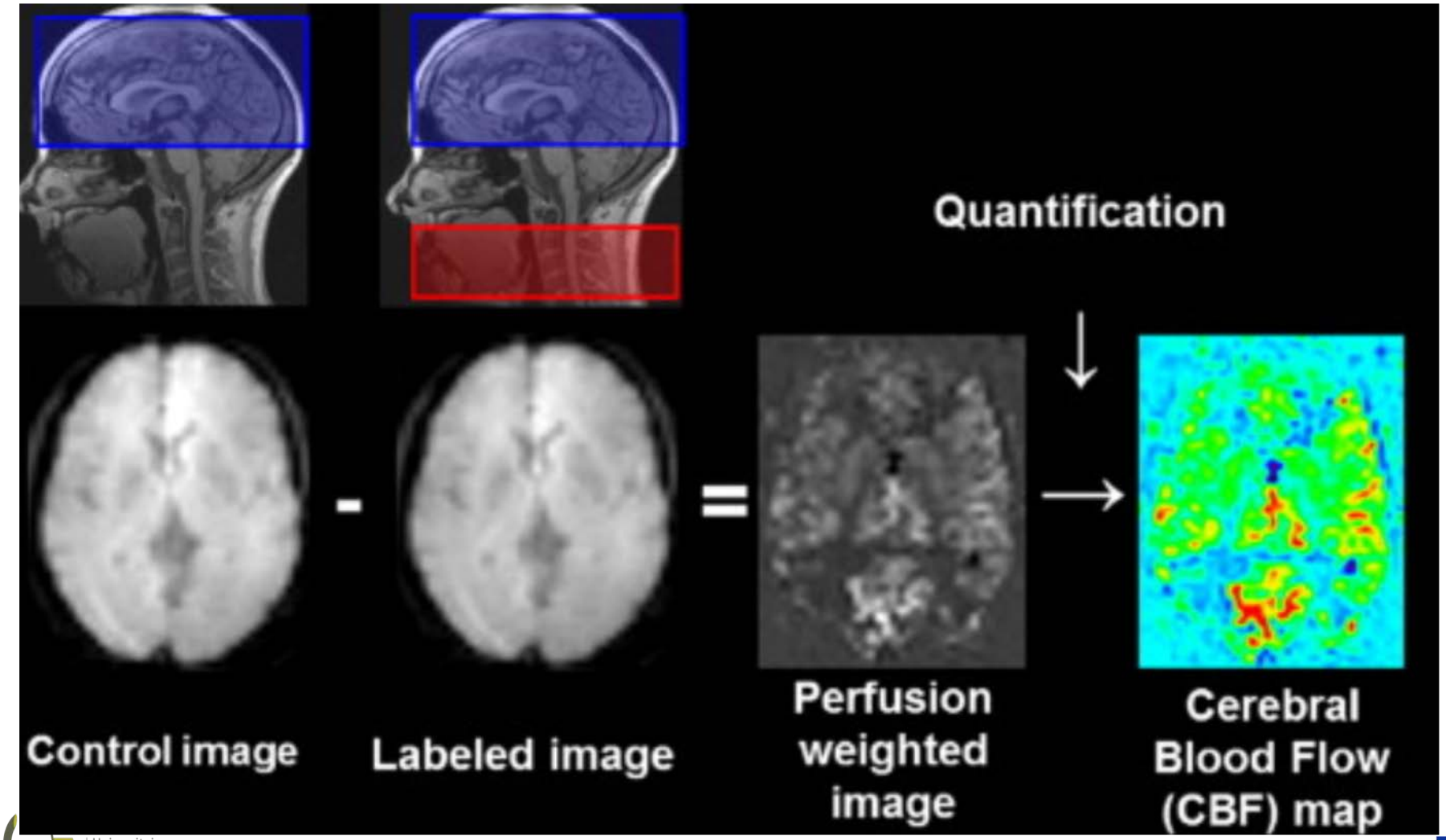
3D T1 TFE

Multiplanar reconstruction

➔Detection of small white matter lesions
➔location in motor tract => risk of impaired motor development

TR:6100
TE:2750
FOV 180

ASL (ARTERIAL SPIN LABELING)

