Fetal MRI update and new applications

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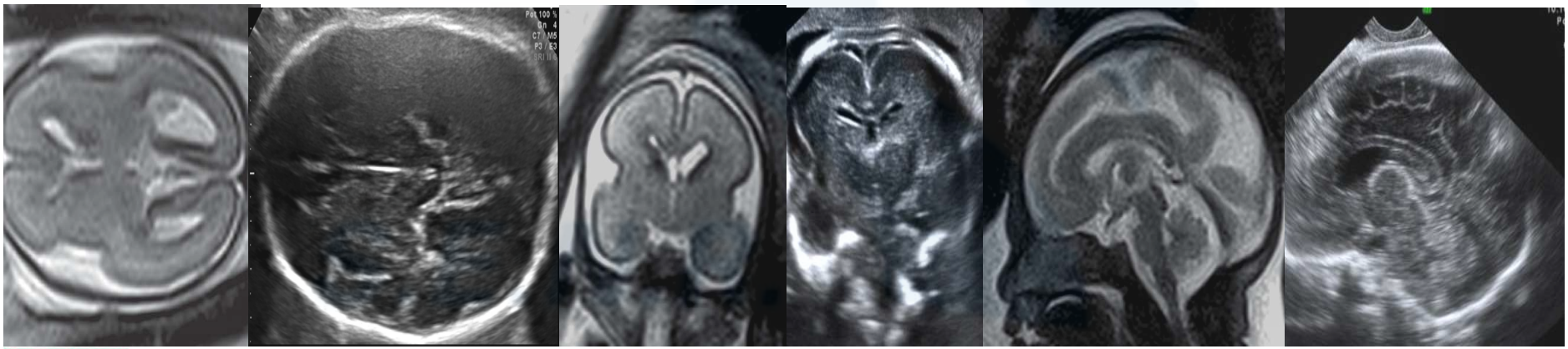
Introduction

- US is the screening technique for the detection and follow up during gestation.
- However, fetal MR has a role in determining brain malformation and injury during the pregnancy.
- The sensibility and the specificity of the fetal MRI is similar or higher that US, depending of the experience of the radiologist/ gynecologist.

Advantages of fetal MRI

- Better contrast between tissues.
- Better FOV.
  - Allow direct visualization of both hemispheres . US usually shows reverberation artifacts in the nearest anterior area.
  - Much better detailed visualization of the brain structures (cortex , parenchyma and sulcation.



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Disadvantages of fetal MRI

- More expensive
- Claustrophobia and incommodity in the last trimester of gestation.
- Not always available
- Limited by movement artifacts (optimal at 28 weeks of gestation).
  - Ultra fast sequences are strongly recommended.
- Long term adverse effect are not well know

Legislation and security.

- Not allowed in the first trimester.
- Is not approved as the main technique in fetal screening.
- Its application is limited to cases that give information that helps with the diagnostic of brain anomalies and provides information about fetal management .
- Paramagnetic contrast administration is not recommended.

ACR Guidance Document for Safe MR Practices: 2007

The information requested from the MR study cannot be acquired via nonionizing means (e.g., ultrasonography).

The data are needed to potentially affect the care of the patient or fetus during the pregnancy.

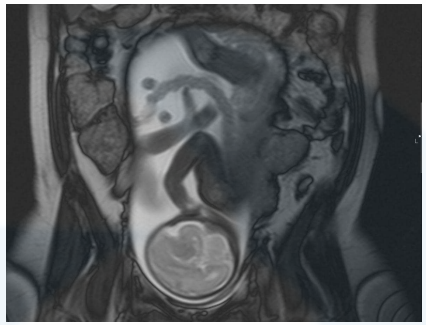
The referring physician does not feel it is prudent to wait until the patient is no longer pregnant to obtain these data.

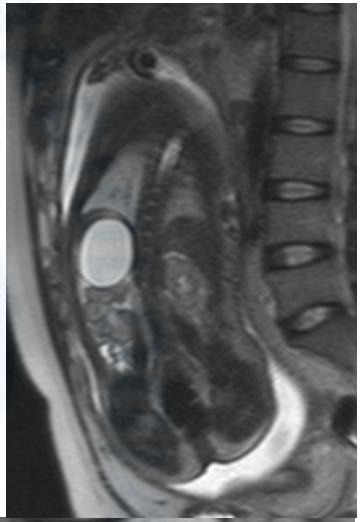
Image Protocol

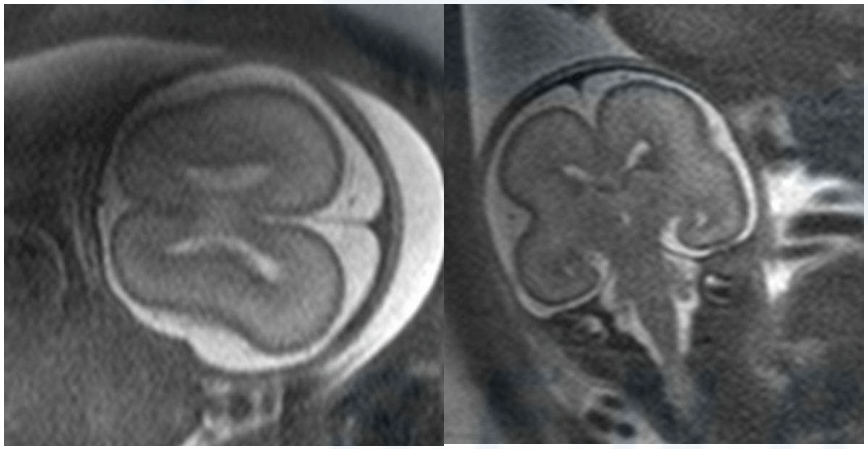
1.Scout: Large FOV and each plane (7mm slice).

