Fetal CNS MRI

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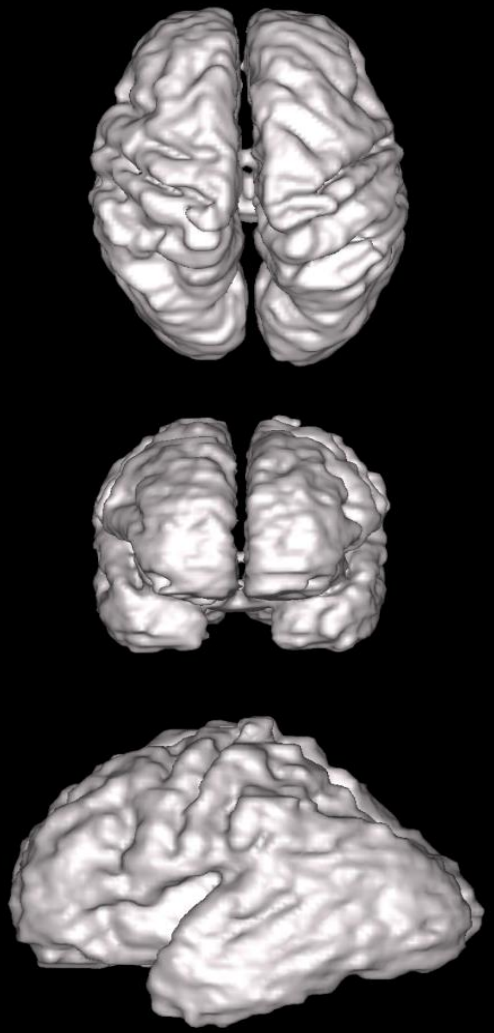
Methods

Normal development

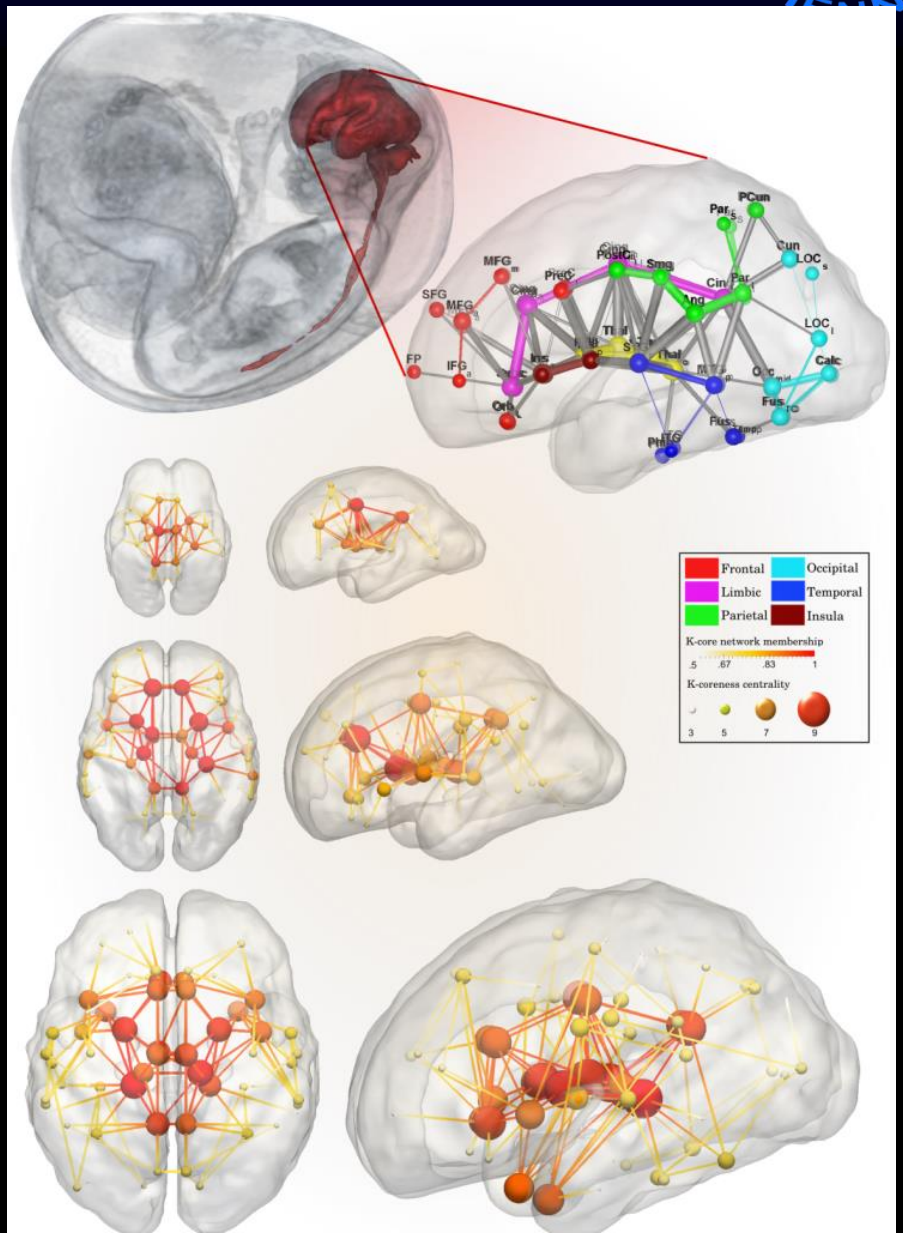
Malformations

Acquired pathology



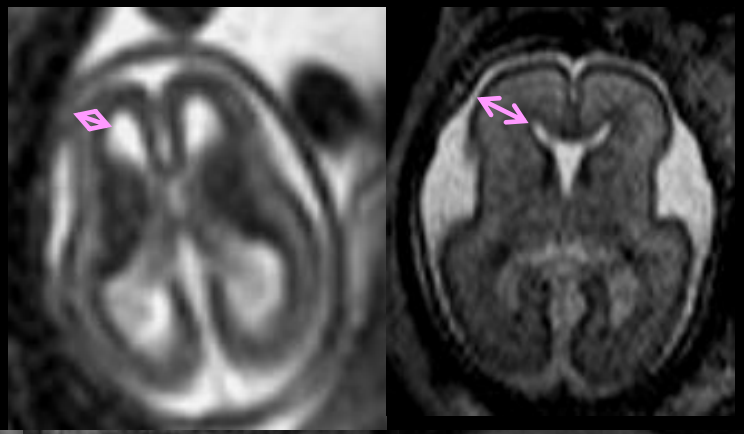
MR- methods for assessment of the fetal CNS

- 2D morphology
- 3D morphology
- Quantification of brain tissue
- Tractography
- Functional MRI
- Movement
- Spectroscopy

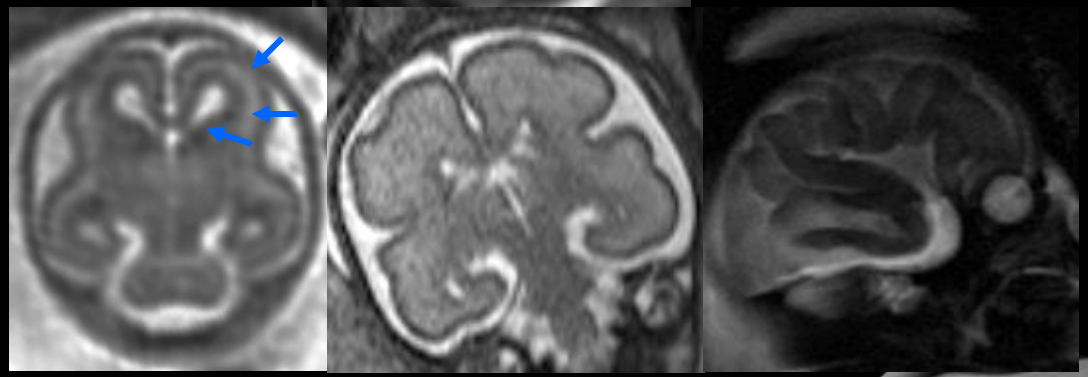


In utero fetal brain development

from thin
to thick

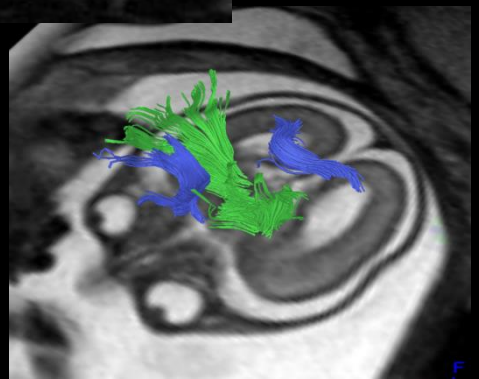


from smooth
to structured



from layered
and disorganized

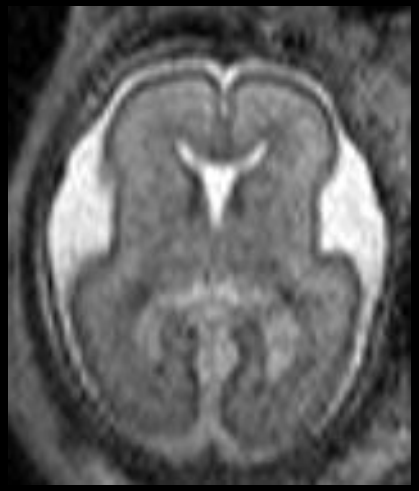
to regionally
organized
and connected



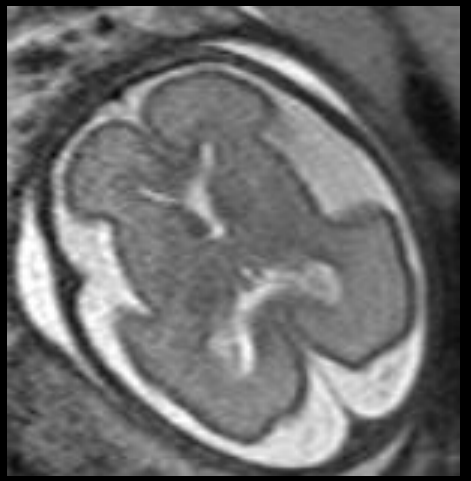
2D morphology surface axial images

GW 18

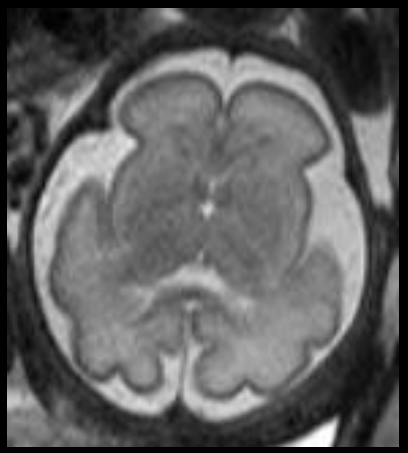
GW 22



GW 24

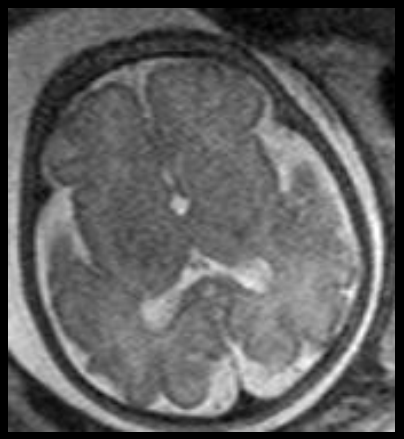


GW 27

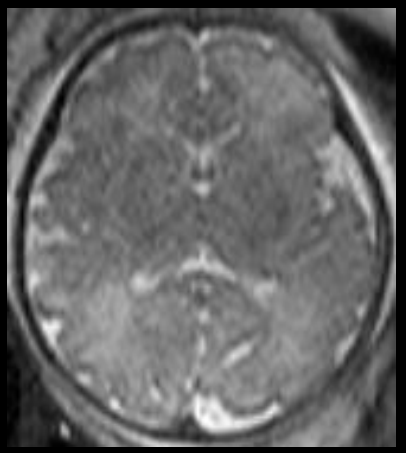


GW 29

GW 32



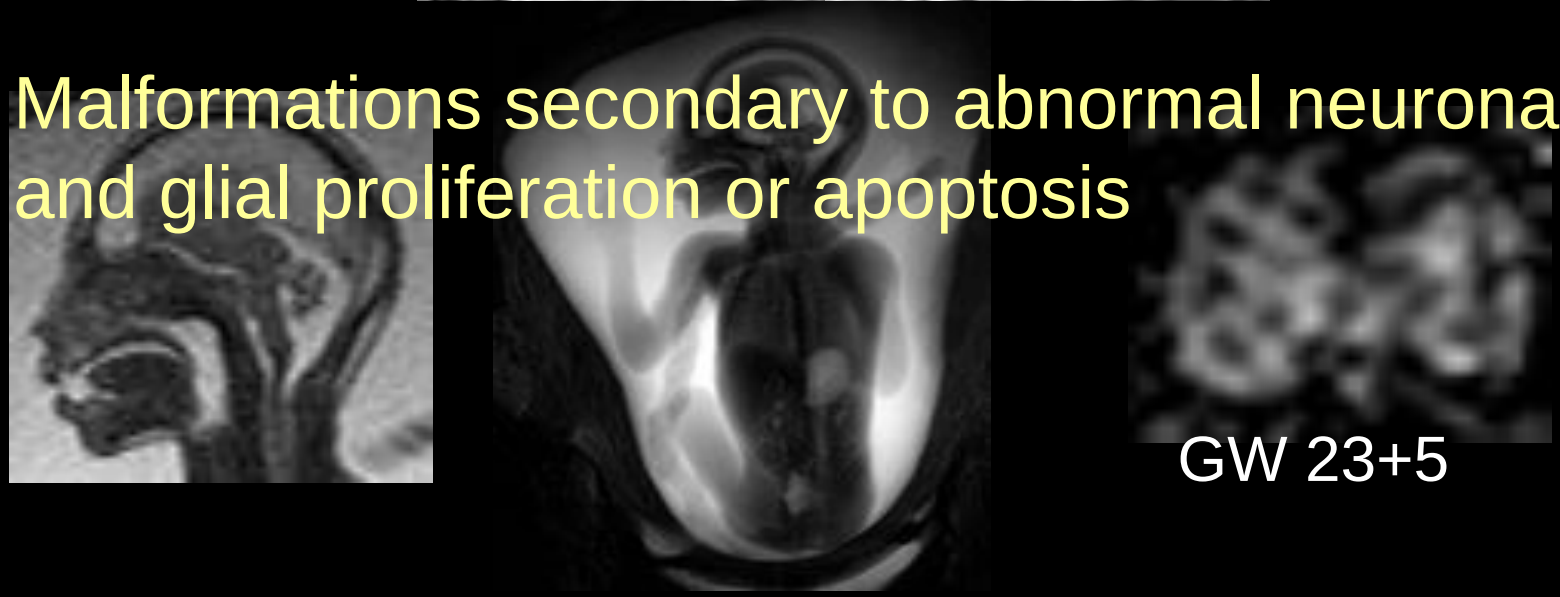
GW 34



GW 37

Insular indentation

Malformations secondary to abnormal neuronal and glial proliferation or apoptosis