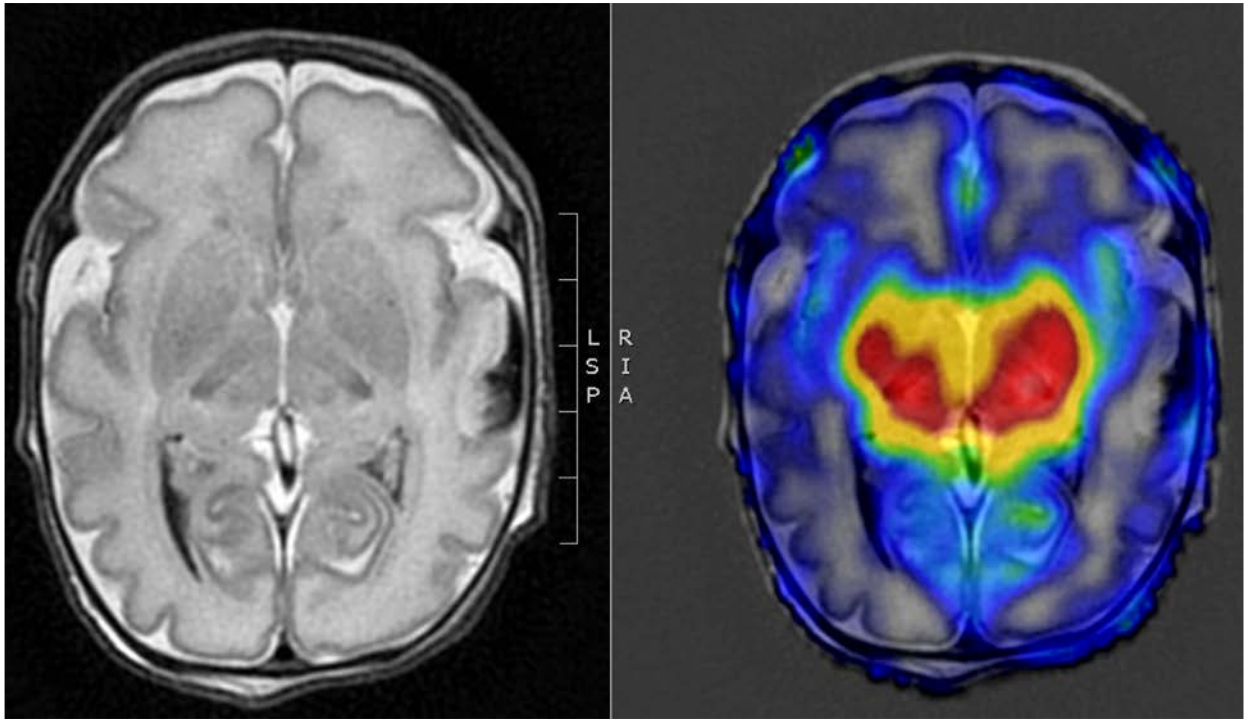


ASL

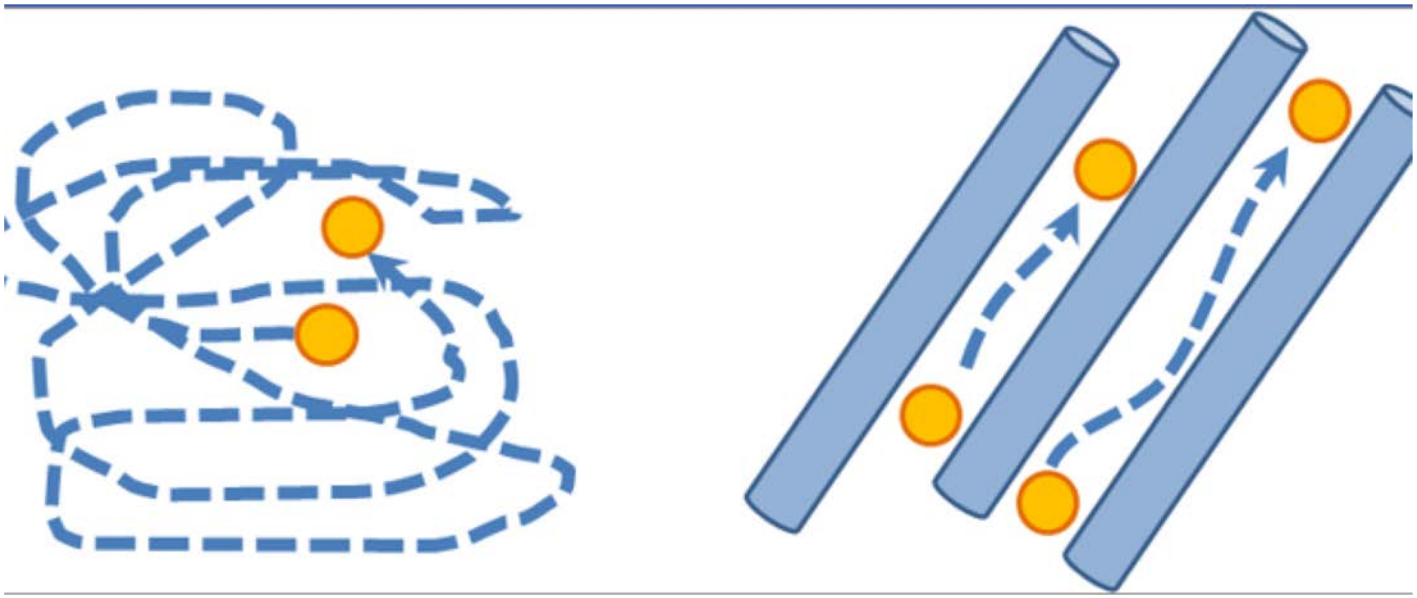
HIE (hypoxic ischemic encephalopathy)

- asfyxia (due to problemd before or during delivery)
- **Cardial** arrest
- Sever oxygen deficit during longer time => **brain damage**

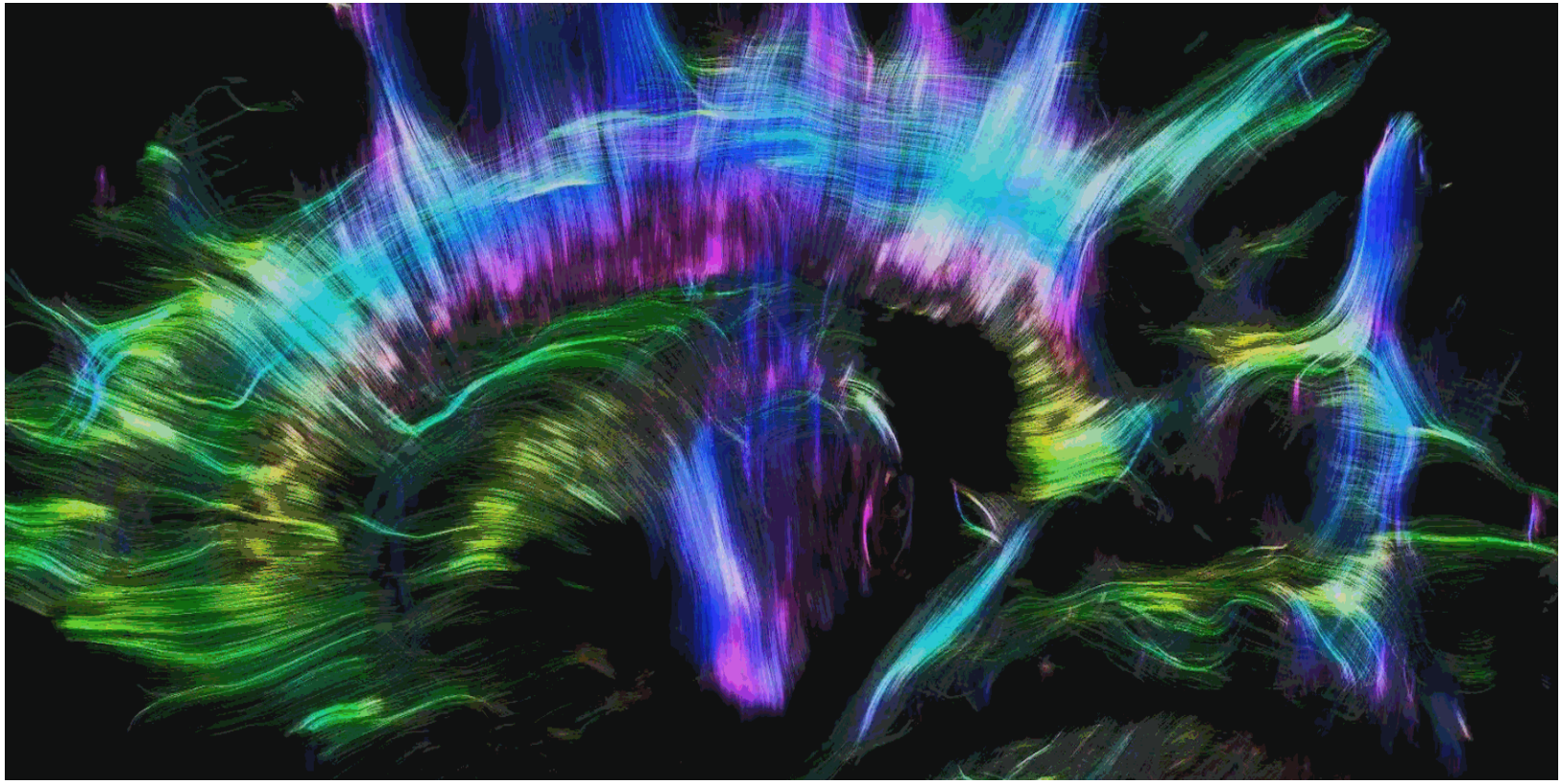
-Hyperperfusion (reperfusion) in basale ganglia + lactate (spectroscopy) ➔ **worse outcome**