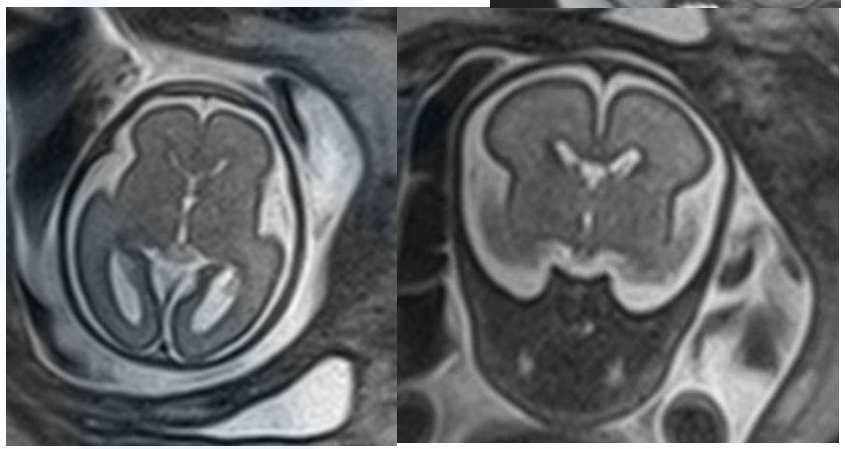
2: Single shot fast spin echo/haste (3 planes)

-4 or 3mm slice thickening.
- No gap or 0.10 gap.
-Large FOV









190 x 208 FOV and 3mm thickness and no gap.

208 x 306 FOV and 3mm thickness and 0.15mm gap.

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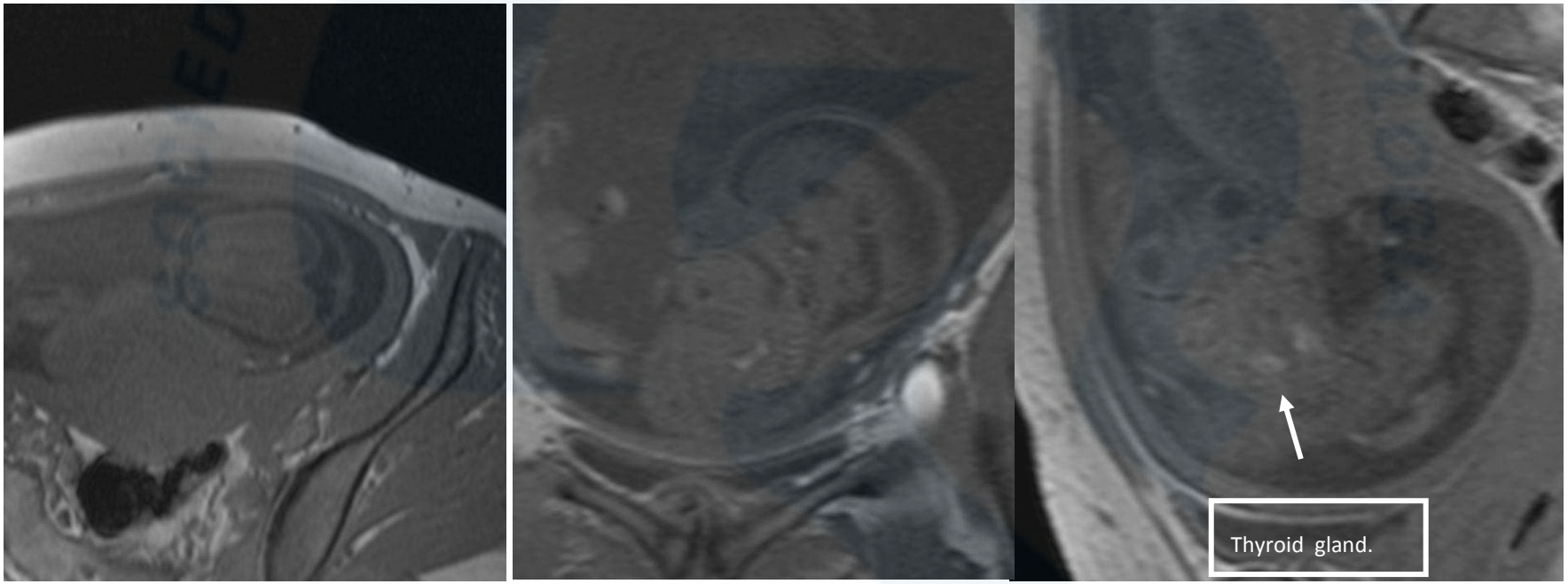
Image Protocol

1. T1WI. 3DGRE T1 sequences Out-phase



300 x 328 FOV and 3mm thickness and no gap.

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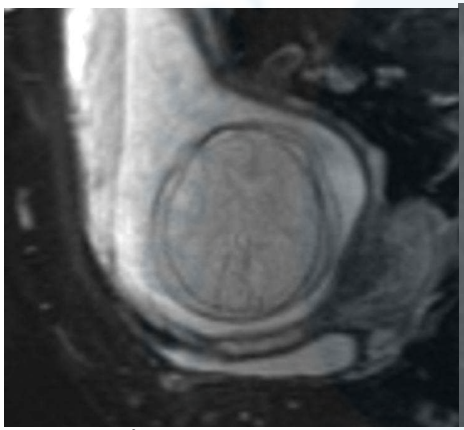
Image Protocol

Advanced image sequences: Diffusion Weighted Imaged



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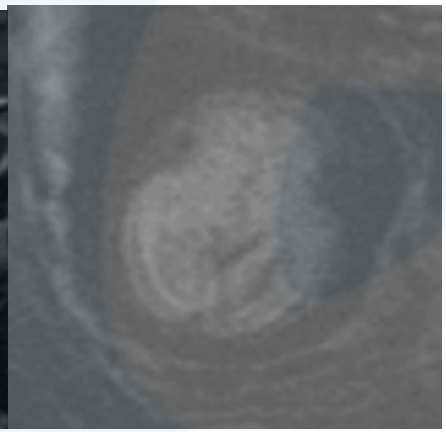