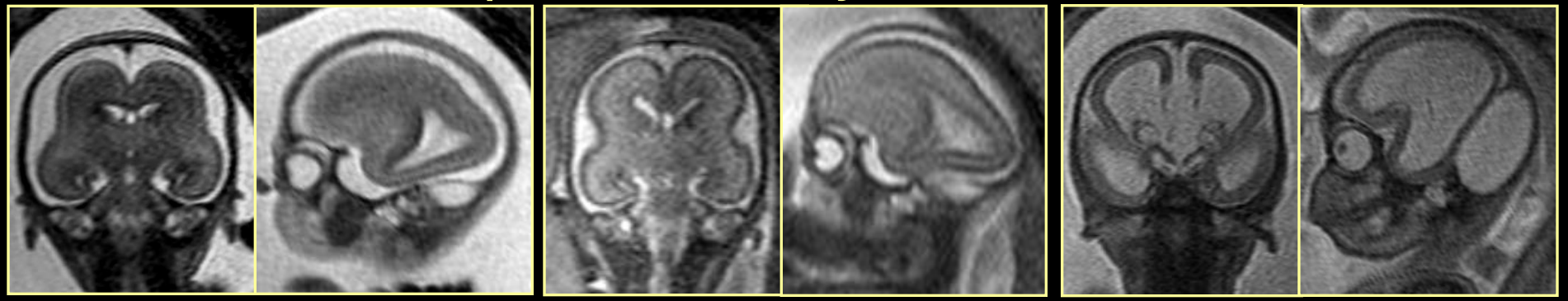
GW 23+5

Barkovich AJ et al Brain 2012: 135 1348-1369

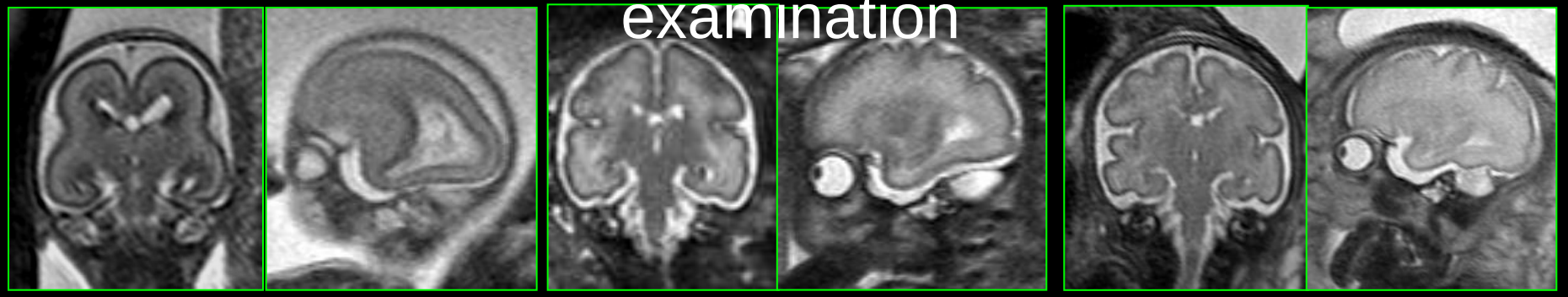
Fetal CNS pathology

Early MR detection of lissencephaly

developmental delay: 5.1 ± 4.0 GW

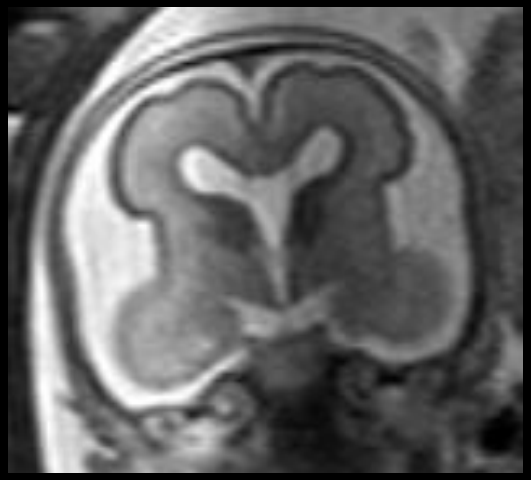


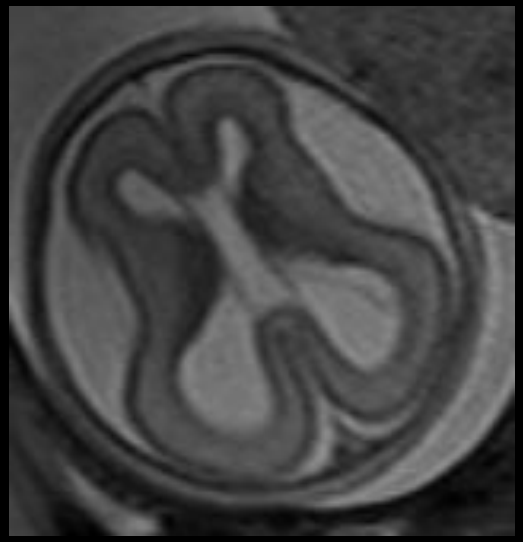
No signs of gyration in 11/19 cases at first MRI examination



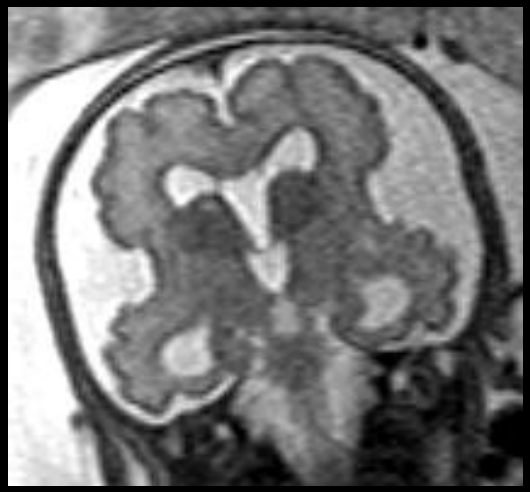
20 GW | 29 GW | 34 GW

Premature gyri



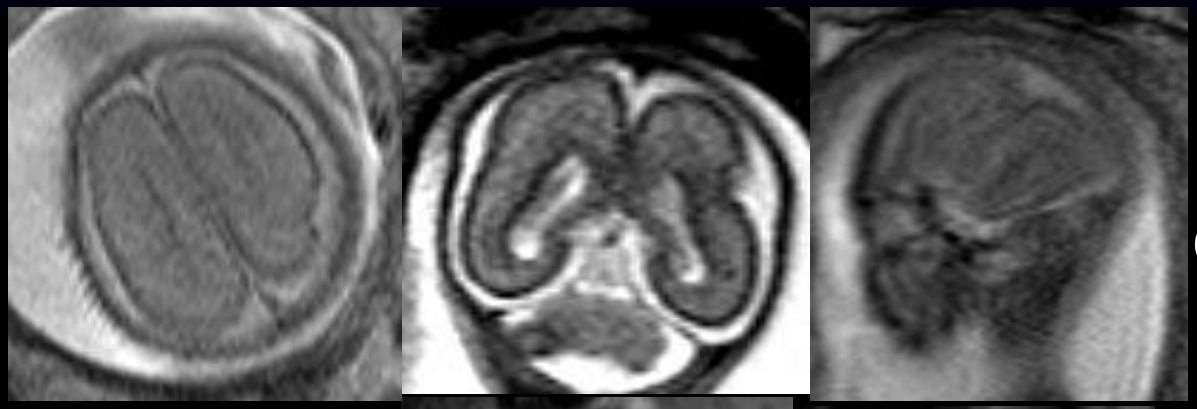


23+5

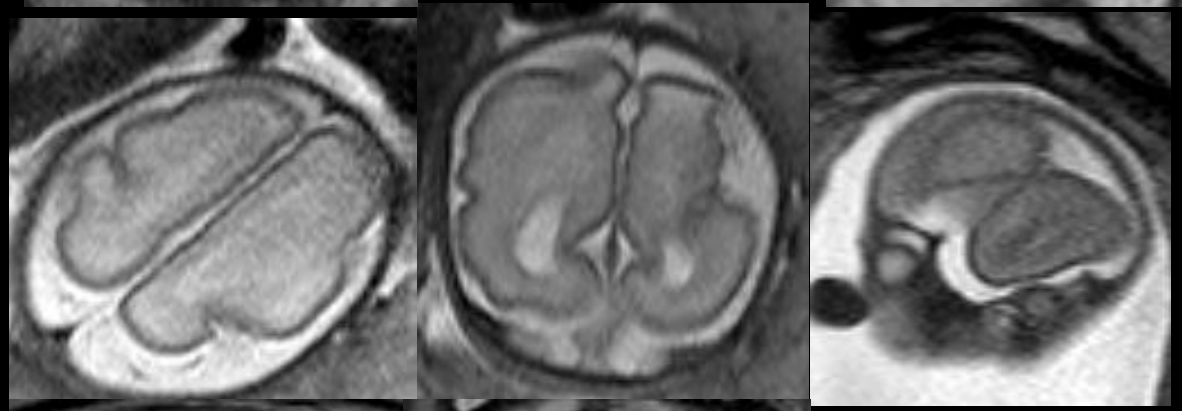


29+3

Aquired cortical pathology

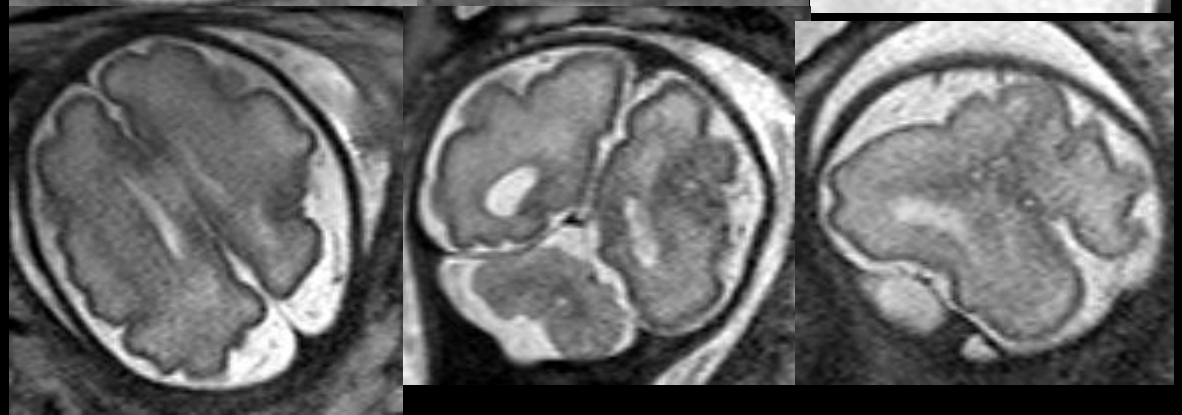


GW 22+6



GW 29+0

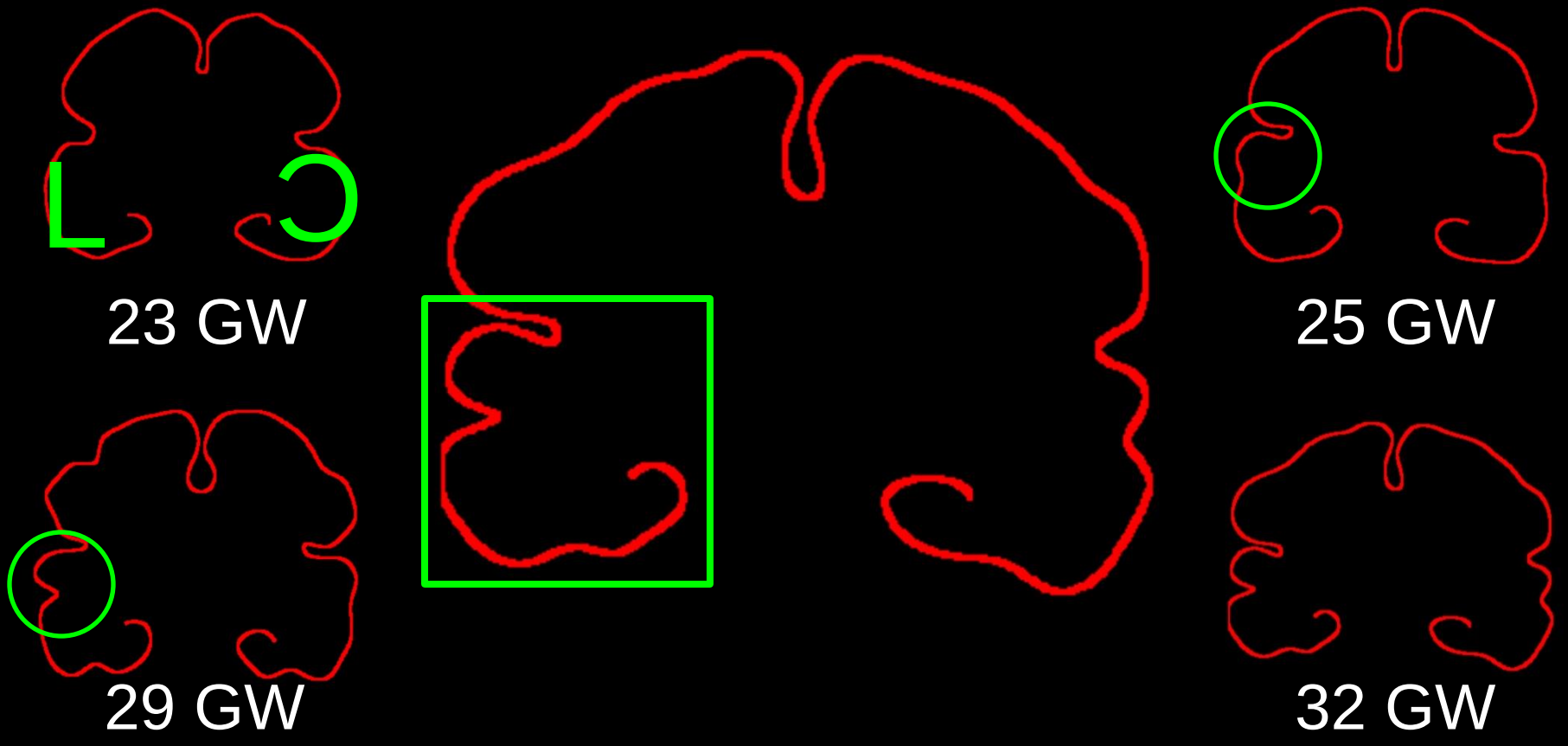
Cord occlusion because of FFTS 2 weeks Before 1st MRI



GW 31+1

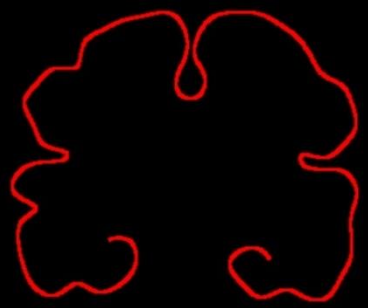
Results - Morphometry

n=16, 22-32 GW



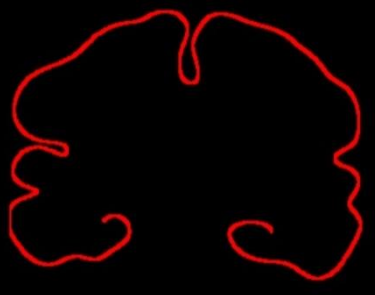
Kasprian G et al Cereb Cortex 2012

Cerebral asymmetry pattern in commissural agenesis



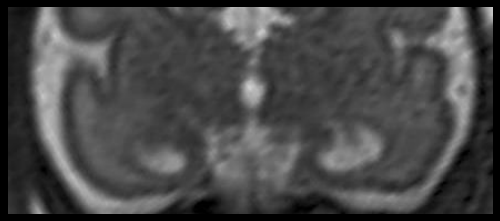
25 GW
“inverted“

23 GW
“classical“

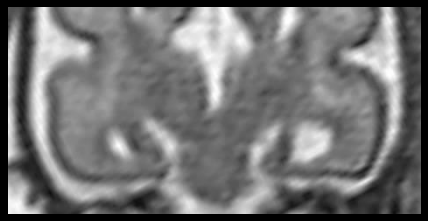


29 GW
“symmetric“

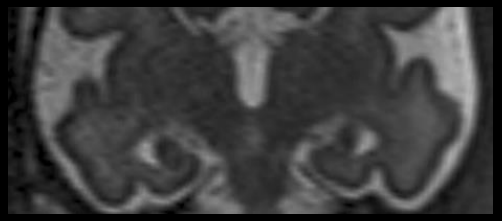
High frequency of abnormal hemispheric asymmetry patterns!