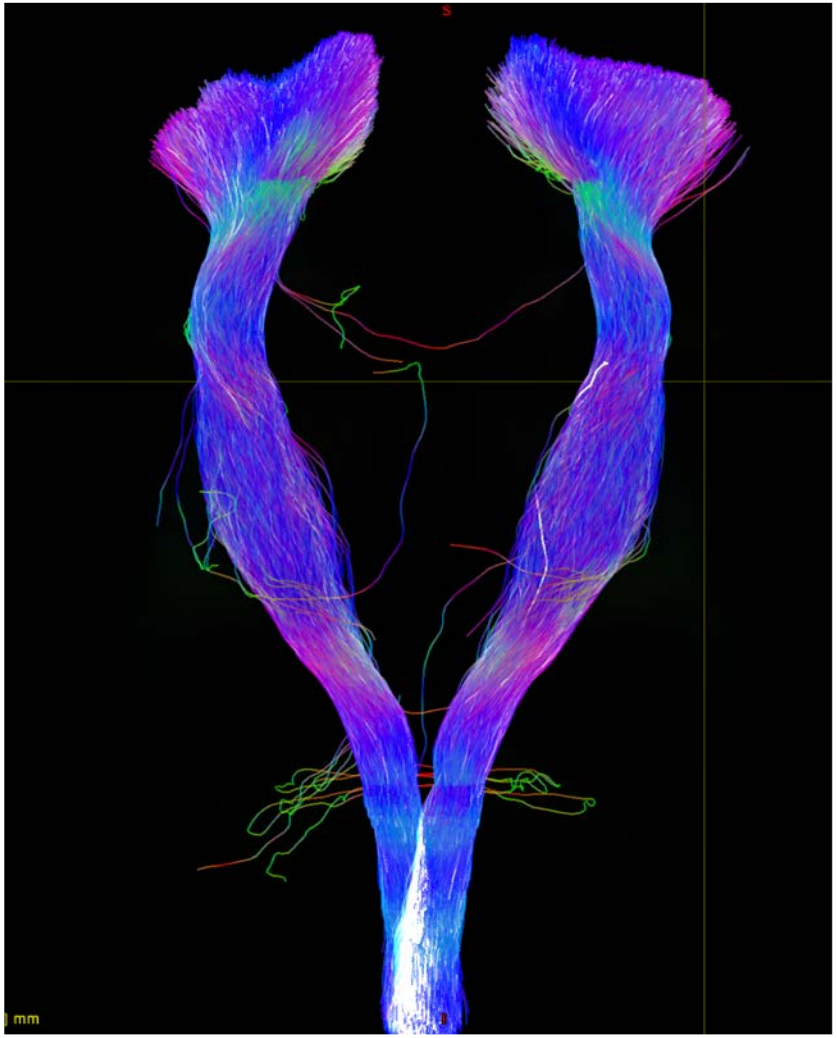
DIFFUSION + TRACTOGRAPHY – BROWNIAN MOTION

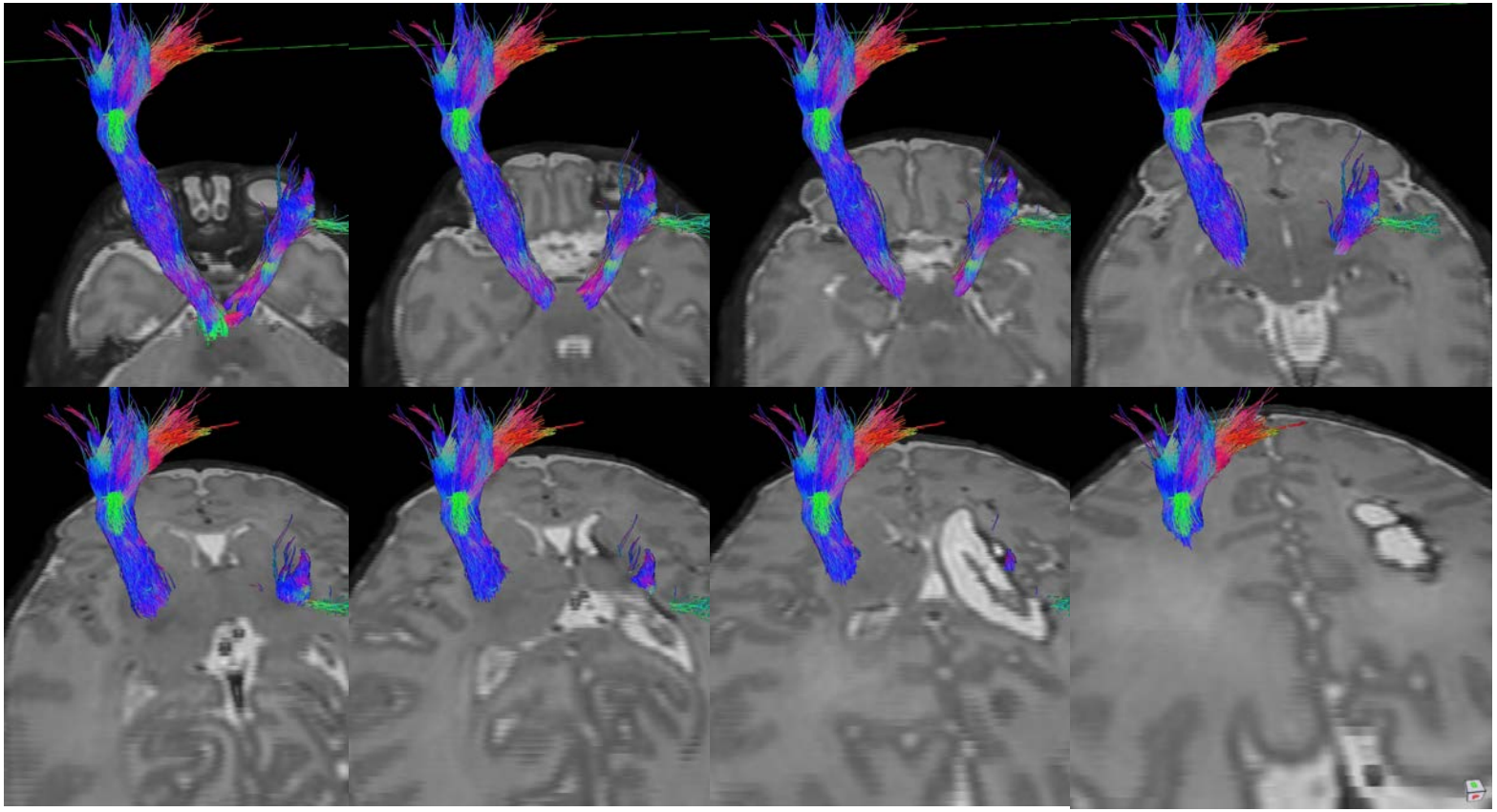


NEONATALE DIFFUSIE TRACTOGRAFIE



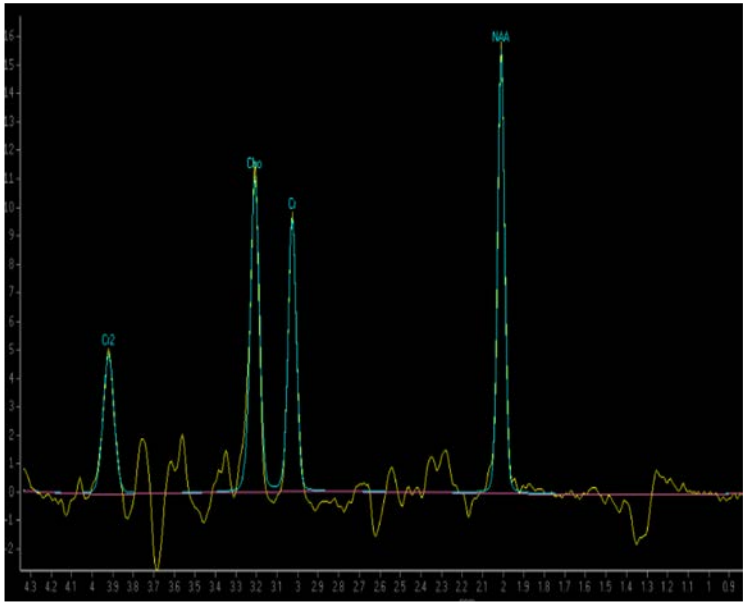
CORTICOSPINAL TRACT

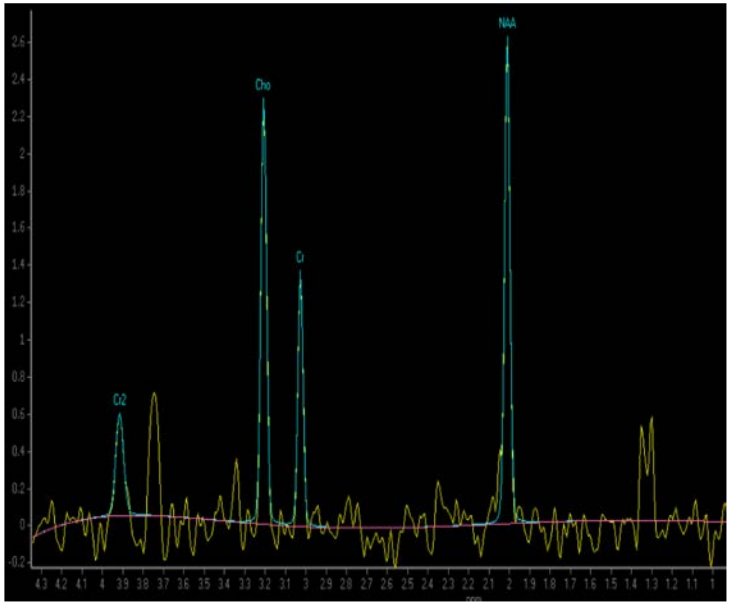




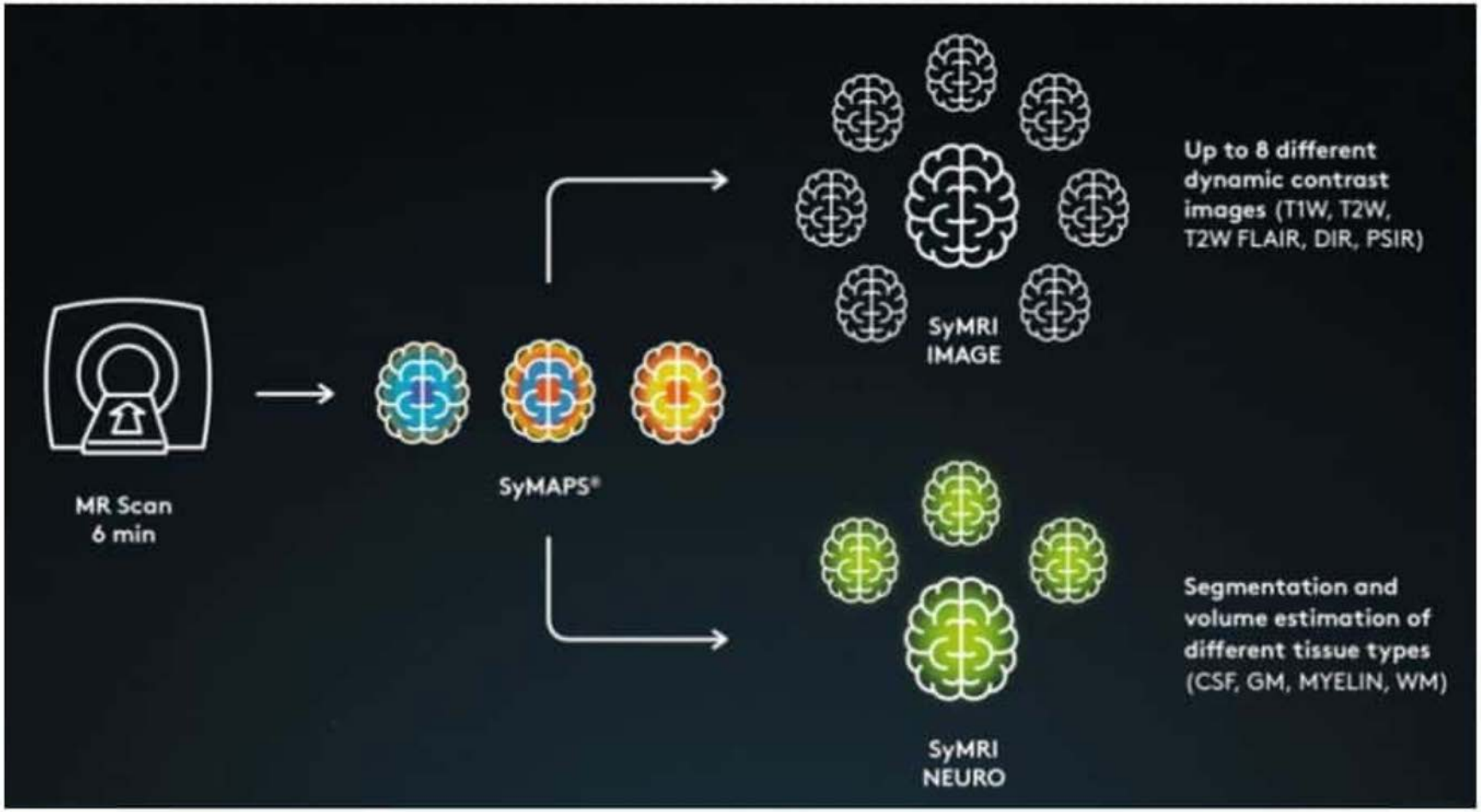
MR SPECTROSCOPY

Hypoxia – mitochondrial white matter diseased : lactate ++
Canavan Leukodystrophy : NA ++++
Non-ketotische hyperglycemie : Glycine (short echo time)





SYNTHETIC MRI



How SyMRI Works

ADVANTAGES OF SYNTHETIC MRI

▪**Quantitative measurements**, physical tissue properties => Easier to compare between different scanners/centers/references.

▪ **Parameters :** TR, TE, TI can be adjusted after the scan => synthetic T1, T2, STIR, PSIR, Proton density images.

▪**Synthetic MRI Volumetry**

- **Brain volume** at terme age in prematurity is correlated with outcome later in life (cognitive, motor)
- **Brain volumetry** in neonates currently only in specialized research centers
  - Techniques for volumetry in adults (freesurfer, SPM, FSL, Icometrx,...) do not work in neonates because of totally different contrast

> **Volume measurement** of the brain in routine with SyMRI, in less than 1 minute!
> Based on known **tissue specific T1 and T2 relaxation times**
> **No atlas needed**