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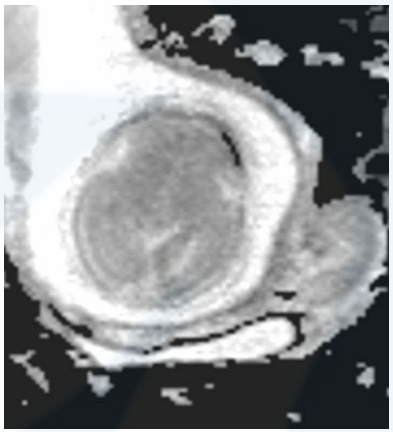
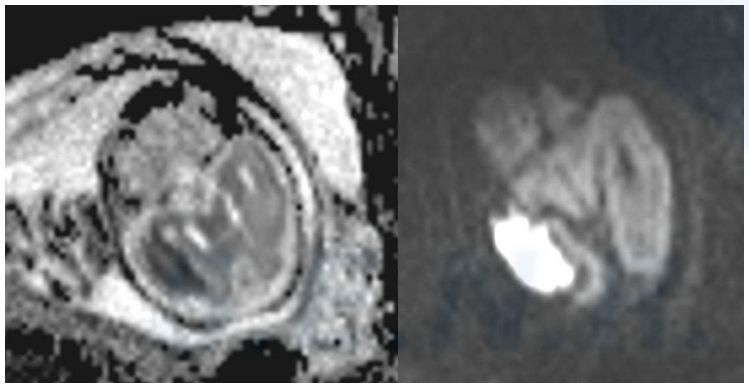


ADC

300 x328 FOV and 5mm thickness and 0.5 mm gap



Ischemic infarct.

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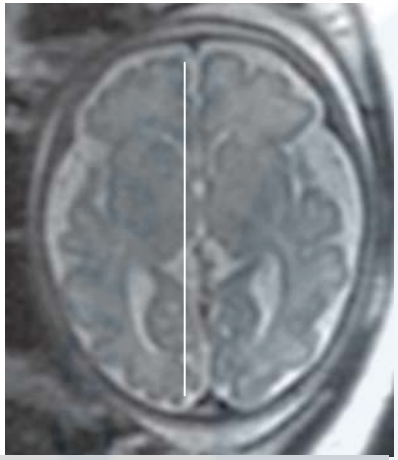
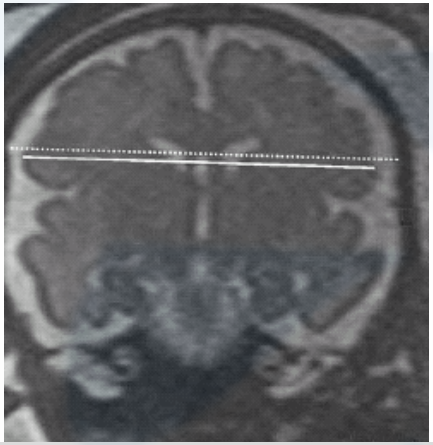
Fetal MR interpretation

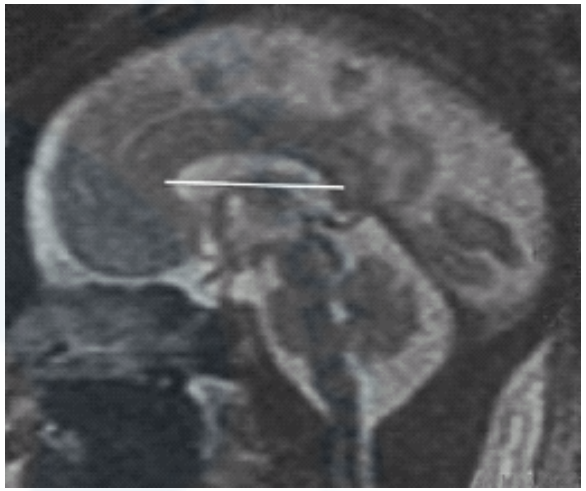
Biometrics.



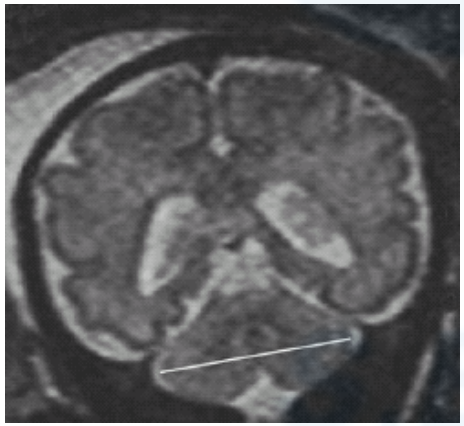
D. Fronto-occipital



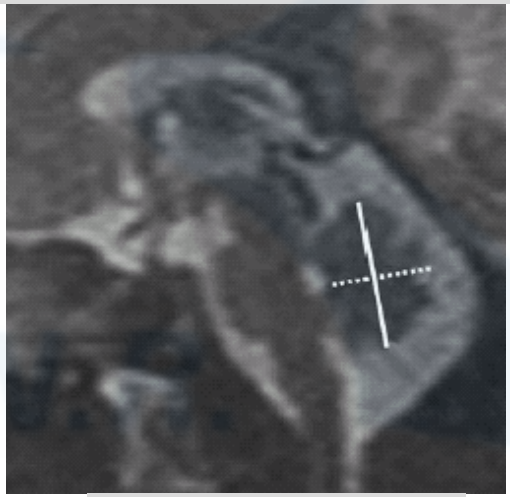
D. Biparietal cerebral and skull



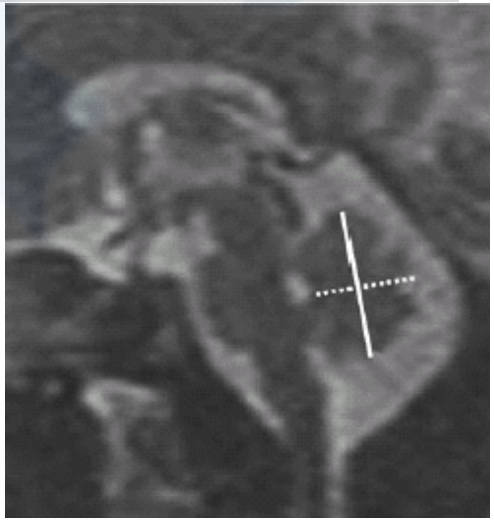
Longitud corpus callosum



Cerebellum transversal



Vermis AP



Vermis high

Fetal MR interpretation
Biometrics.