18-23/37; 55%
vs. 3.2% normal



17-2/37; 32.7%
vs. 94.2% normal



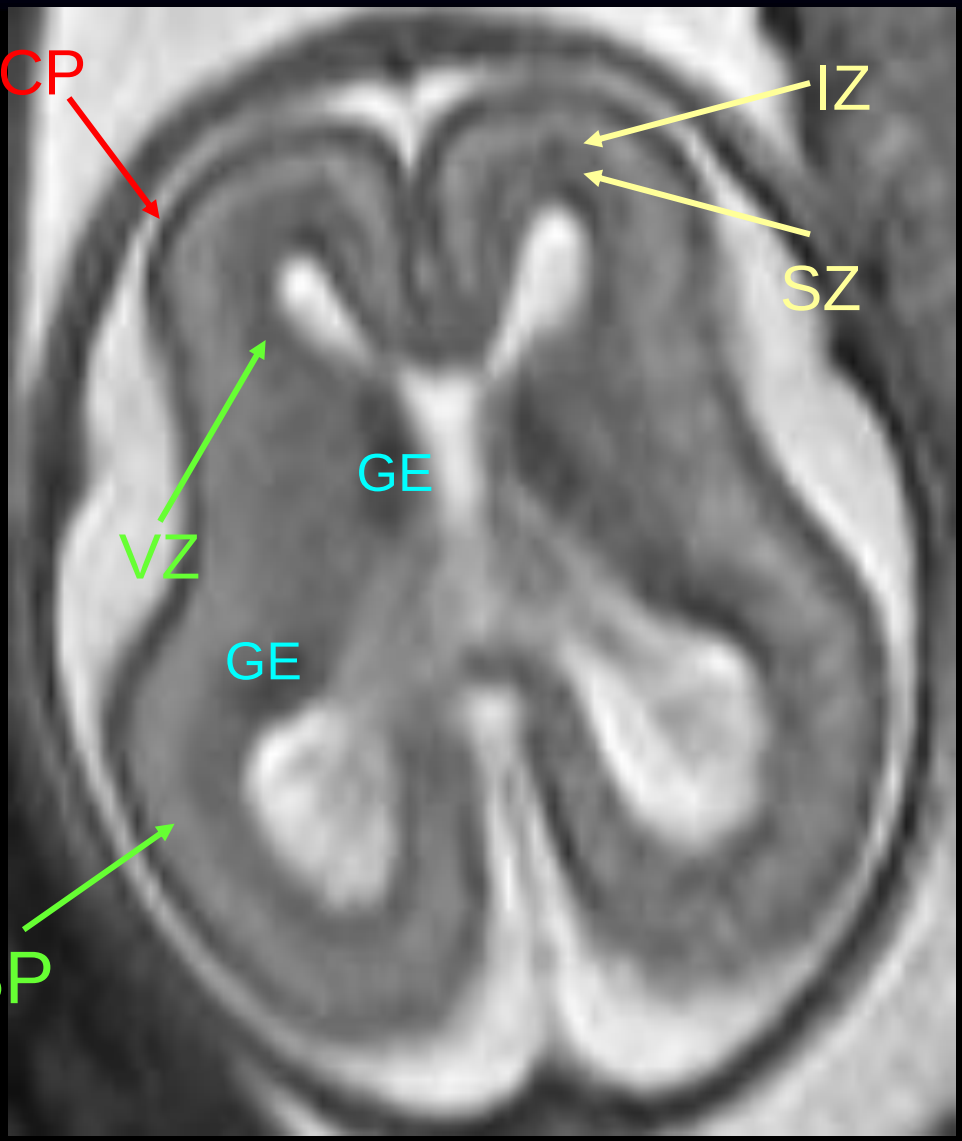
1-8/37; 12.3%
vs. 2.6% normal

Lamination of the fetal brain

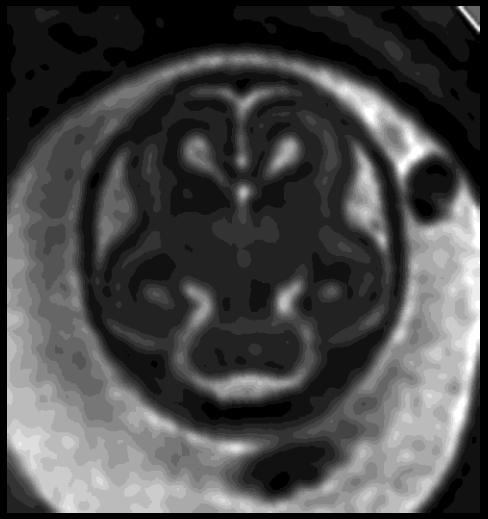
Histology

Ventricular Zone
+ Ganglionic Eminences
Periventricular Zone
Subventricular Zone
Intermediate Zone
Subplate
Cortical Plate
Marginal Zone

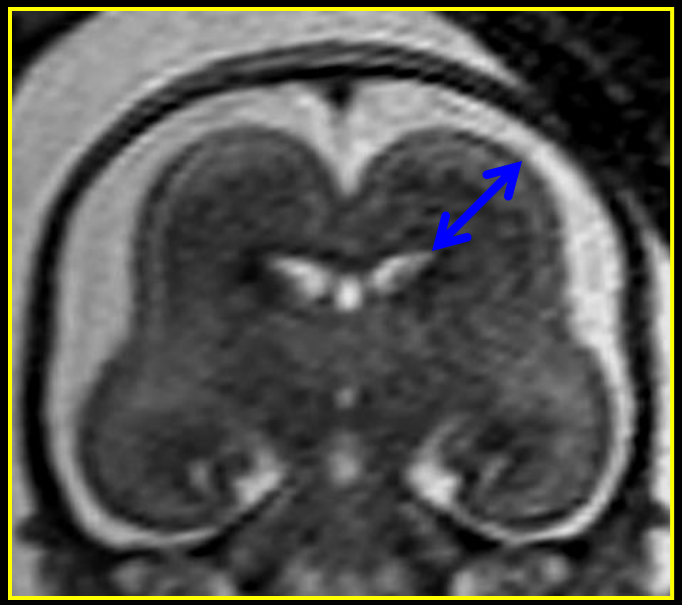
GW 20+4 T2



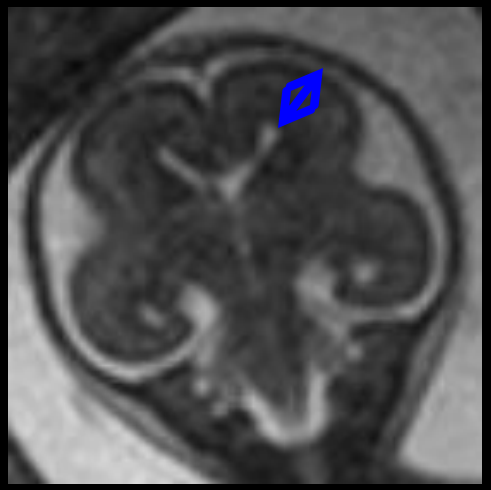
Fetus at 22 GW:
With abnormal lamination



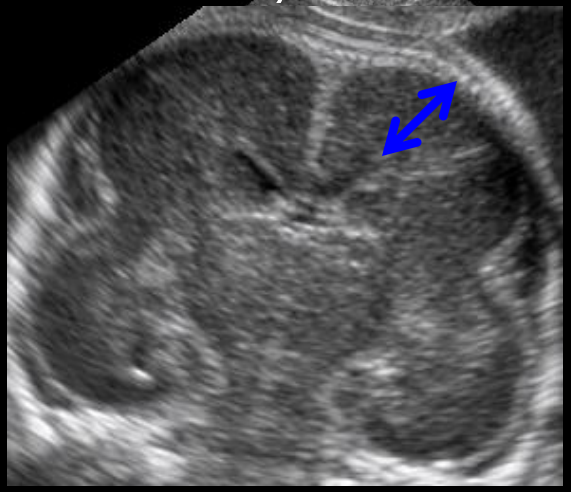
17 GW, normal



22 GW

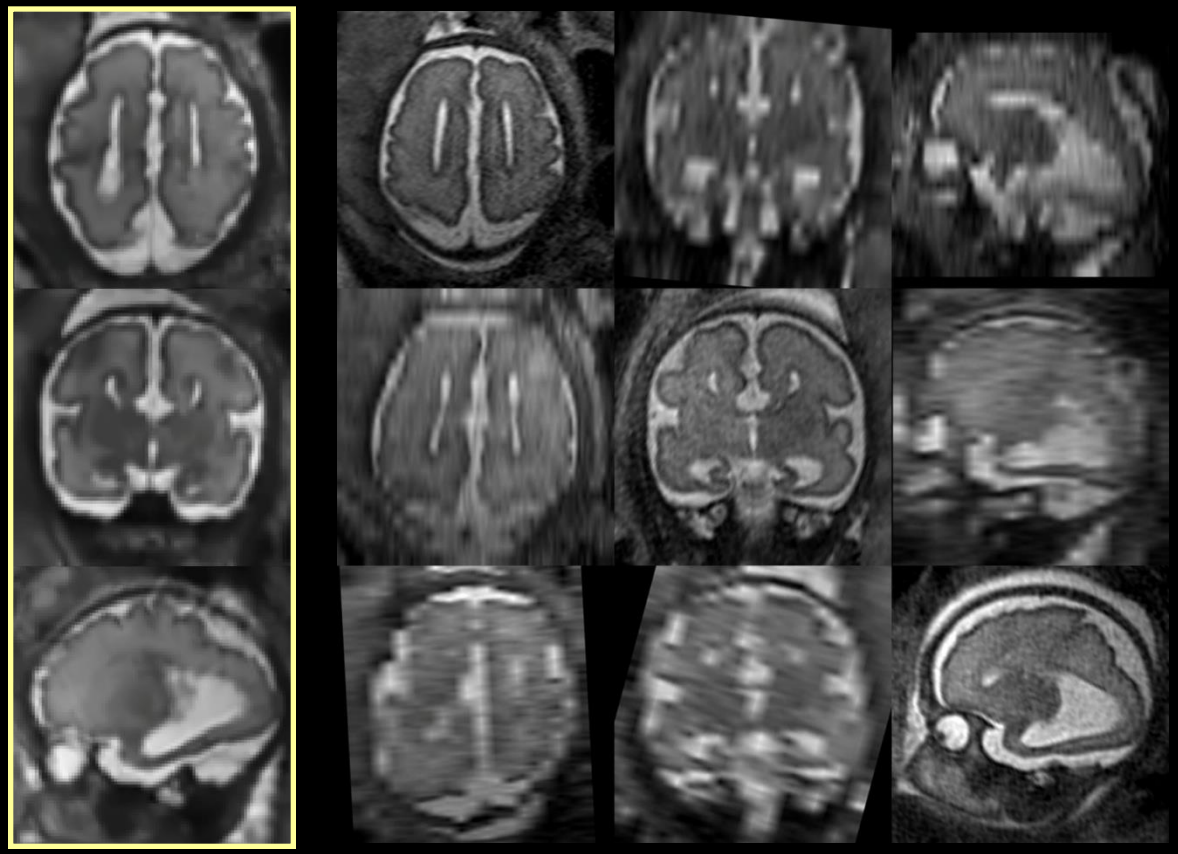


22 GW, normal



Super-resolution

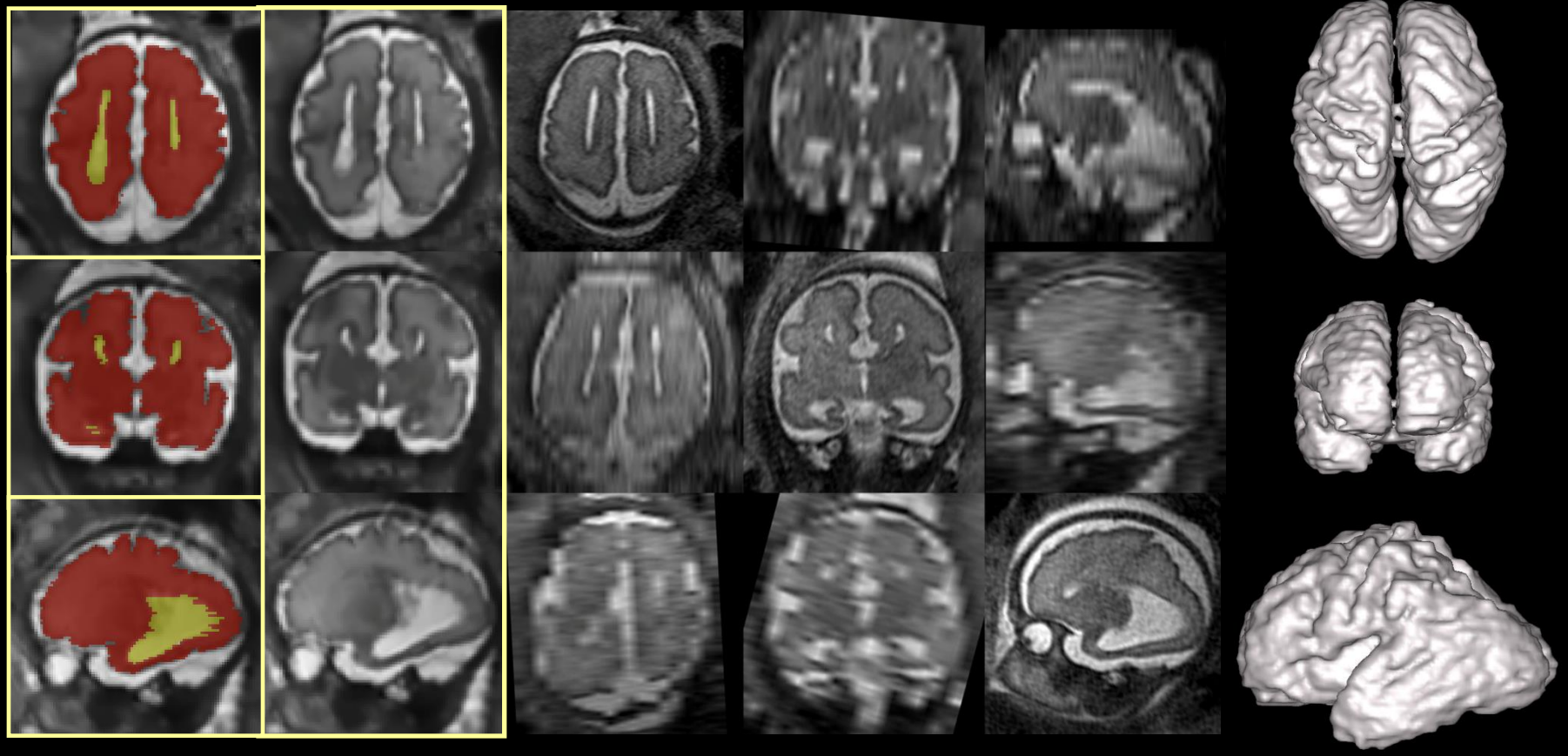
= 3D reconstruction technique from 2D data resulting In images with higher resolution than the originally acquired ones



Rousseau F, Kim K, Studholme C, et al. Med Image Comput Comput Assist Interv 2010;13:355-362

Super-resolution

(0.78-1.02mm isovoxel)