SYNTHETIC MRI - MYELINE

C. Andica et al. / Journal of Neuroradiology 46 (2019) 268–275

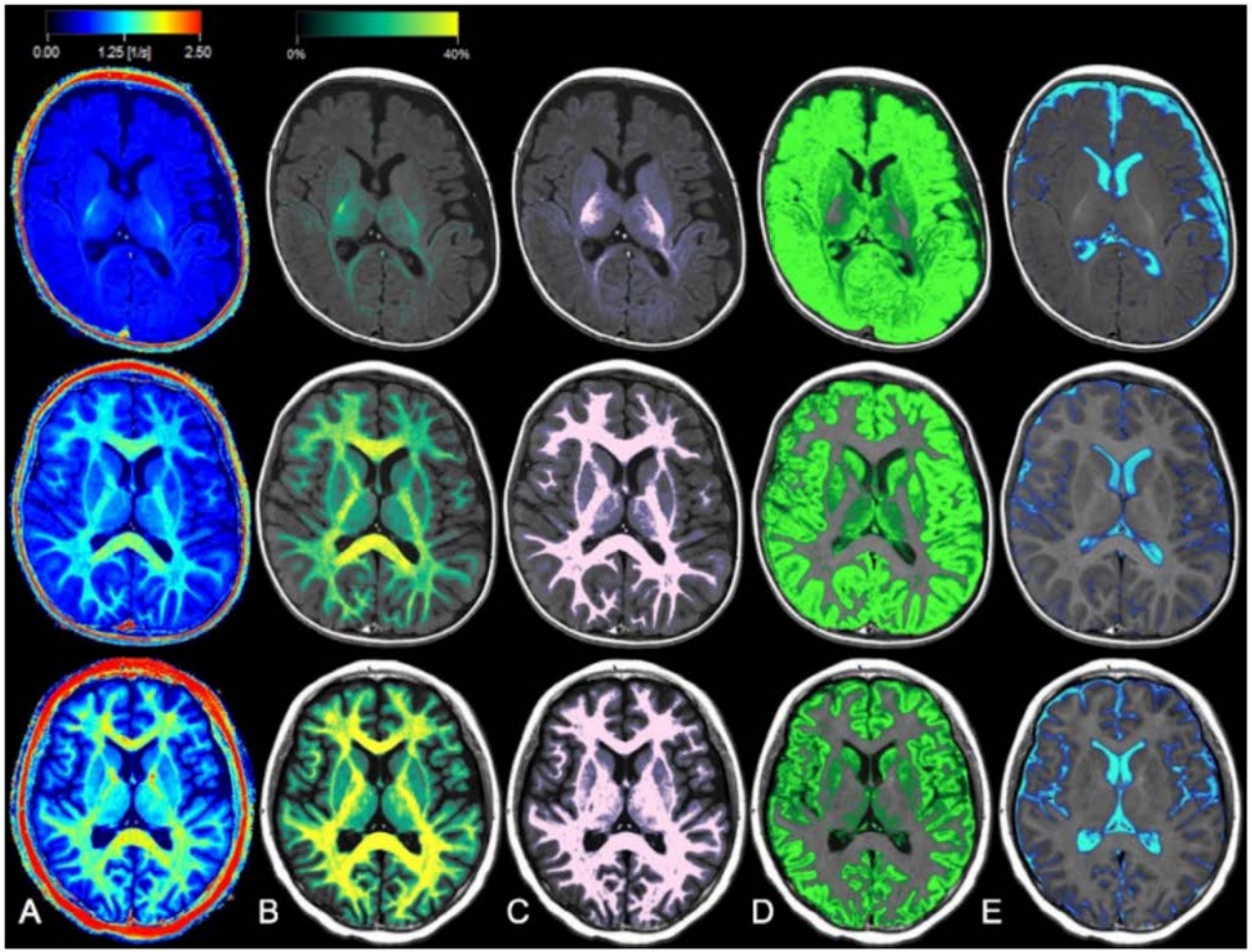


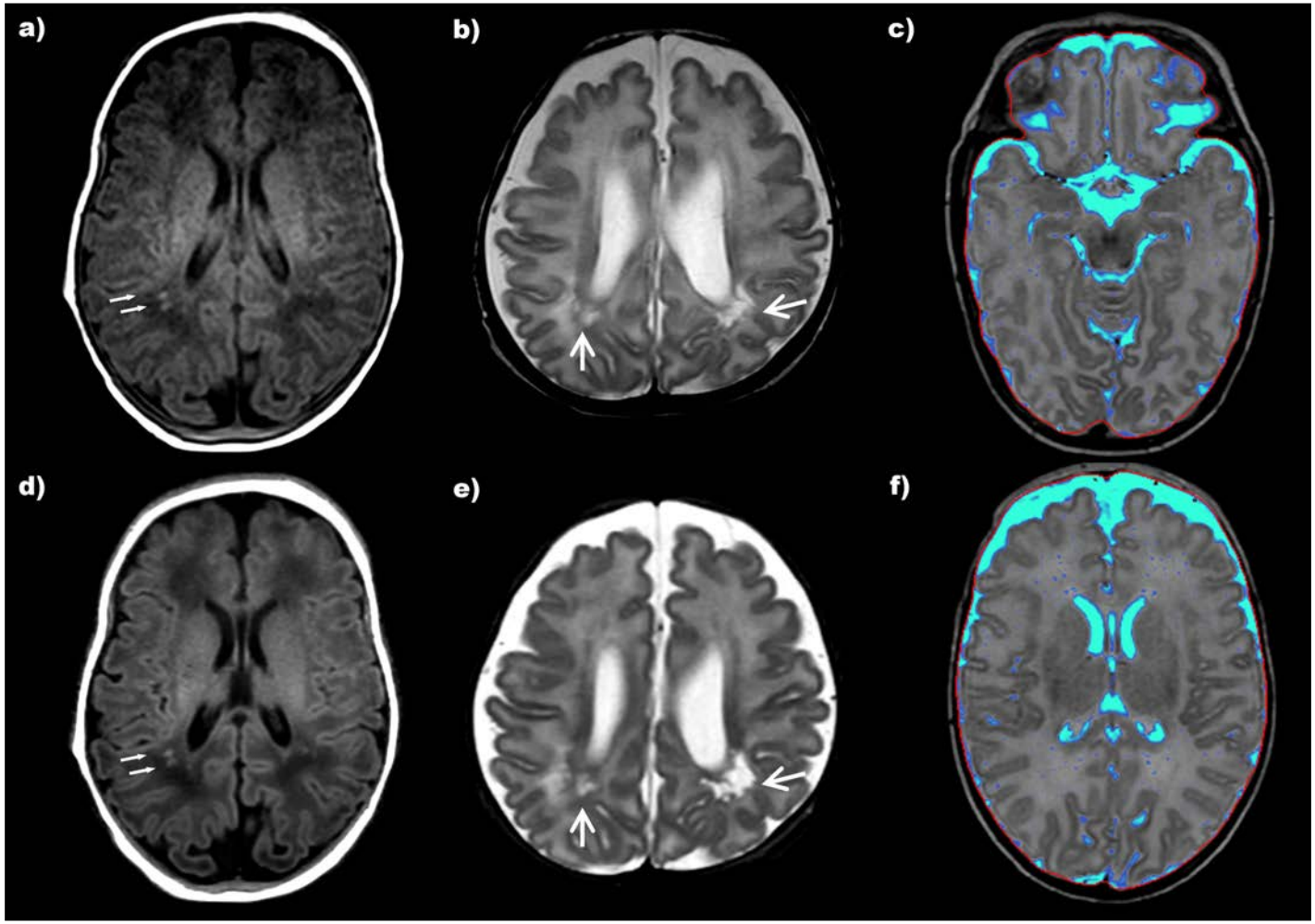
Fig. 1. The brains of a **3-month-old** male infant (first row), a **2-year-old** boy (second row), and a **13-year-old** girl (third row). SyMRI quantitative maps [only R1 map (shown on a scale 0–2.5 s-1) is shown (A)], myelin partial volume map (shown on a scale 0–40%) (B), WM segmentation (C), GM segmentation (D), and CSF segmentation (E) can be used to evaluate development of the brain. However, in young children, WM and GM segmentation is suboptimal because the unmyelinated WM is assigned as GM, which is a limitation of the currently implemented algorithm