Table 1 Observed raw centiles from a previous cohort study[10,54]

		10–90th centile							
GA (weeks)	n	*FOD (mm)*	*BPDc (mm)*	*BPDb (mm)*	*LCC (mm)*	*Vermis height (mm)*	*Vermis APD (mm)*	*Vermis surface area (mm^2)*	*TCD (mm)*
27	16	78–88	55–62	62–69	30–39	13–17	8–12	—	29–35
29	18	79–91	62–70	67–76	32–39	15–17	10–12	158–223	33–38
31	21	86–96	65–76	70–81	33–41	16–19	10–14	178–242	36–41
33	20	92–103	70–80	74–87	37–45	17–21	11–16	221–300	40–44
35	28	98–106	76–85	81–91	37–45	19–23	12–18	266–372	44–50

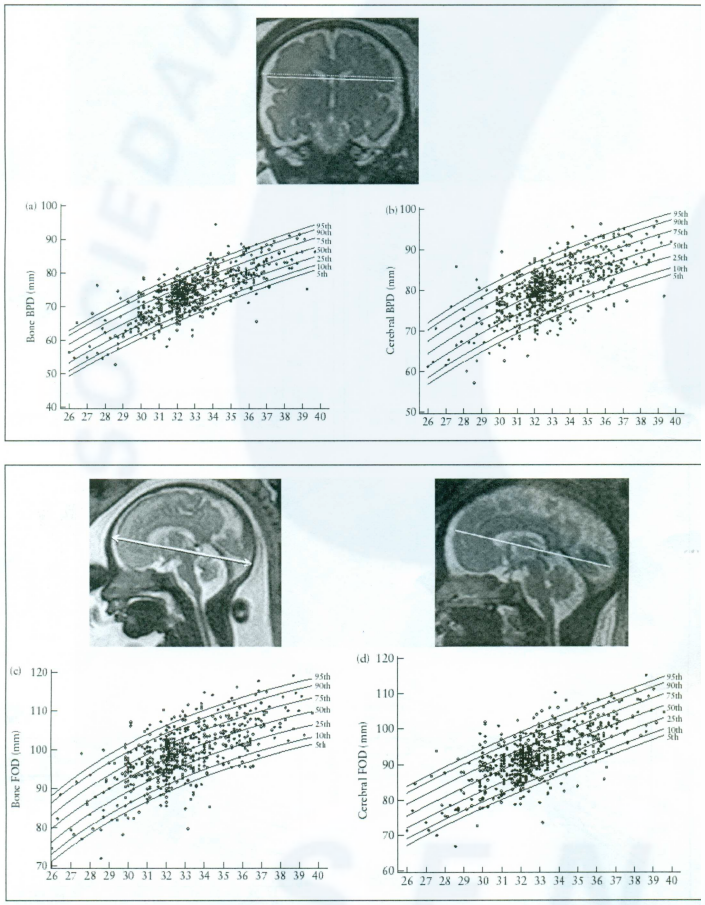
These are crude observed measurements without smoothing. APD, anteroposterior diameter; BPDc, cerebral biparietal diameter; BPDb, bone biparietal diameter; FOD, fronto-occipital diameter; GA, gestational age; LCC, length of corpus callosum; TCD, transverse cerebellar diameter.

Ultrasound Obstet Gynecol (2007).

Fetal MR interpretation

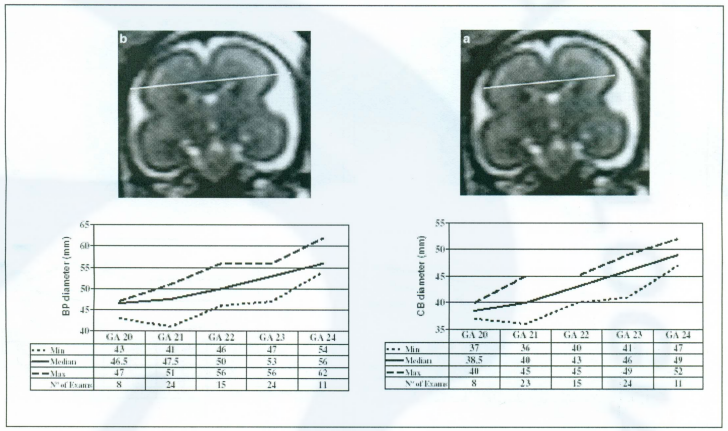
Biometrics.

NORMALITY VALUES 26-40 weeks



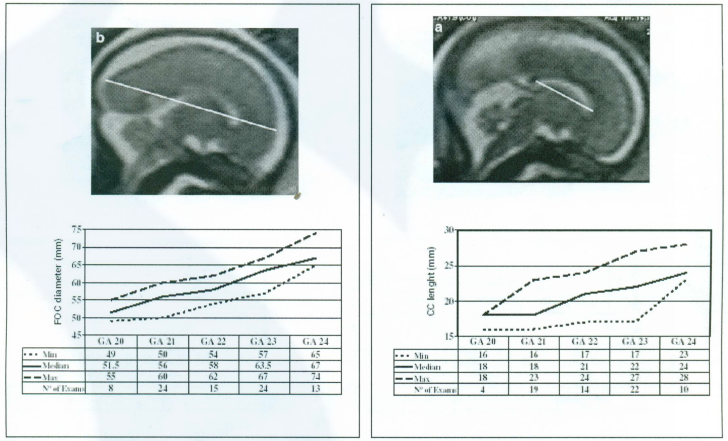
Cerebral biometry in fetal magnetic resonance imaging: new reference data. Tilea et al. *Ultrasound Obste Gynecol (2009;)33:173-18*