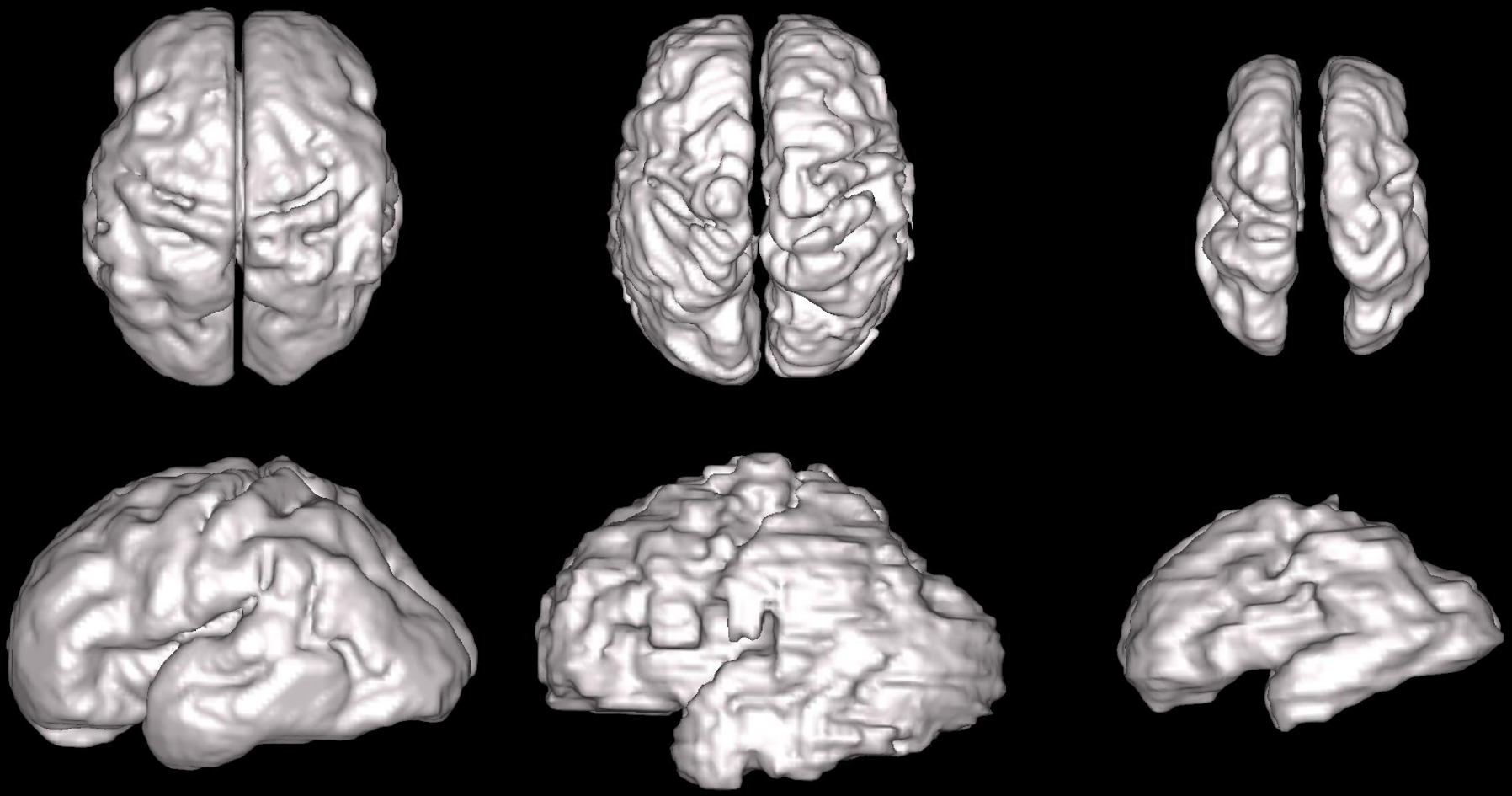
Neuroimage. 2015

Disorders of axon guidance: effect on brain volume

normal

isolated CCA

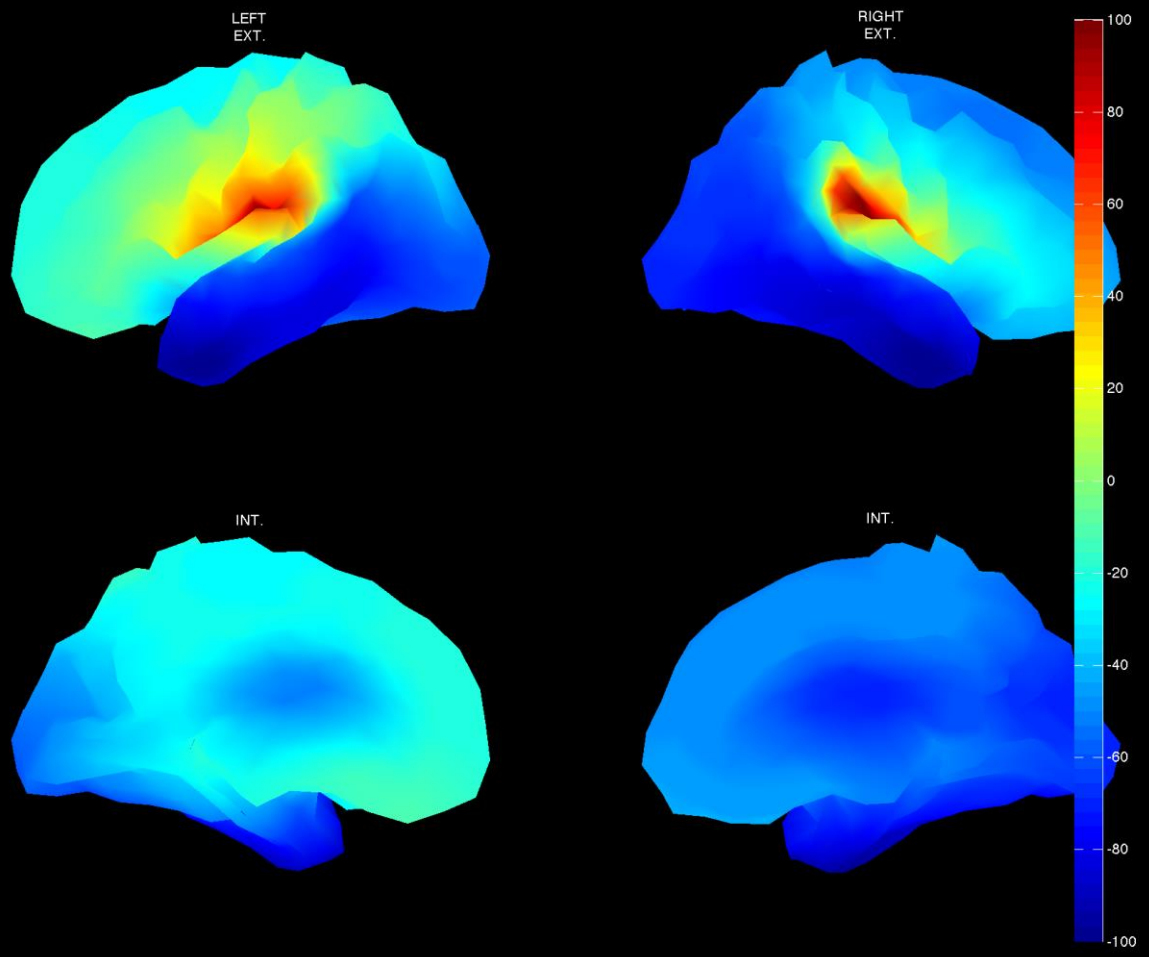
associated CCA



Results

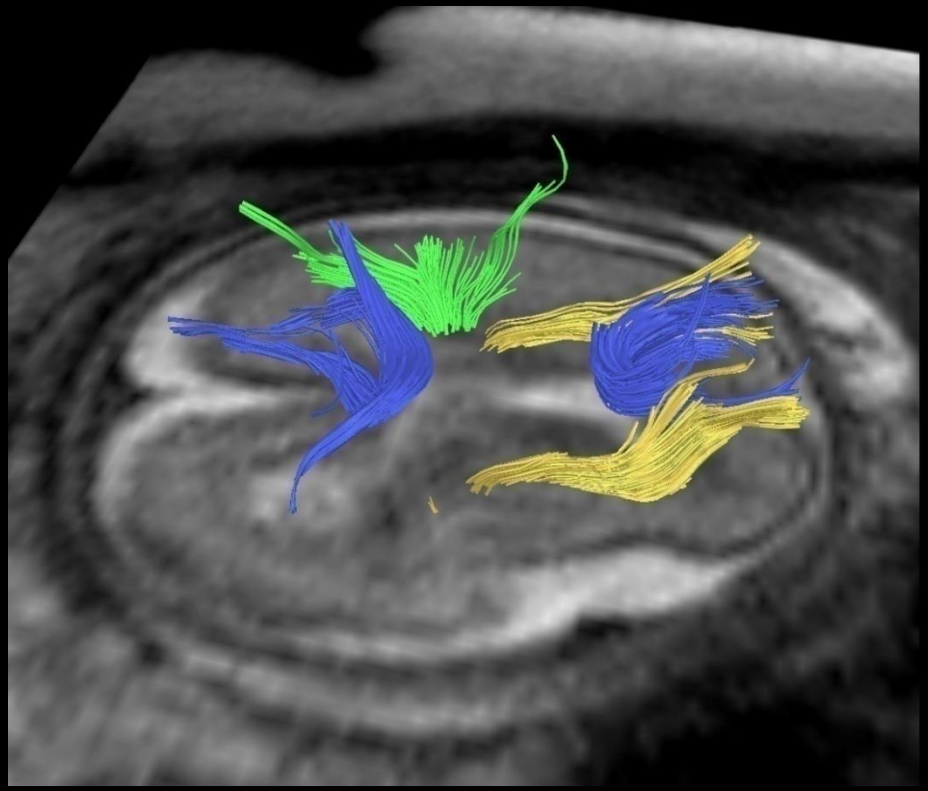
group analysis – parenchymal thickness

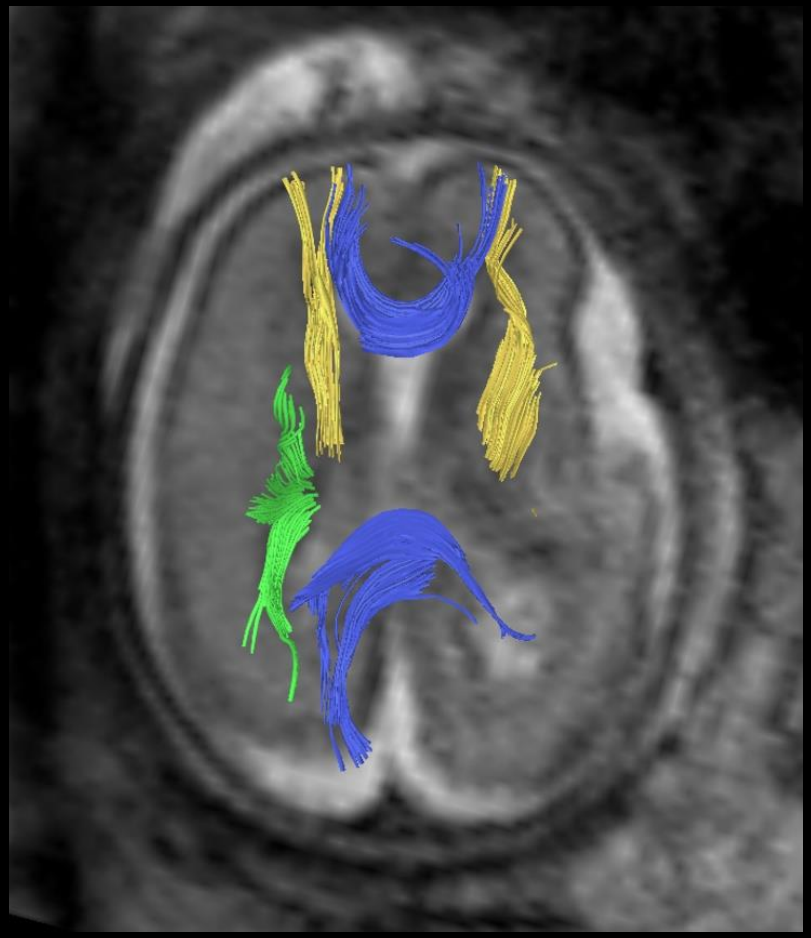
normal vs. isolated CCA



Fetal brain parenchyma

Connectivity at 23GW

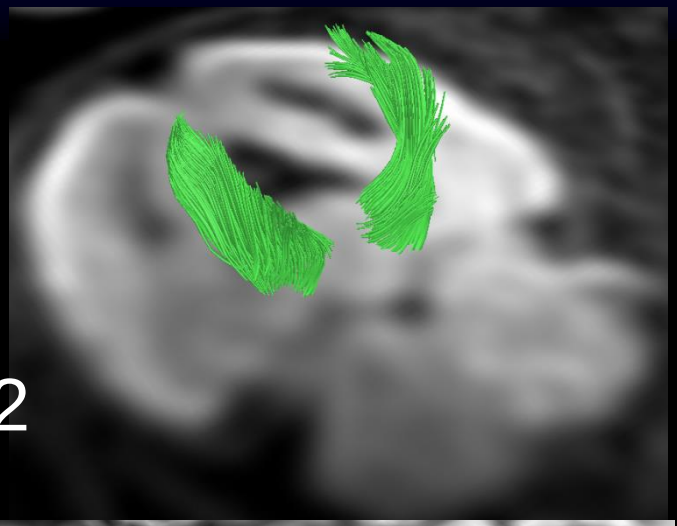


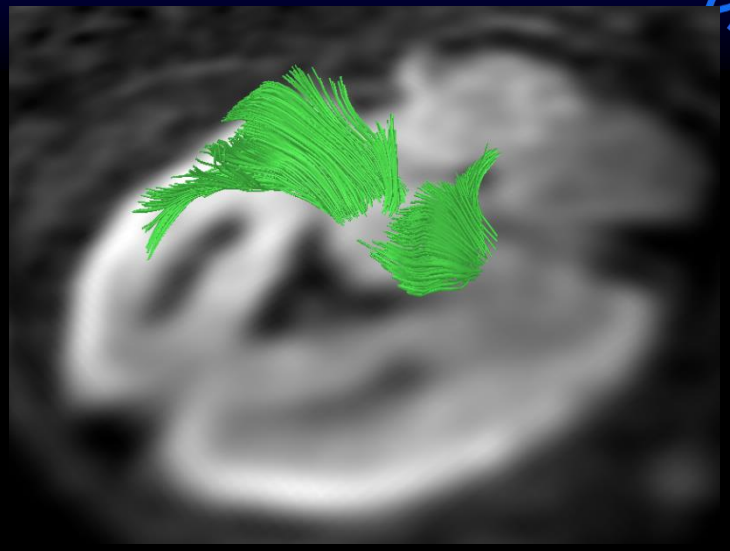


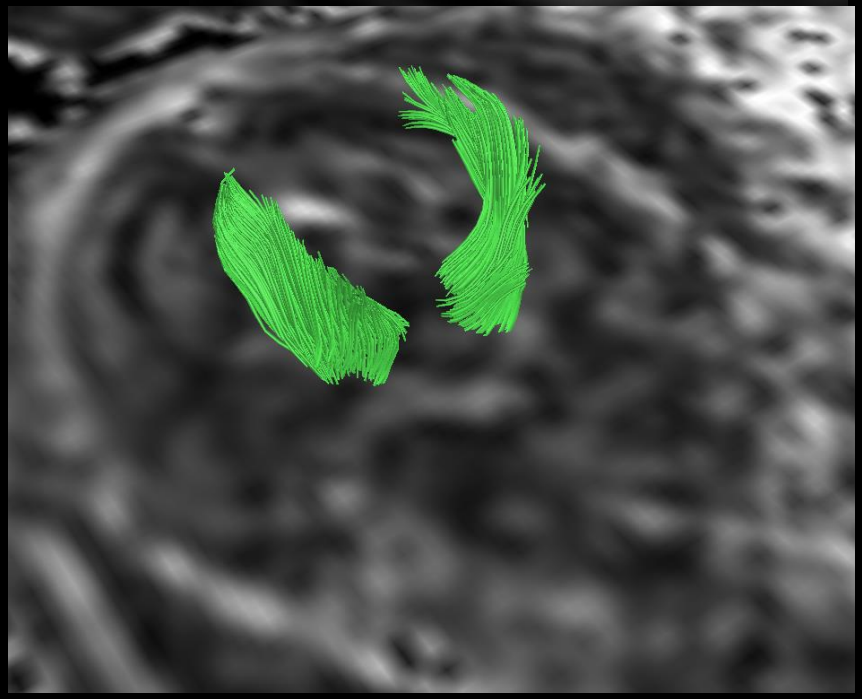
23 GW

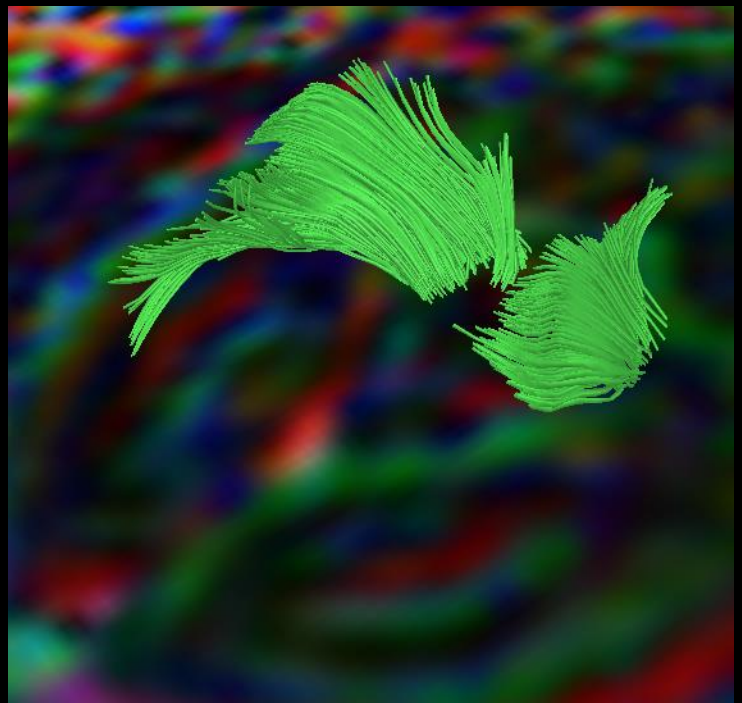
Low resolution tensor at 3T

GW 22







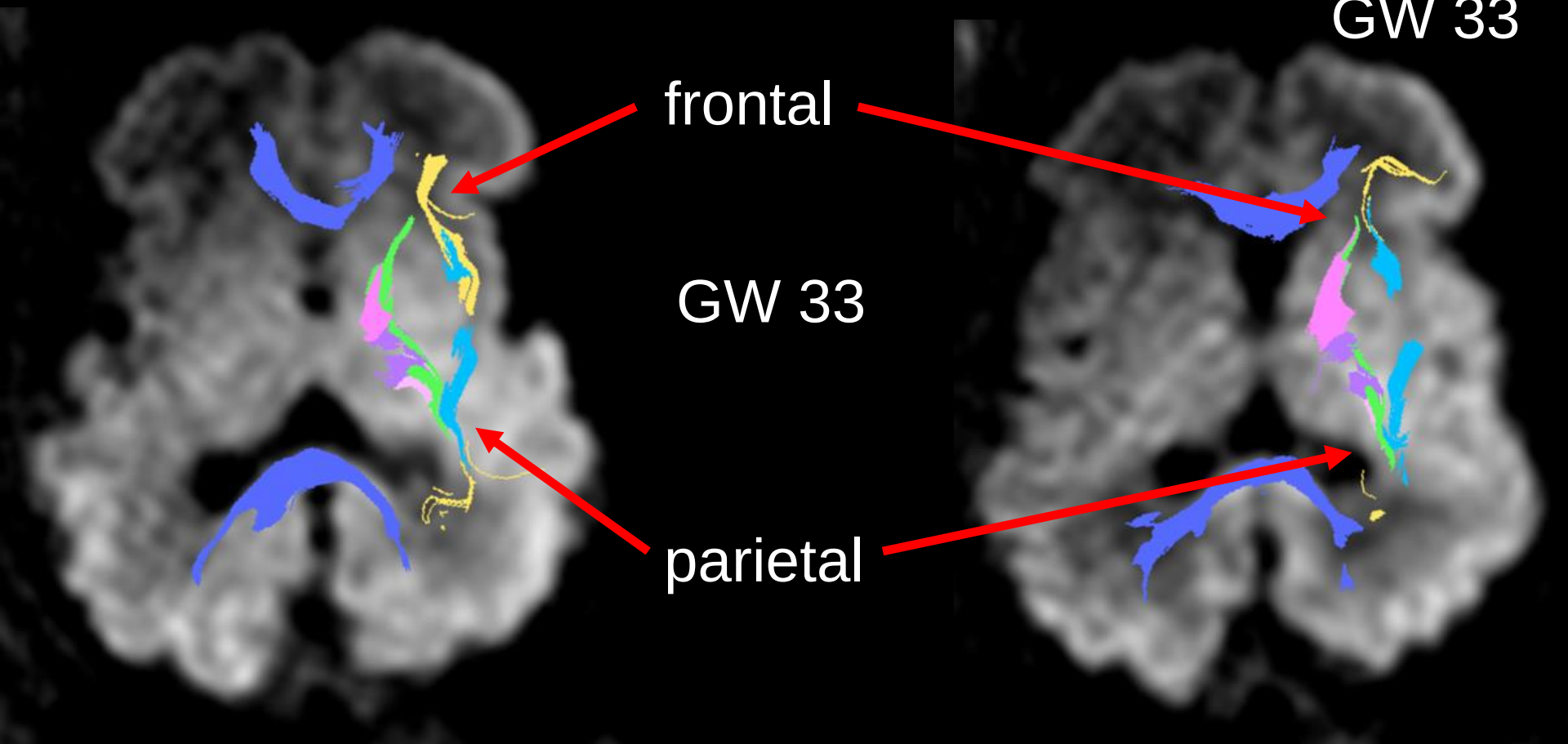


What tracts can we see?

CST/CPT
ATR STR PTR

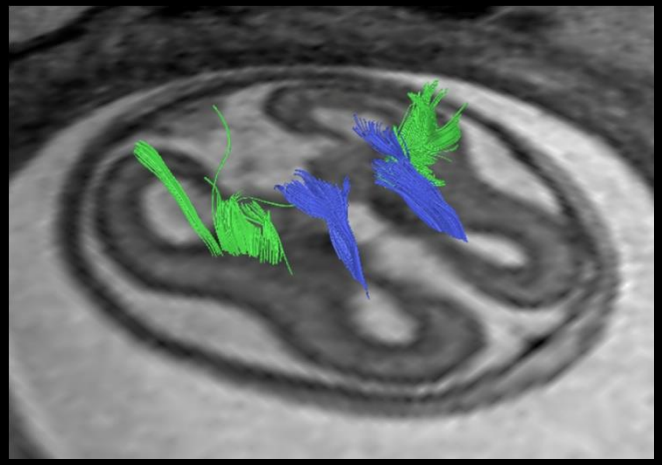
EC
IFO

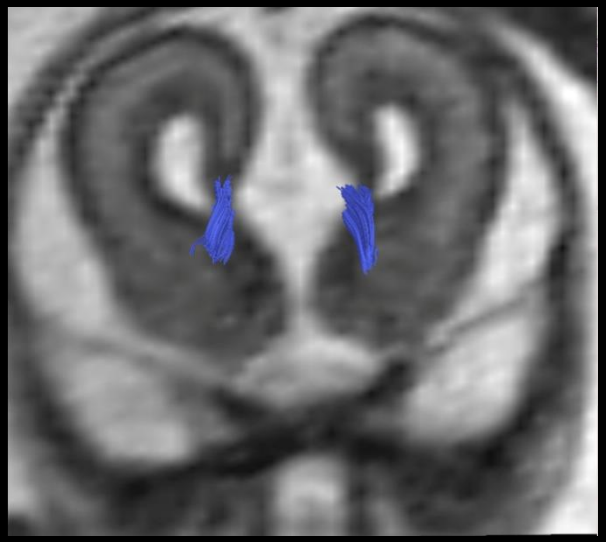
Corpus Callosum