SYNTHETIC MRI

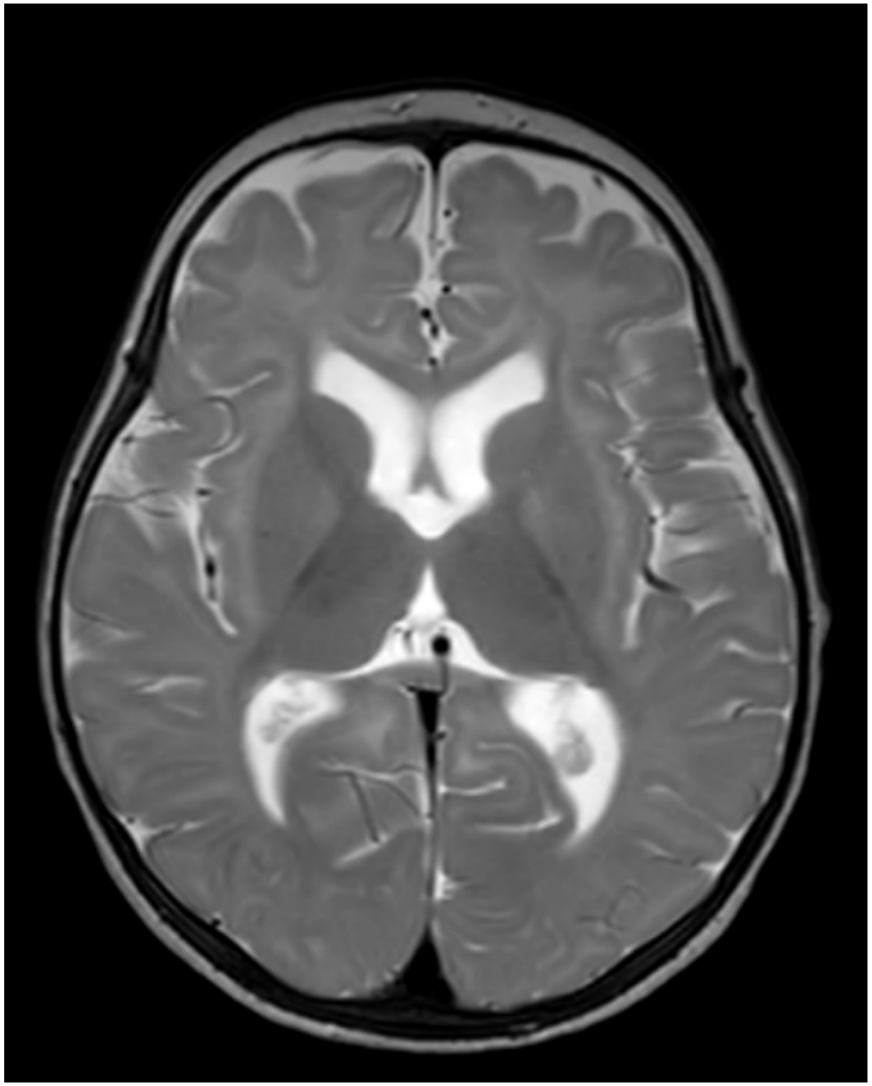
Volumetry - SyMRI

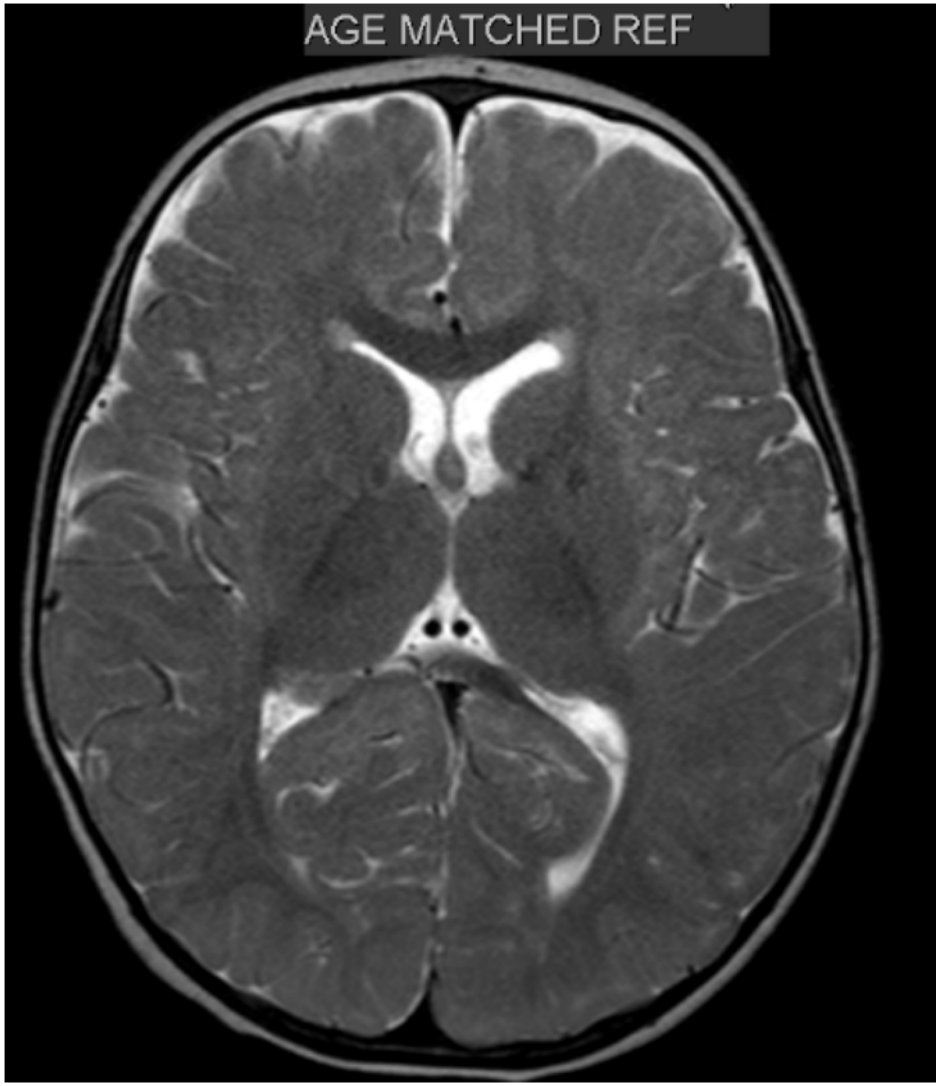