NORMALITY VALUES 20-24 weeks



	GA 20	GA 21	GA 22	GA 23	GA 24
Min	43	41	46	47	54
Median	46.5	47.5	50	53	56
Max	47	51	56	56	62
N° of Exams	8	24	15	24	11

	GA 20	GA 21	GA 22	GA 23	GA 24
Min	37	36	40	41	47
Median	38.5	40	43	46	49
Max	40	45	45	49	52
N° of Exams	8	23	15	24	11



	GA 20	GA 21	GA 22	GA 23	GA 24
Min	49	50	54	57	65
Median	51.5	56	58	63.5	67
Max	55	60	62	67	74
N° of Exams	8	24	15	24	13

	GA 20	GA 21	GA 22	GA 23	GA 24
Min	16	16	17	17	23
Median	18	18	21	22	24
Max	18	23	24	27	28
N° of Exams	4	19	14	22	10

Prenatal magnetic resonance imaging:brain normal linear biometric values below 24 gestational weeks. Parazzini et al. Neuroradiology (2008) 50:877-883

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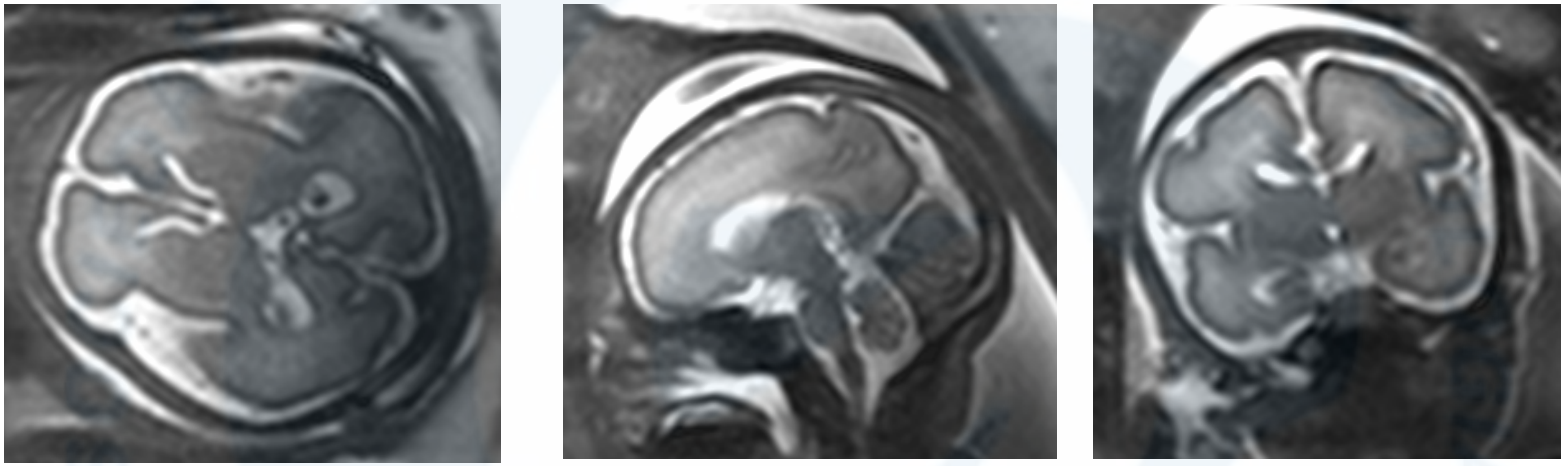
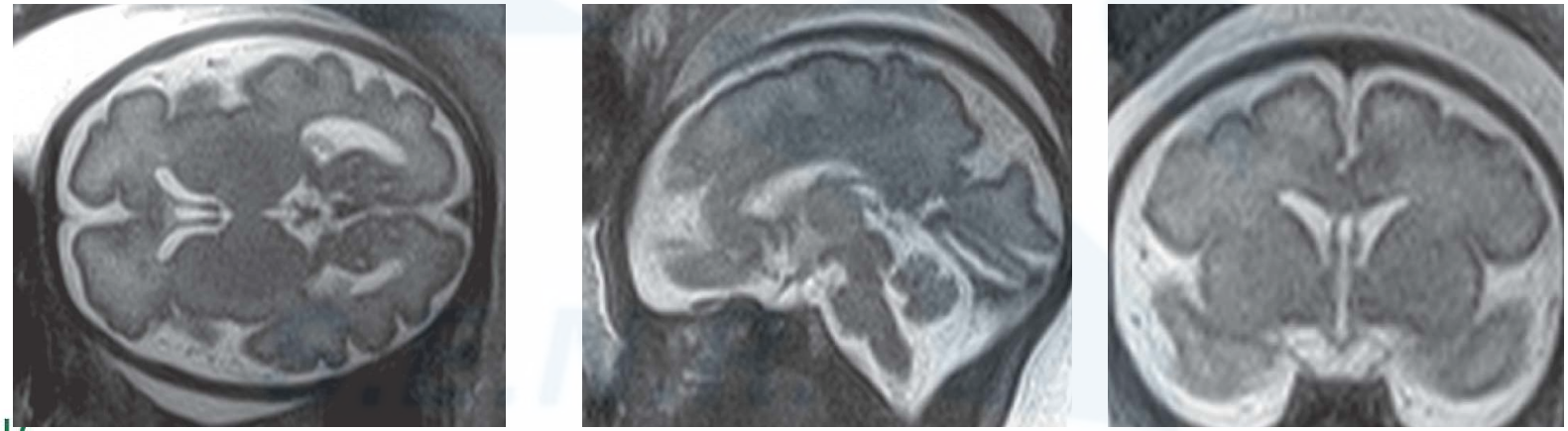
Brain development



28 semanas



33 semanas.