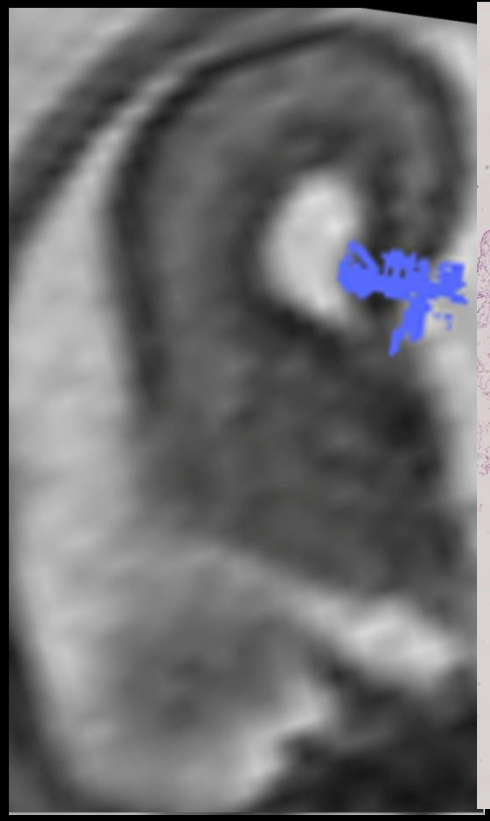


Corpus callosum agenesis

20GW





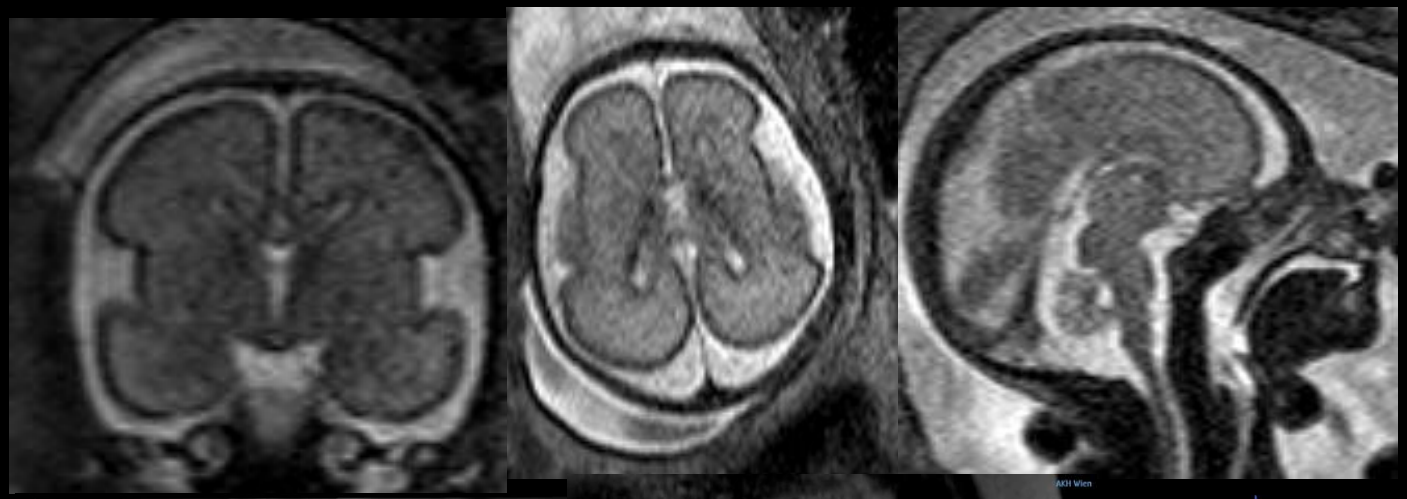


Postmortem/Histology Correlation
Probst bundles

Corpus callosum agenesis

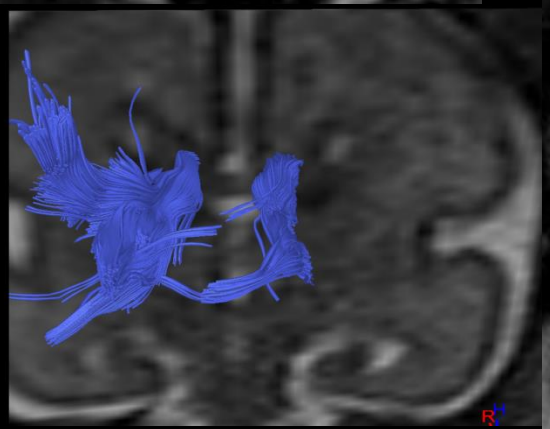
Dysgenetic corpus callosum?

28GW



Persisting hippocampal commissure

Functional structure

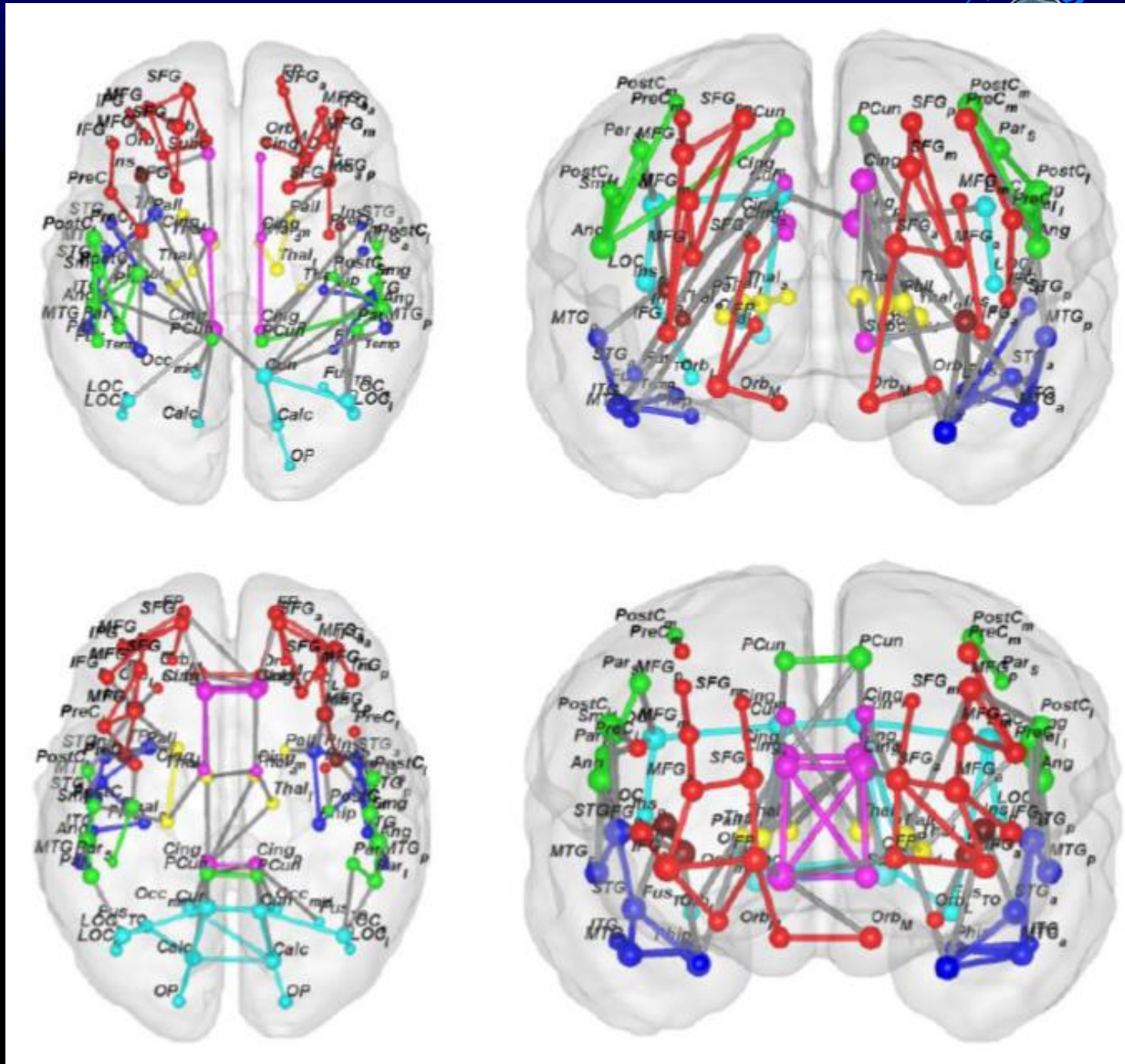


Tortori-Donati, Pediatric Radiology Brain, Springer 2005

CCA

Whole Brain Connectome Calcualted From Diffusion Tensor Data

Healthy Fetuses



“ Node“ in a network:

Location from and to which connections go:

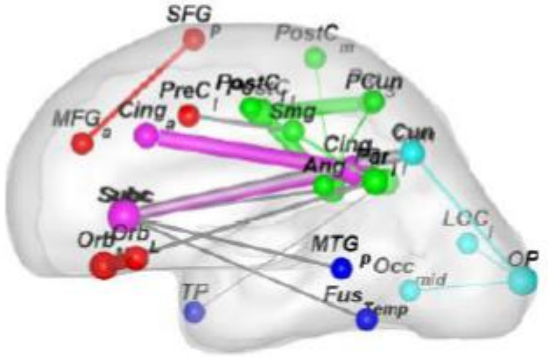
Centrality – relative importance within a graph – influence of a node within a network

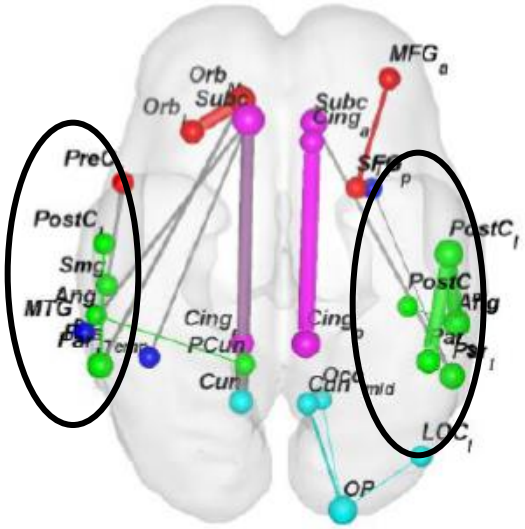
Centrality of a node: proportional to the combined centralities of its neighbors