Conv

Syntetisch



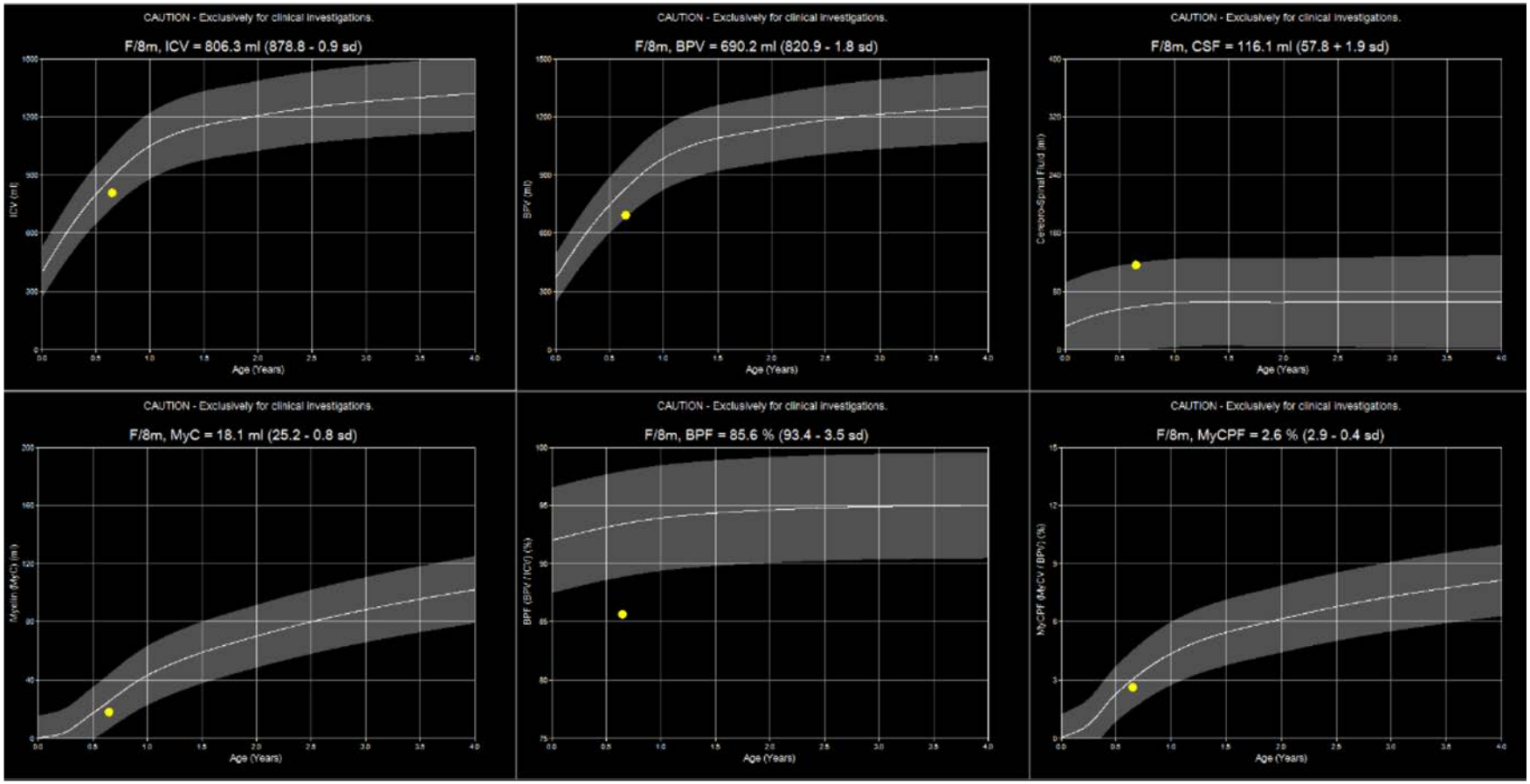
NORMAL OR NOT? COMPARATIVE IMAGES!!!