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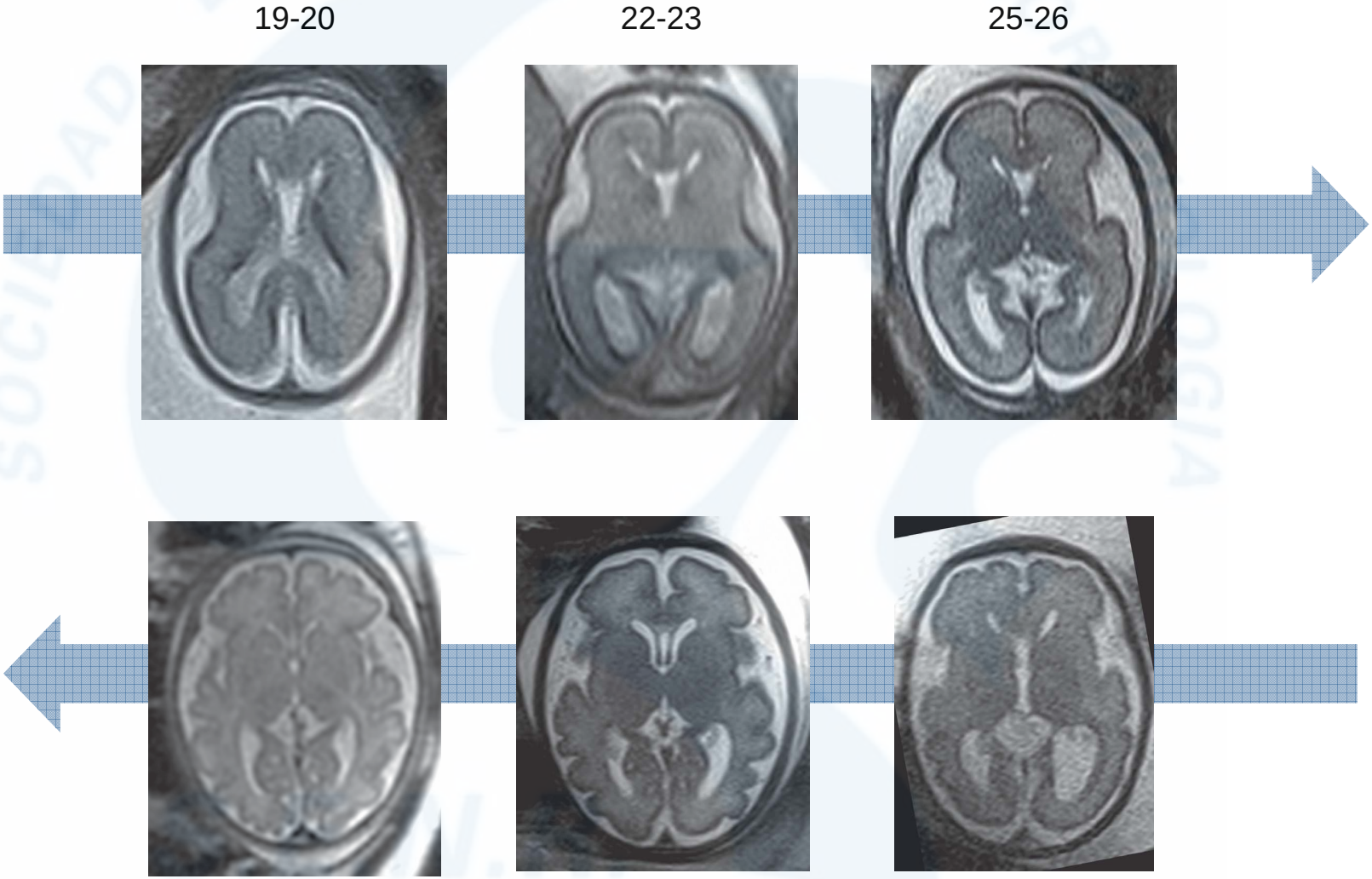
Fetal MR interpretation

Surcation paterns



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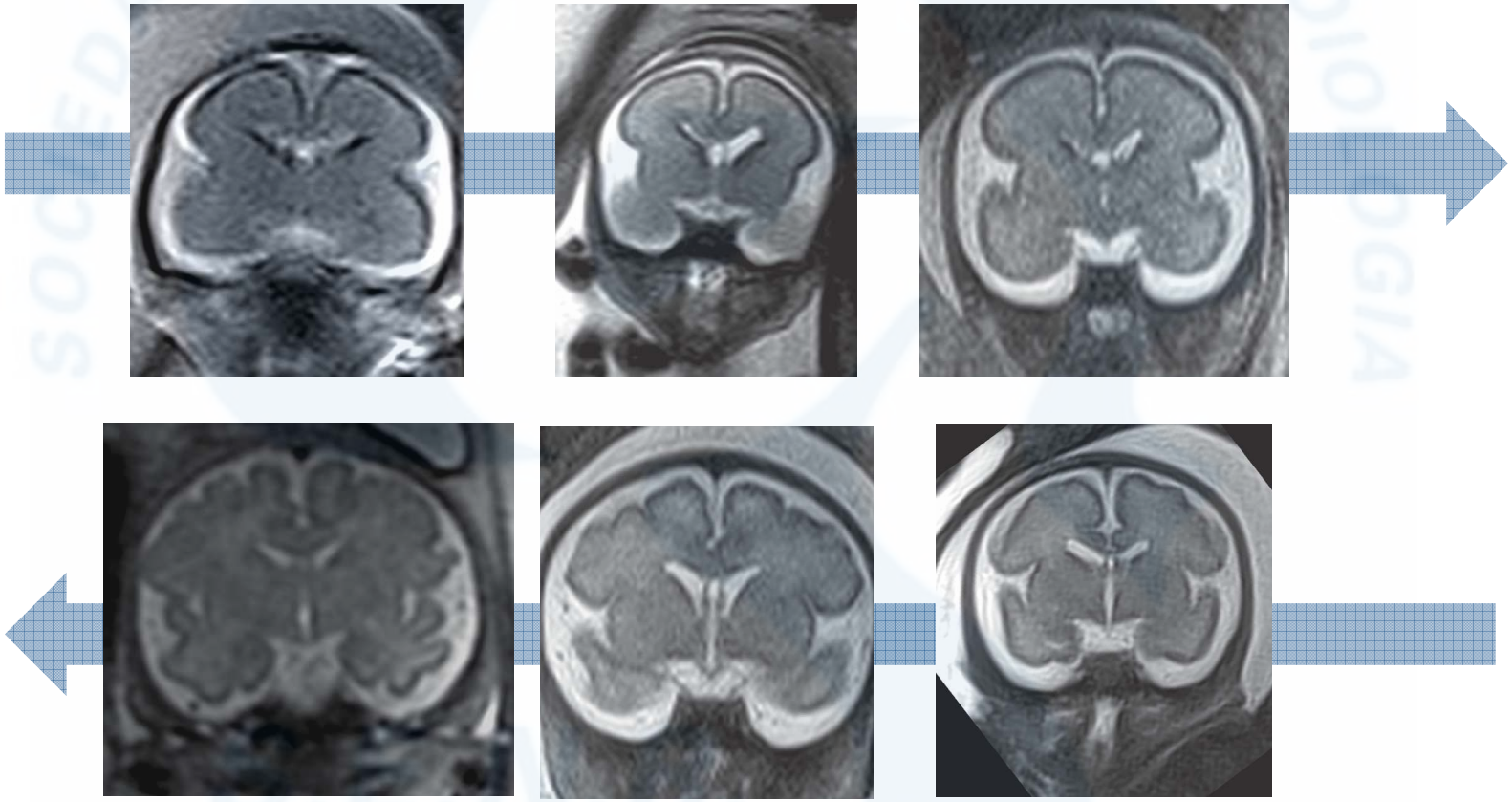
Fetal MR interpretation