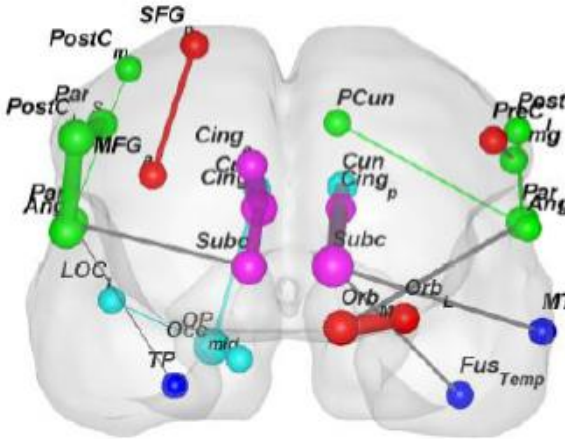
(Re?)organization of connections in CCA

Tract count differences

GW <25



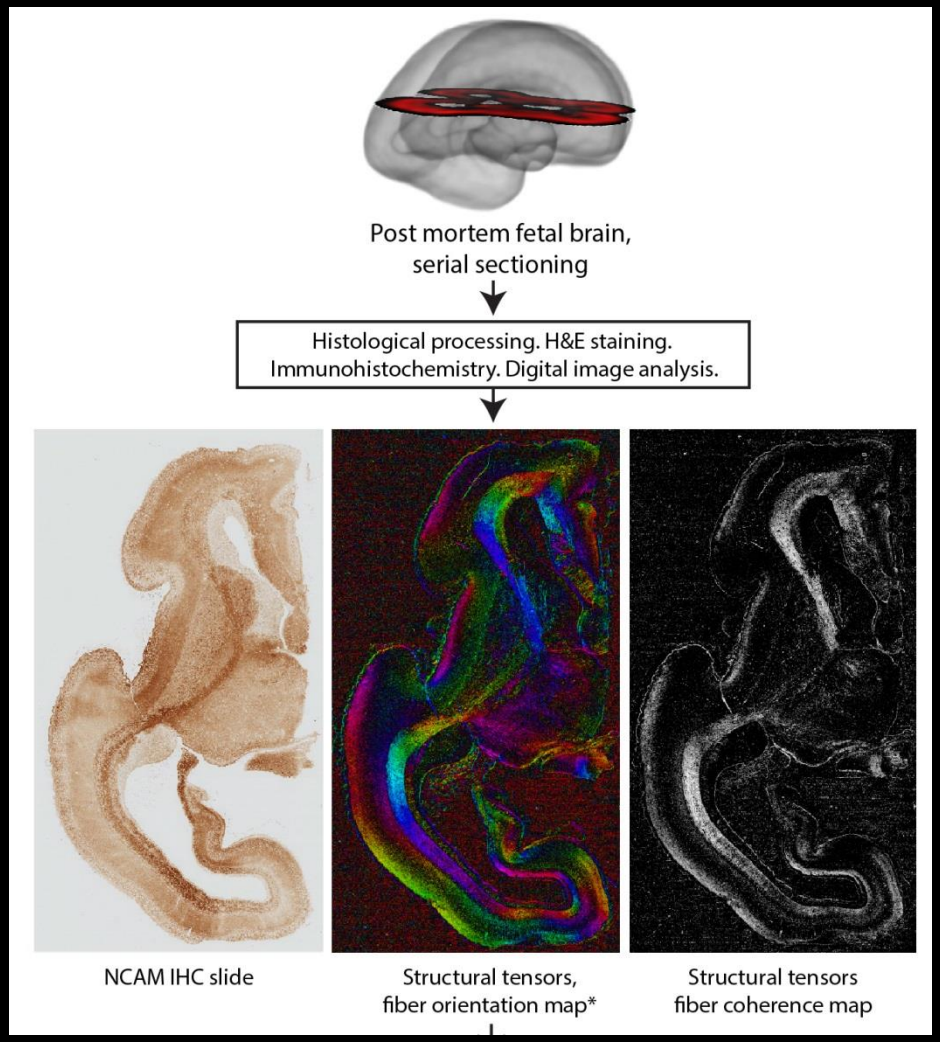




More and shorter fibers in the temporal lobes!

How do we know that what we see is true?

Validation of in utero Diffusion Tensor Imaging

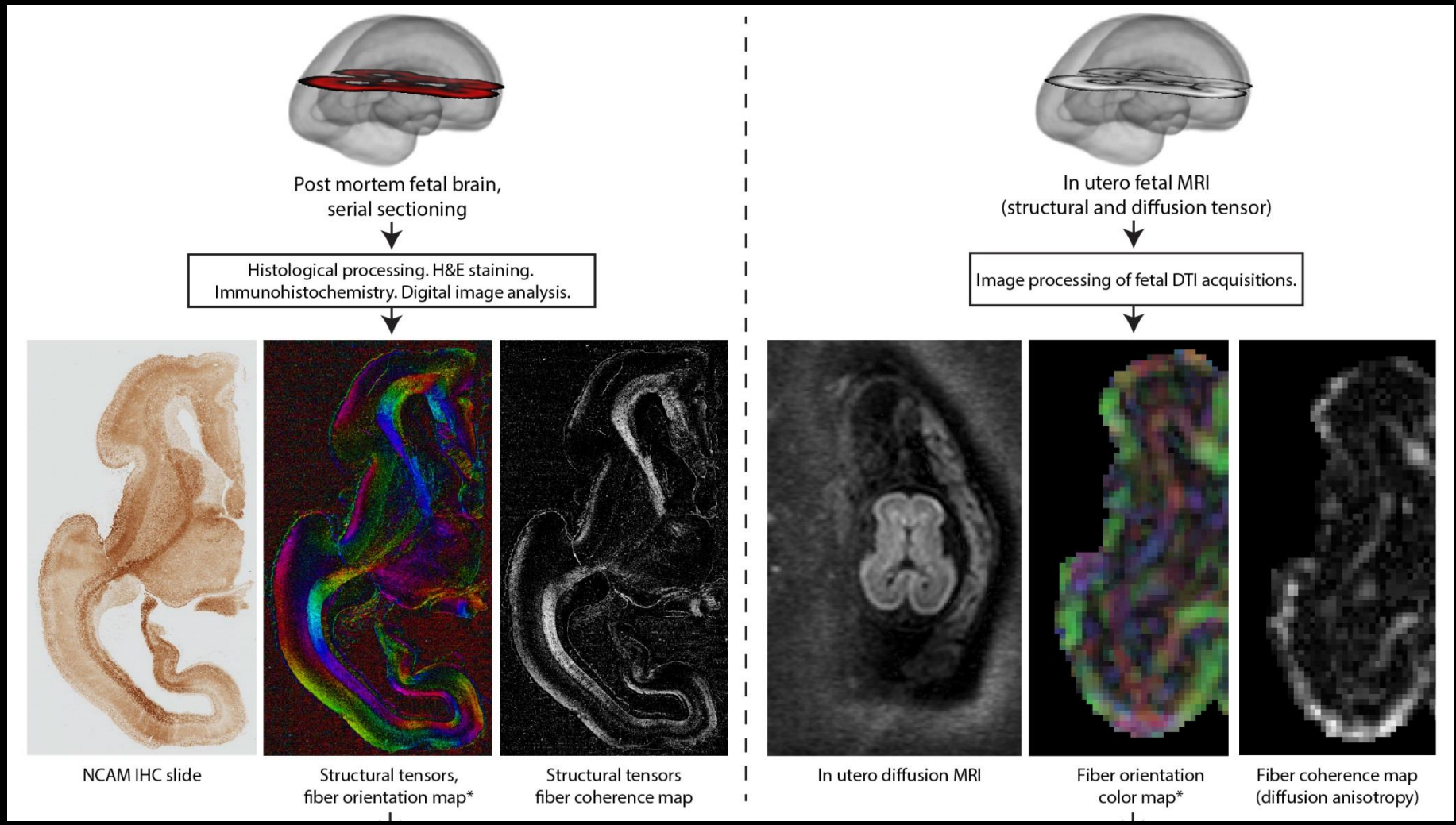


Structural tensor:
Image postprocessing for directional analysis of fibers on a microscopic scale

Image grascale gradients allow estimation of Orientation of underlying strcture

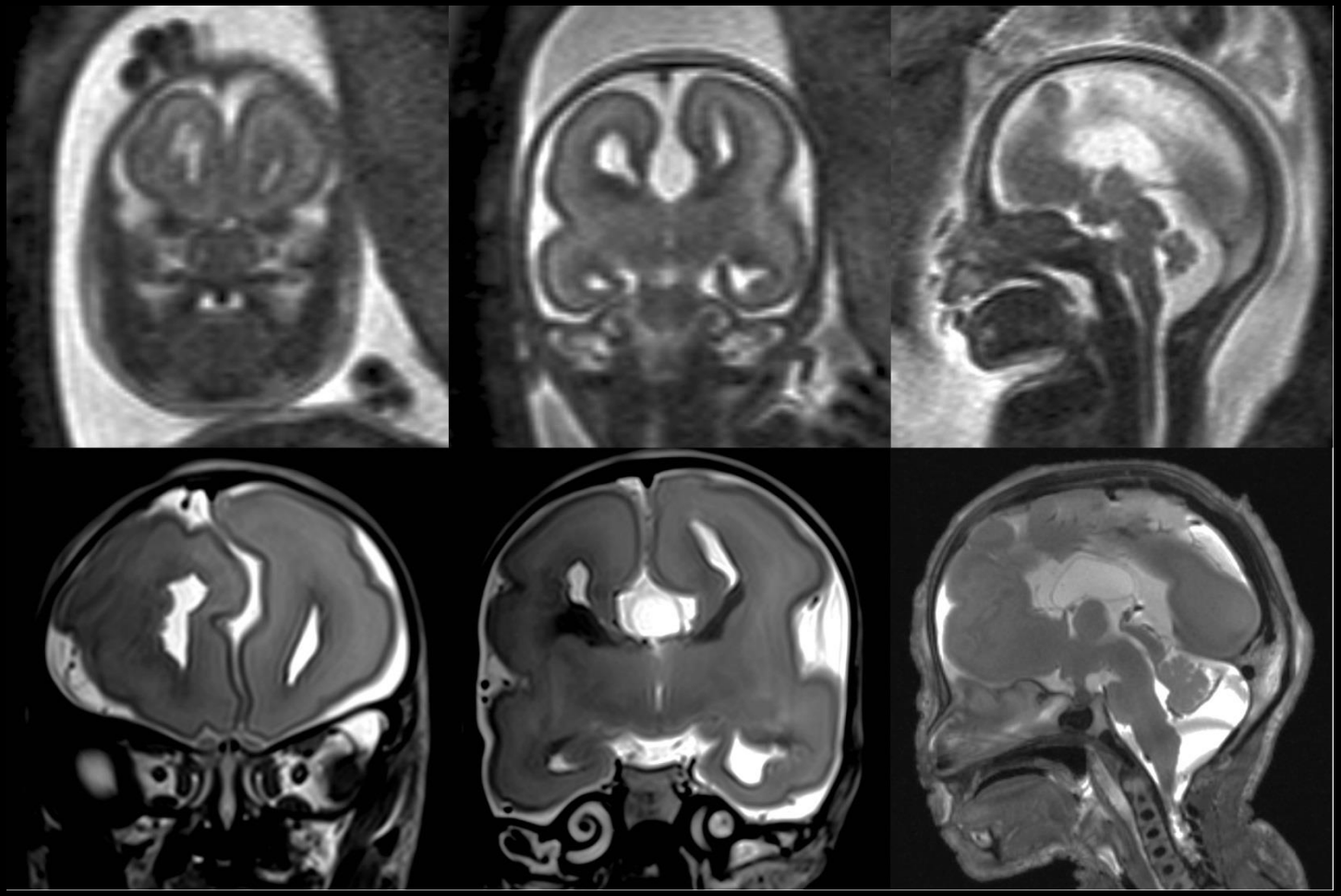
How do we know that what we see is true?