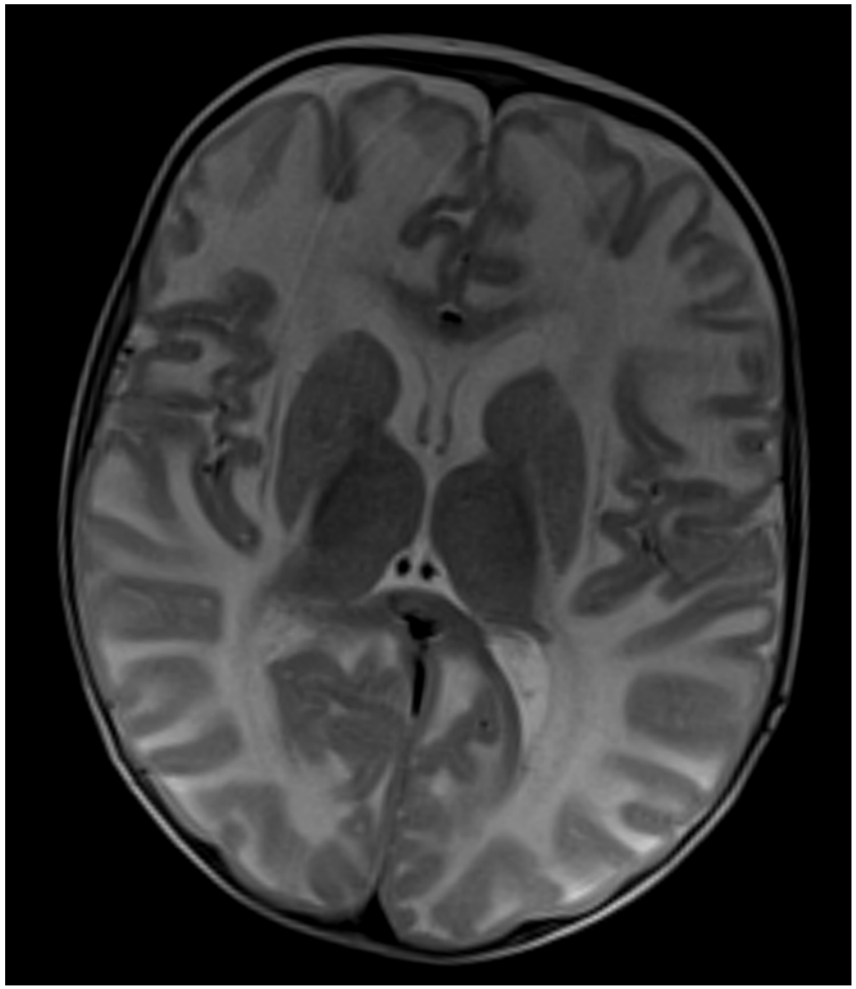
Girl, 8 months old

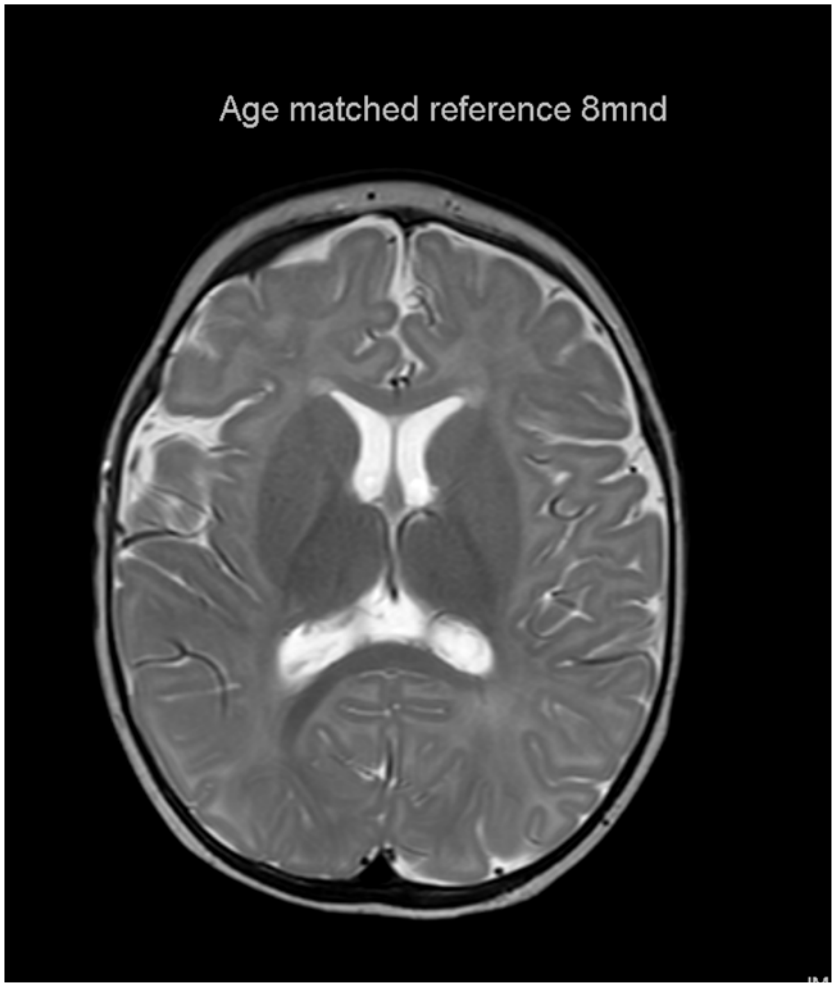
NORMAL OR NOT? AGE MATCHED REFERENCES



Synthetic MRI – Reference curves

NORMAL OR NOT? COMPARATIVE IMAGES!!!





Boy, 8 months old , GLIACAM mutation (megalencephalic leukoencephalopathy with cysts)

CONCLUSION

- MRI in neonates and young children is a challenge!

- Custom protocols with adjusted FOV, TE and TR are needed.

- Good sedation is important for image quality

  ➔ Chloralhydrate syrup or “feed and sleep”

  ➔ Good collaboration needed with pediatricians/day hospitalists/technologists/radiologists

- Myelination proceeds according to fixed pattern and has a major influence on tissue contrast

- Synthetic MRI supplement/alternative to conventional images

  ➔ Quantitative, brain volumetry, synthetic image reconstructi

- Importance of reference images and values

THANK YOU

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