Surcation paterns



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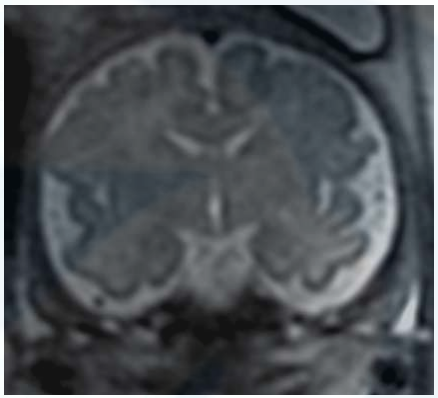
Fetal MR interpretation

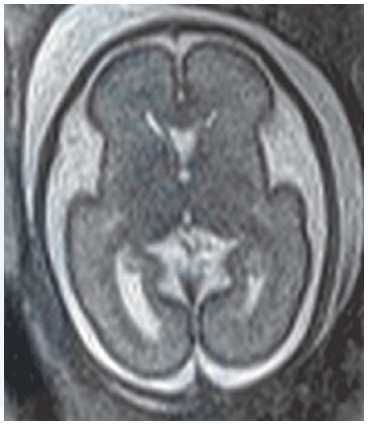
Surcation paterns

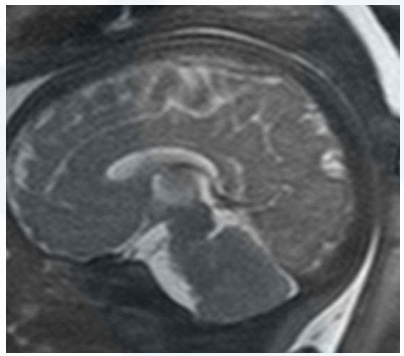
GYRATION NORMALITY

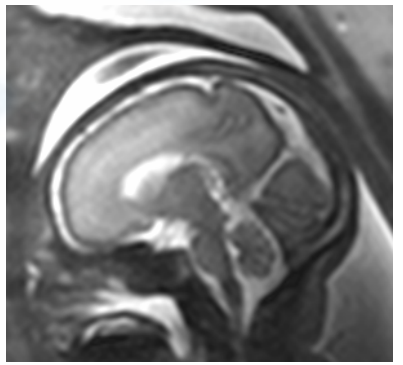
Table 2 Main results of gyration for each sulcus observed [9]

Present in more than 75% of brains in present MR study	
Sulci of the medial cerebral surface	Gestational ages (weeks)
Interhemispheric fissure	22–23 WG
Callosal sulcus	22–23
Parieto-occipital fissure	22–23
Cingular sulcus	24–25
Secondary cingular sulci	33
Marginal sulcus	27
Calcarine fissure	24–25
Secondary occipital sulci	34
Sulci of the ventral cerebral surface	
Hippocampic fissure	22–23
Collateral sulcus	26
Occipitotemporal sulcus	33
Sulci of the lateral cerebral surface	
Superior frontal sulcus	29
Inferior frontal sulcus	29
Superior temporal sulcus (posterior part)	27
Superior temporal sulcus (anterior part)	32
Inferior temporal sulcus	33
Intraparietal sulcus	28
Insular sulci	34
Sulci of the vertex	
Central sulcus	26
Precentral sulcus	27
Postcentral sulcus	28









Fetal MRI: normal gestational landmarks for cerebral biometry, gyration and myelination. Garel et al. Childs Nerv Syst (2003) 19:422.425

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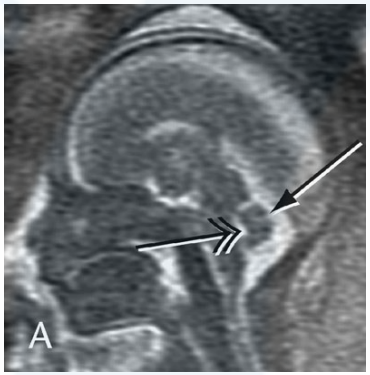
Fetal MR interpretation