Validation of in utero Diffusion Tensor Imaging



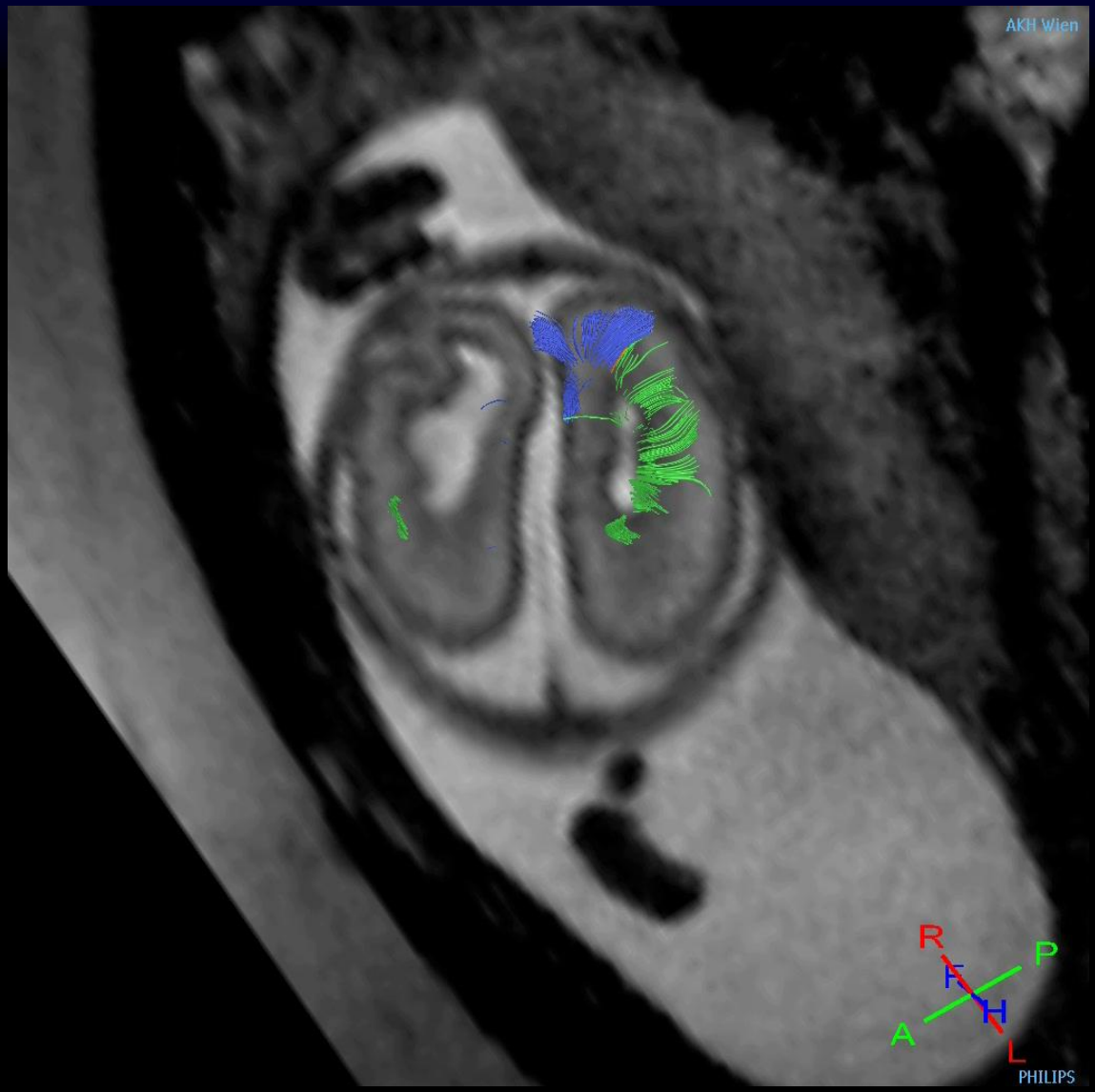
Abnormal Connectivity

CCA, Heterotopia, Abnormal Gyration

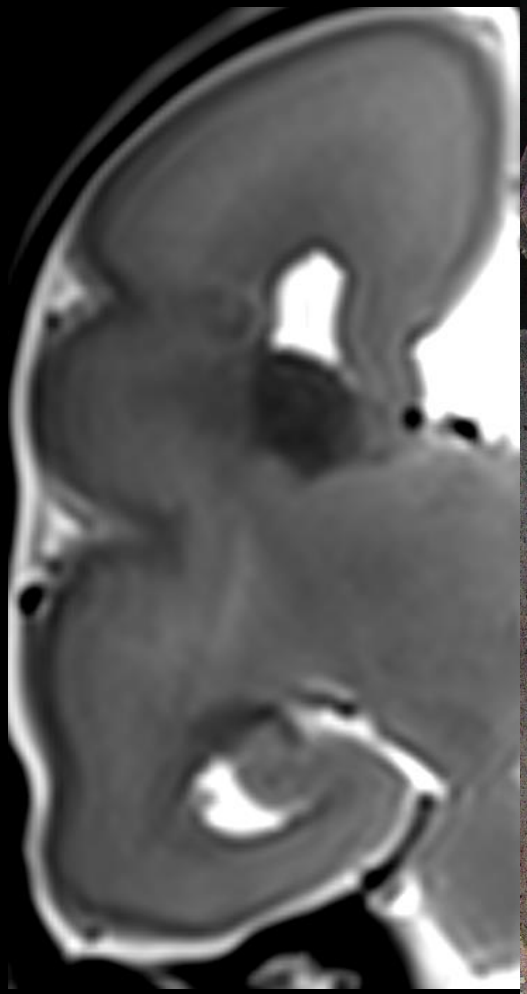


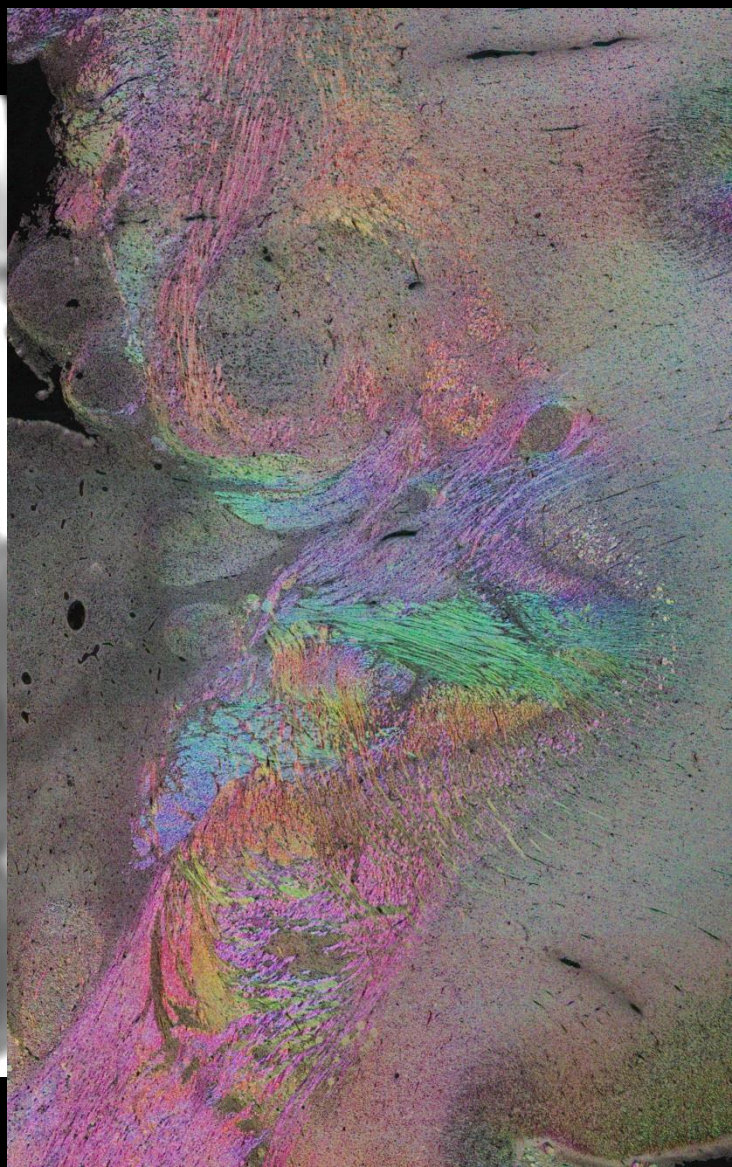
25GW

Abnormal Connectivity



Structure tensor analysis



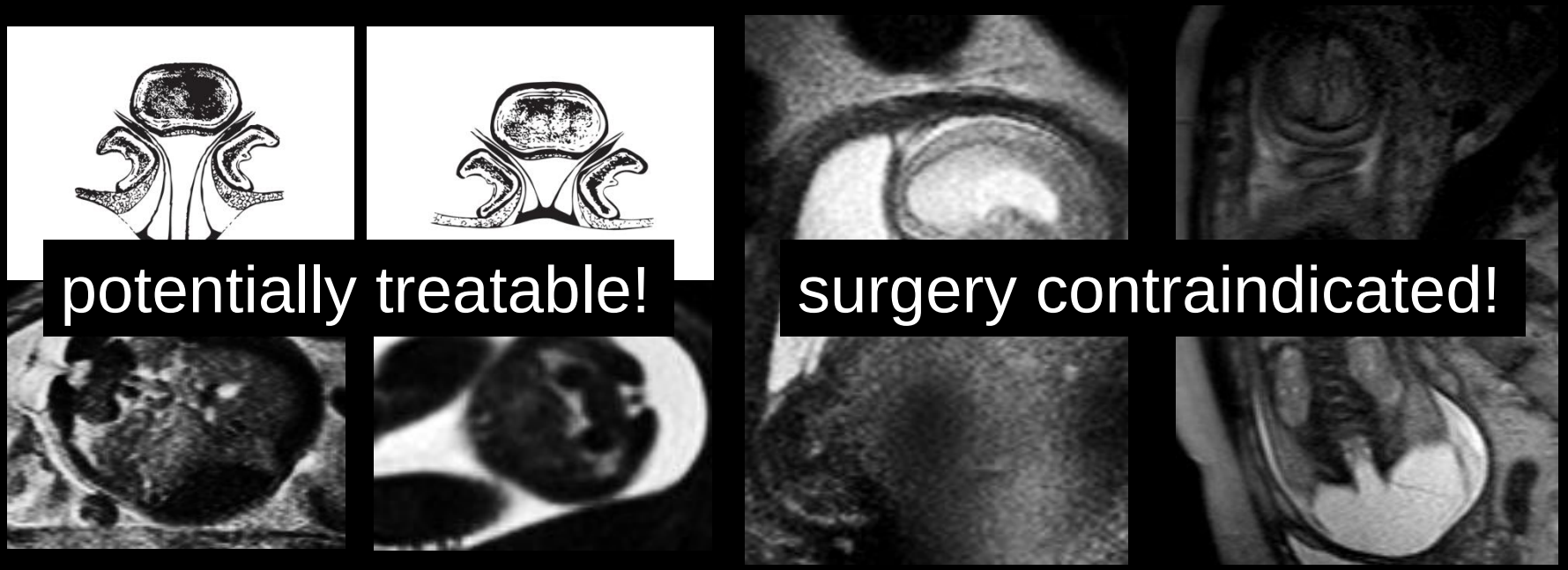


Classification

“Spina bifida“

open neural tube defects [1] ← ? → closed neural tube defects [1]

potentially treatable!



surgery contraindicated!

Myelo-meningocele

Myelocele

Meningocele

Myelo-cystocele

1: Tortori-Donati P, Rossi AMD, Biancheri R. Pediatric neuroradiology. Berlin ; [Great Britain]: Springer 2005.

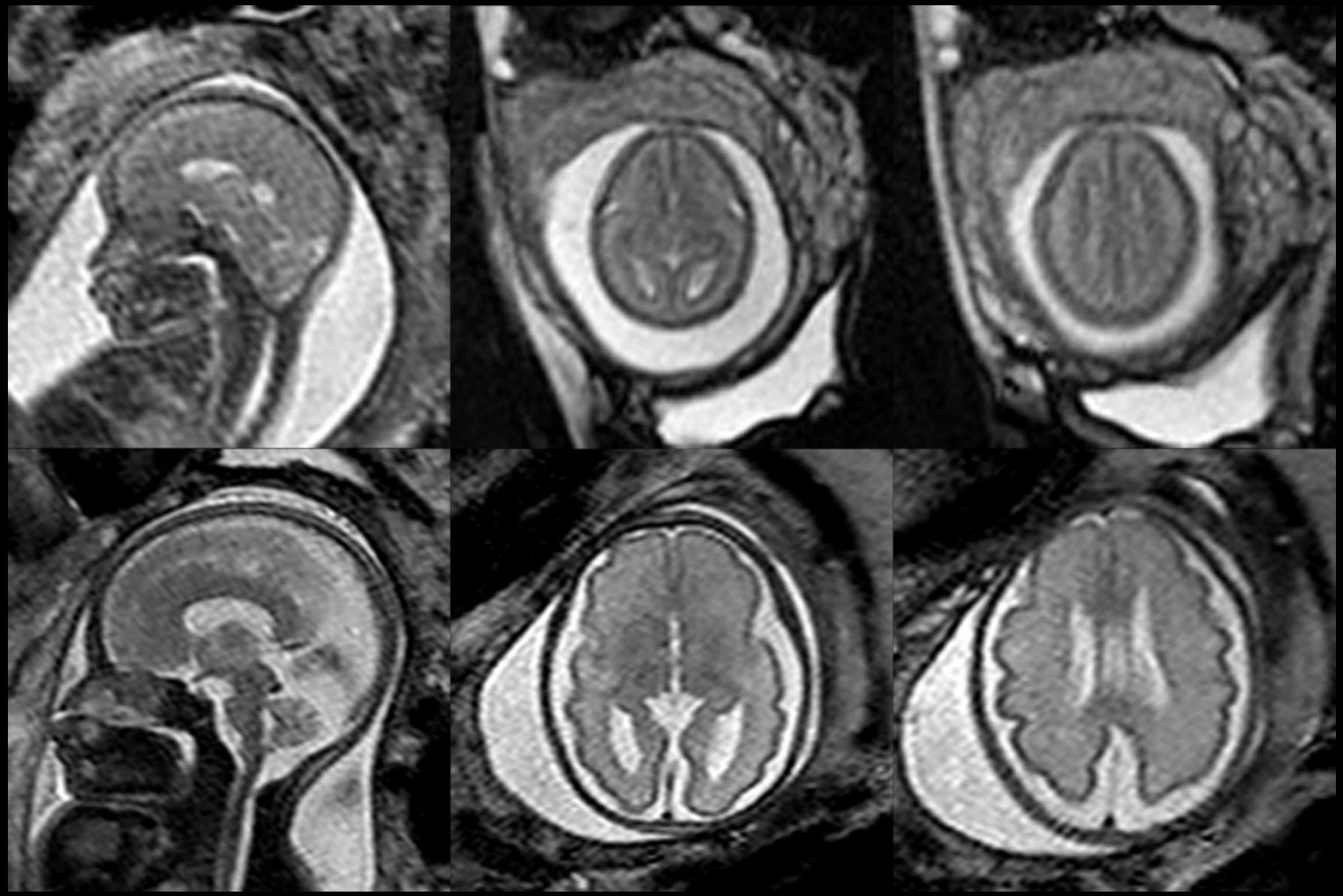
Chiari II

Success of fetal surgery

BCM
Baylor College of Medicine

23GW
before

28GW
after

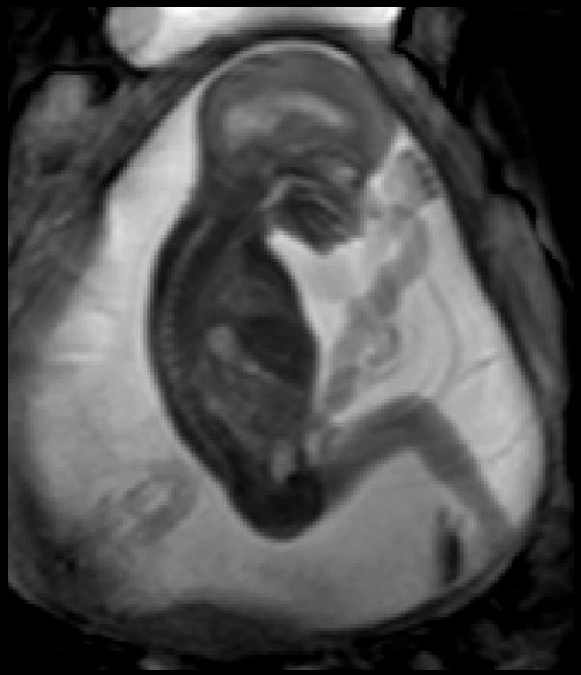


Neural tube defects

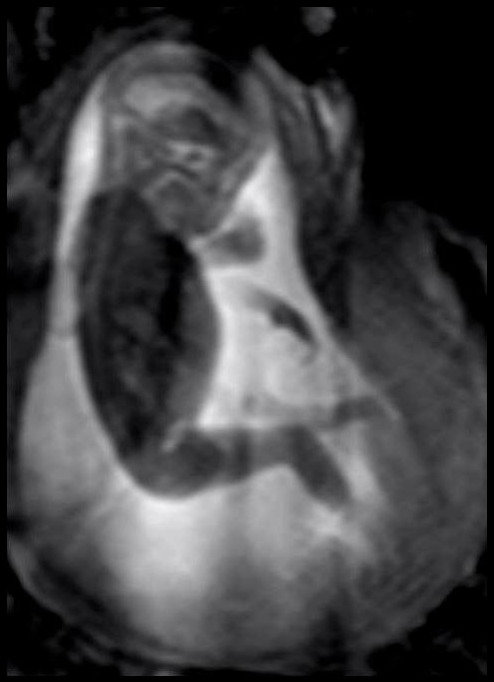
functional assessment

Case 1, 22GW

Case 2, 20GW



Case 3



hip flexion:	L1/2	knee flexion:	L4
knee extension:	L3	foot dorsiflexion:	L5

foot plantarflexion: sacral

Lindseth RE. (1976) Treatment of the lower extremity in children paralyzed by myelomeningocele (birth to 18 months).AAOSIC Lectures 25: 76–82.

Neural tube defects

functional assessment

Case 1, 22GW

Case 2, 20GW

Case 3

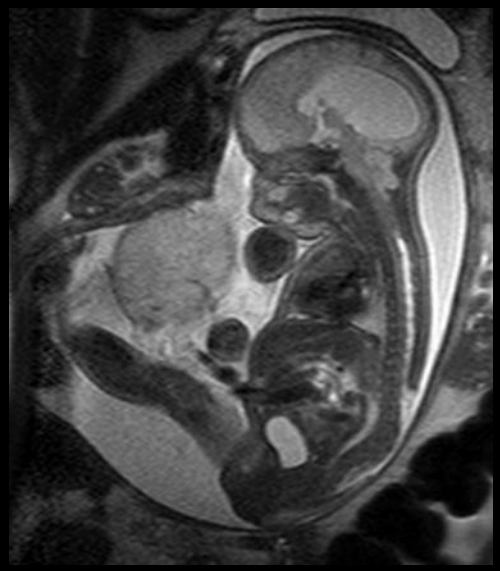
No placode,
Closed NTD!

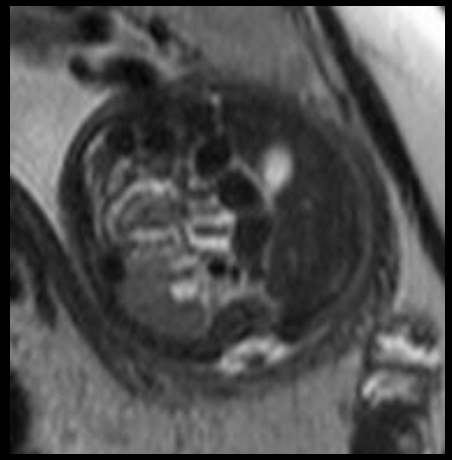
9/12 ratings correlated with ± 1 level of anatomical defect

postnatal correlation?

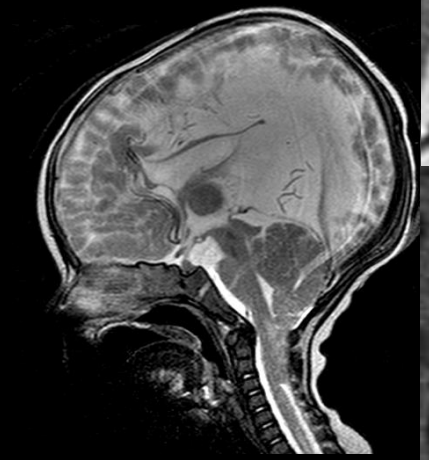
Open vs. closed defect

Vermian displacement





29+4

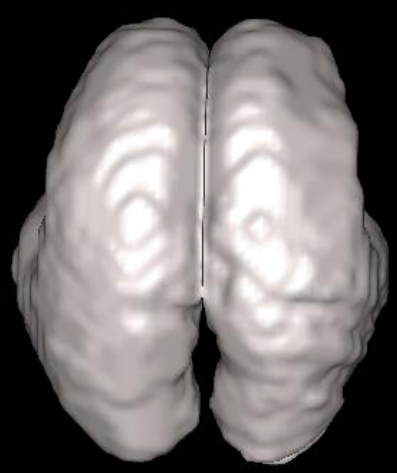


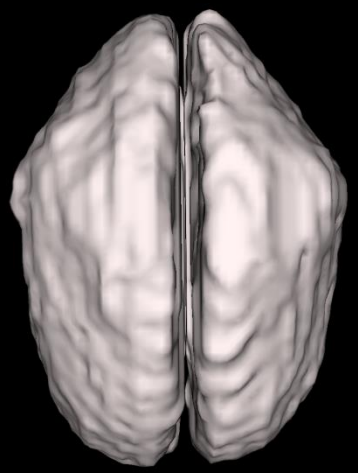
31+5

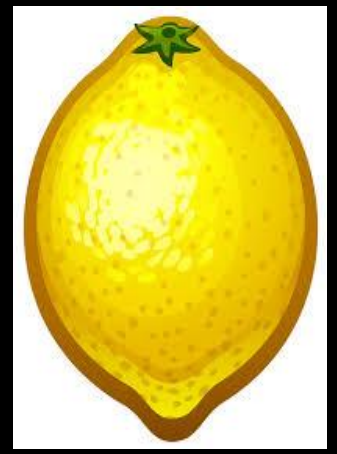
3D volumetric MRI

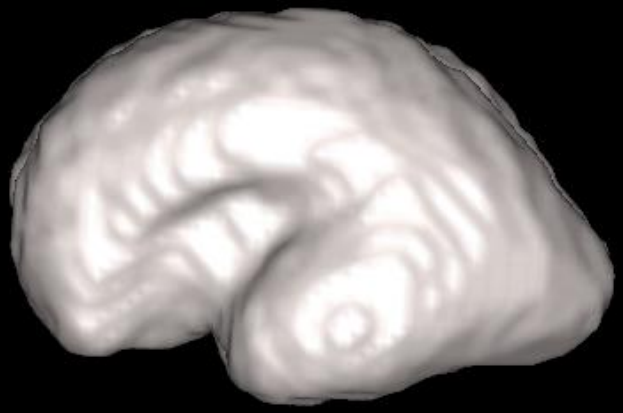
Quantification

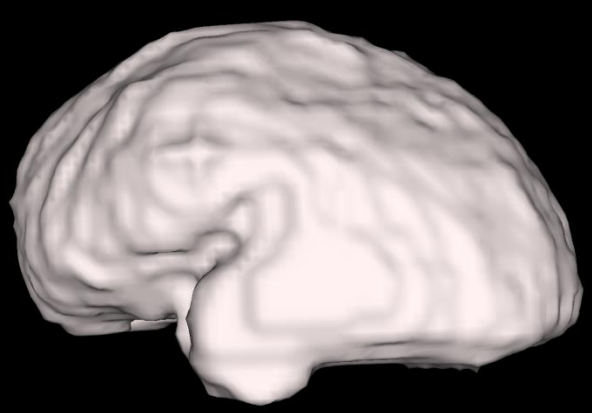
normal 22GW Chiari II







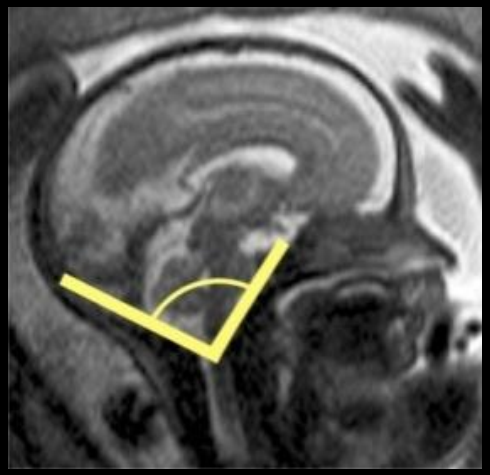




Open vs. closed defect

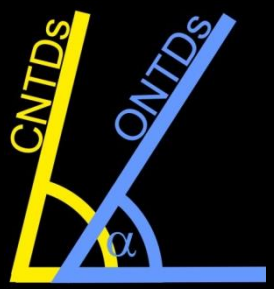
Clivus supraoccput angle

Normal



CNTD

ONTD

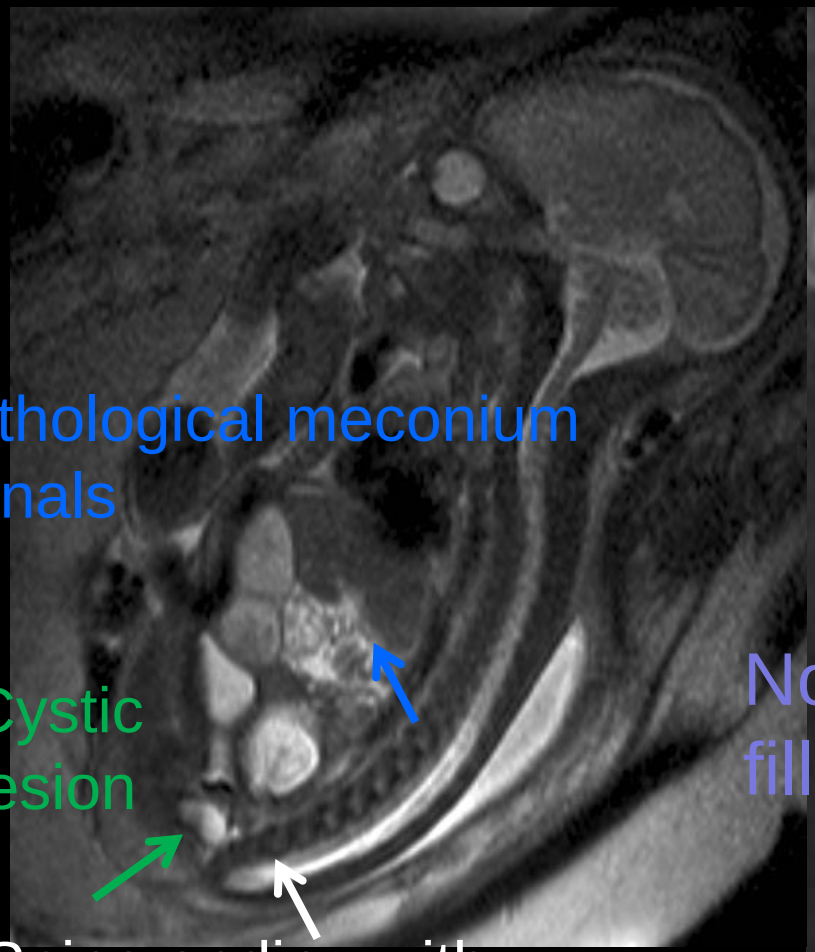


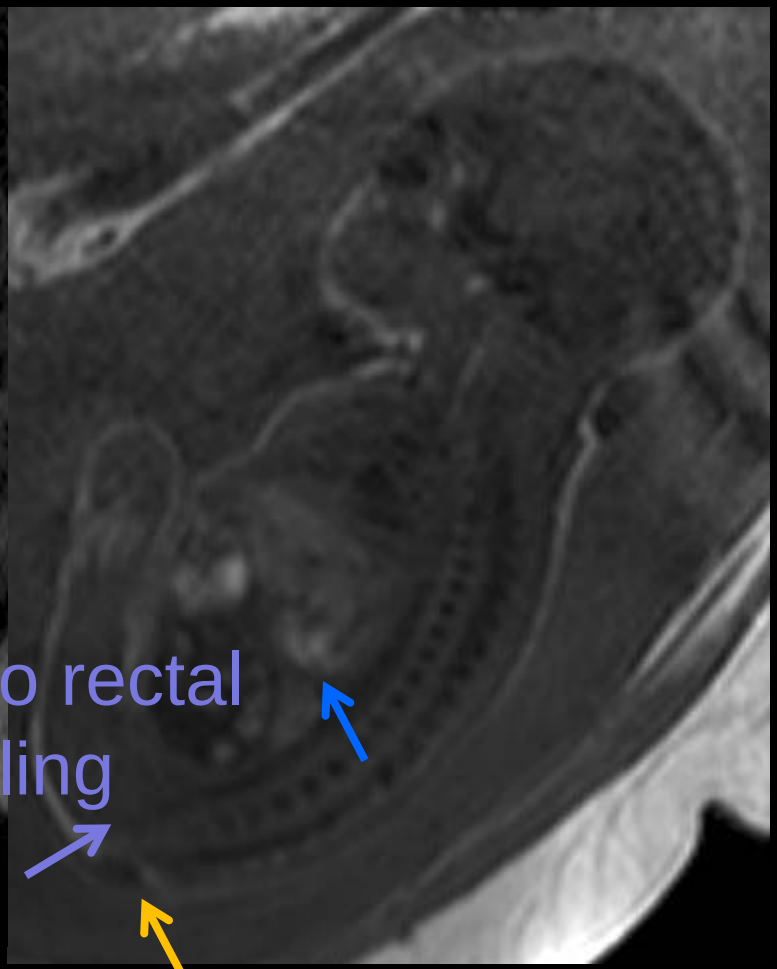
(p<.001)**

Ramona Woitek et al.

Closed spinal defects- syndromes

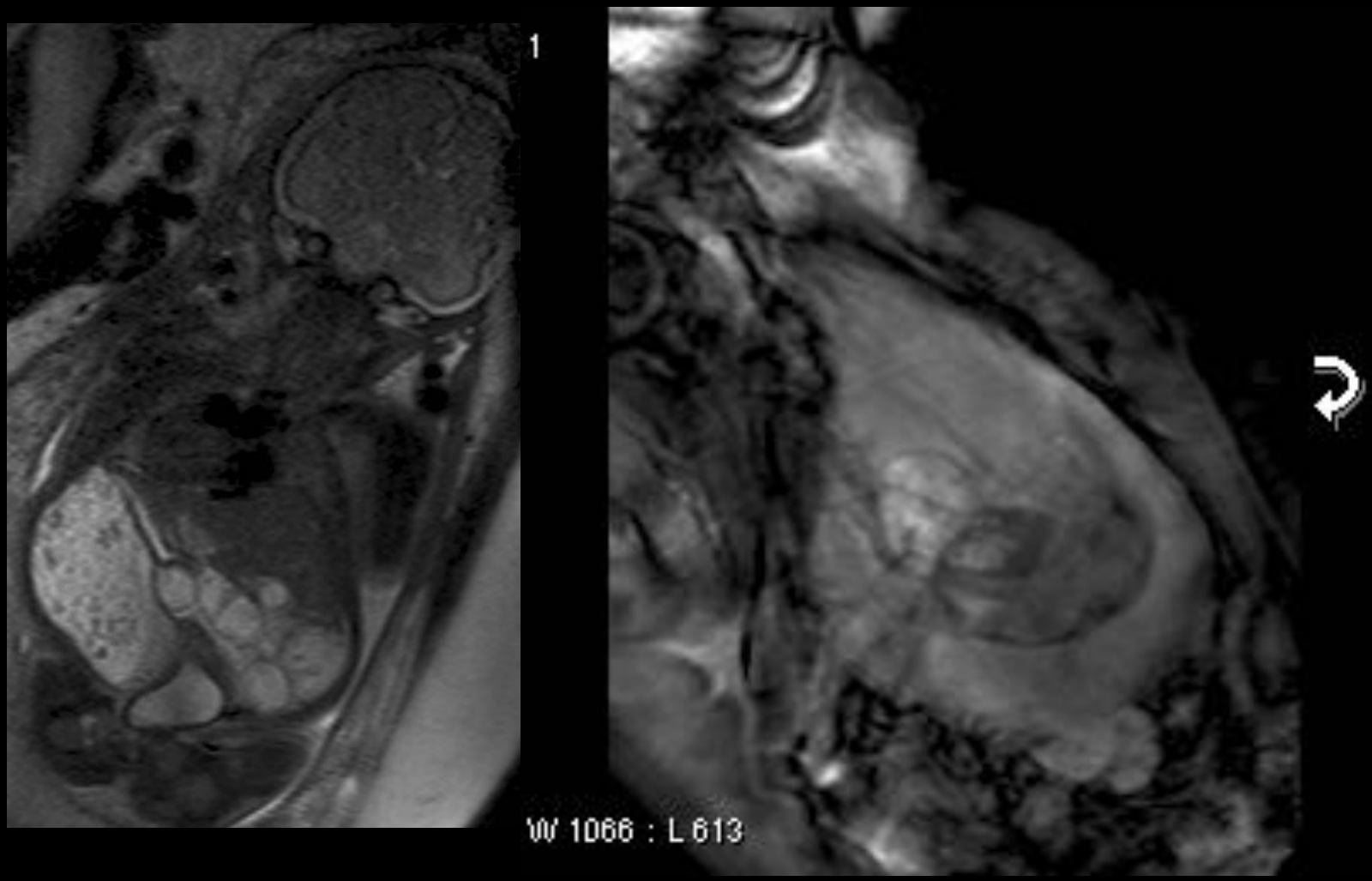
Caudal regression syndrome Type II: GW 27+4





Caudal regression syndrome

Type II:



GW 27+4

No peristalsis

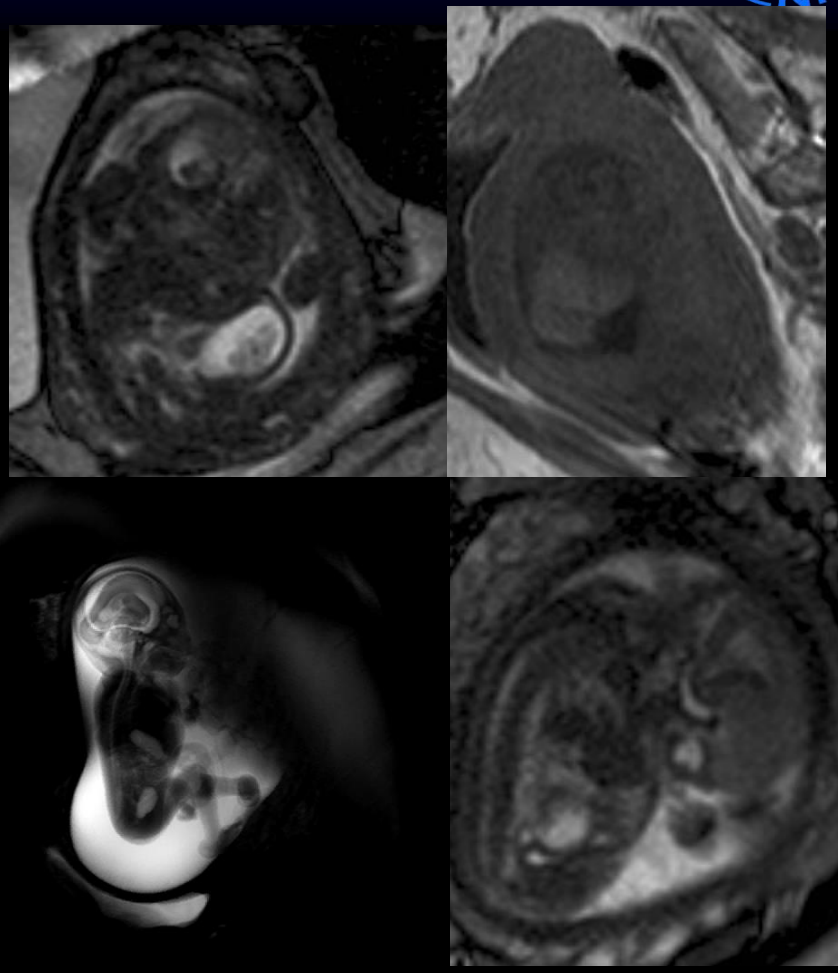
Caudal regression syndrome

Type II:

Curarino Triad:

Caudal regression syndrome
Presacral lesion
Megacolon spectrum

+/- anorectal abnorm
focal skin defect
kidney abnormalities



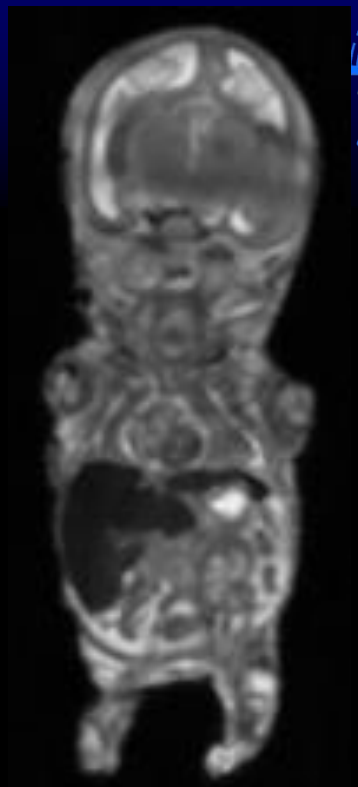
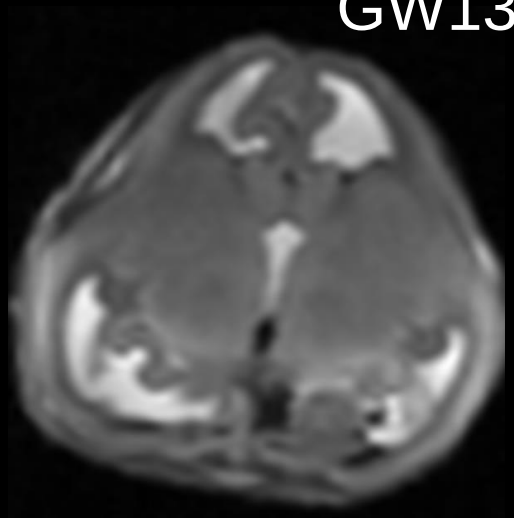
Eliás P, et al: Prenat Diagn. 2002 ,22(11):1005-10.

GW 19+1

Take home:

MRI of the fetal CNS comprises cerebral and spinal assessment.

Detailed morphology is most important, demonstration of connectivity and movement patterns may refine the prognostic accuracy



GW13+5