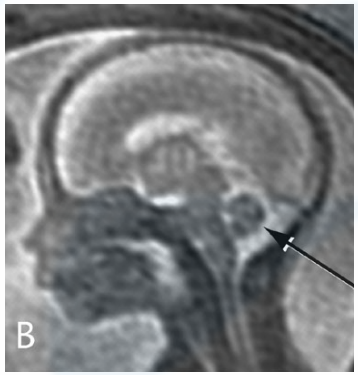
Cerebellum development

17 w

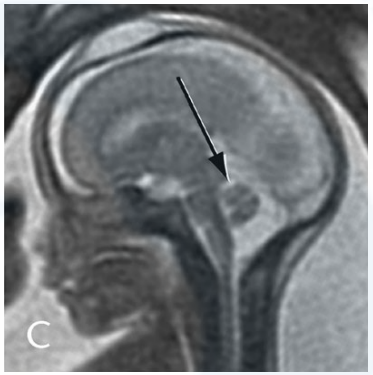
18 w



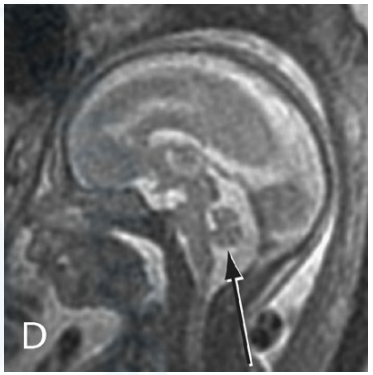
21 w



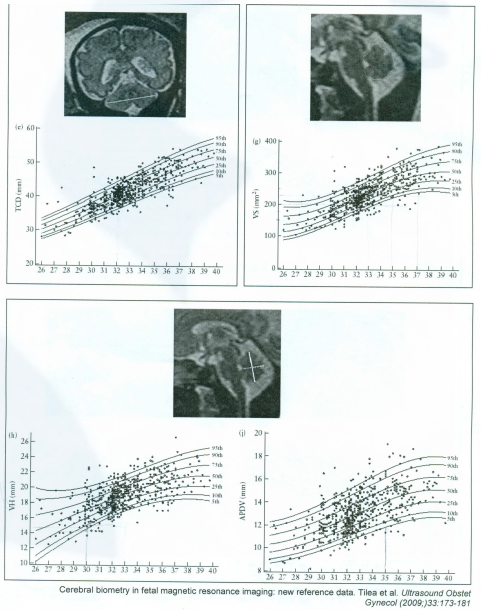
22 w



24 w



27 w



Cerebral biometry in fetal magnetic resonance imaging: new reference data. Tilea et al. *Ultrasound Obstet Gynecol (2009);33:173-181*

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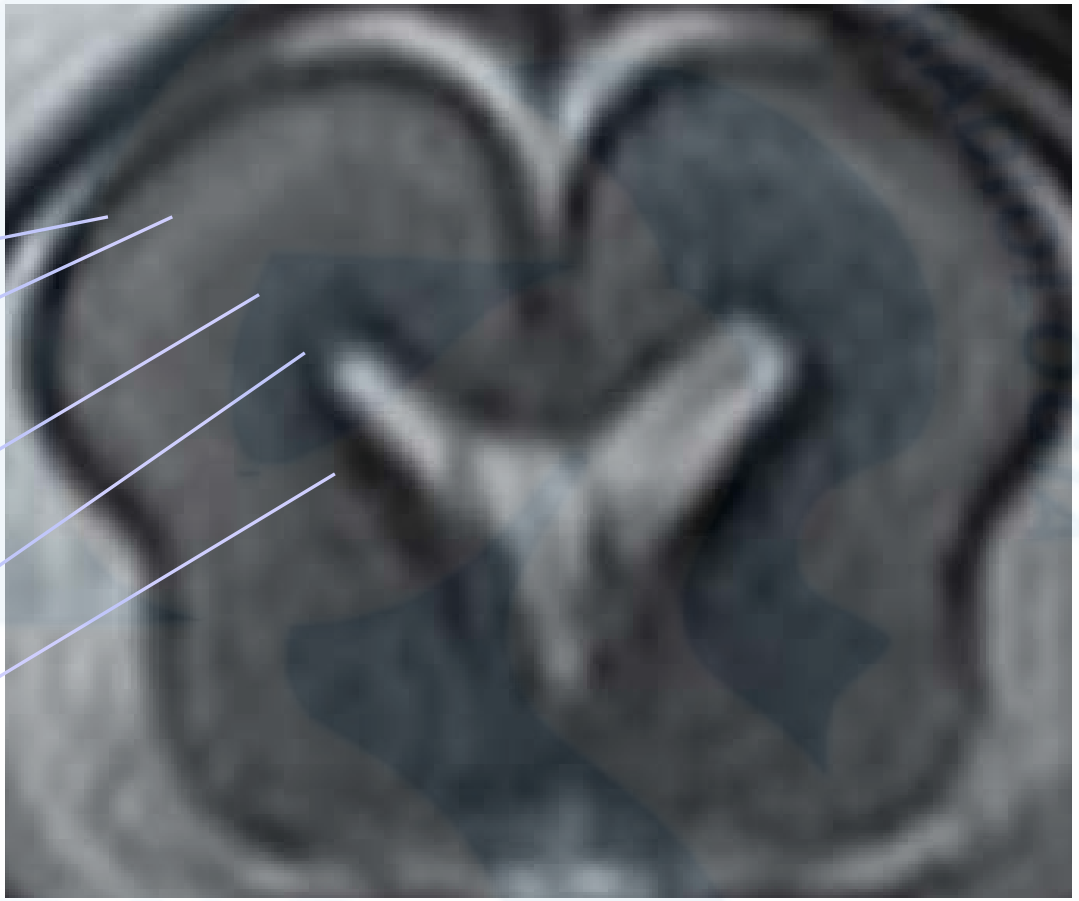
Fetal MR interpretation

Layer patter.



till 28 gestational weeks

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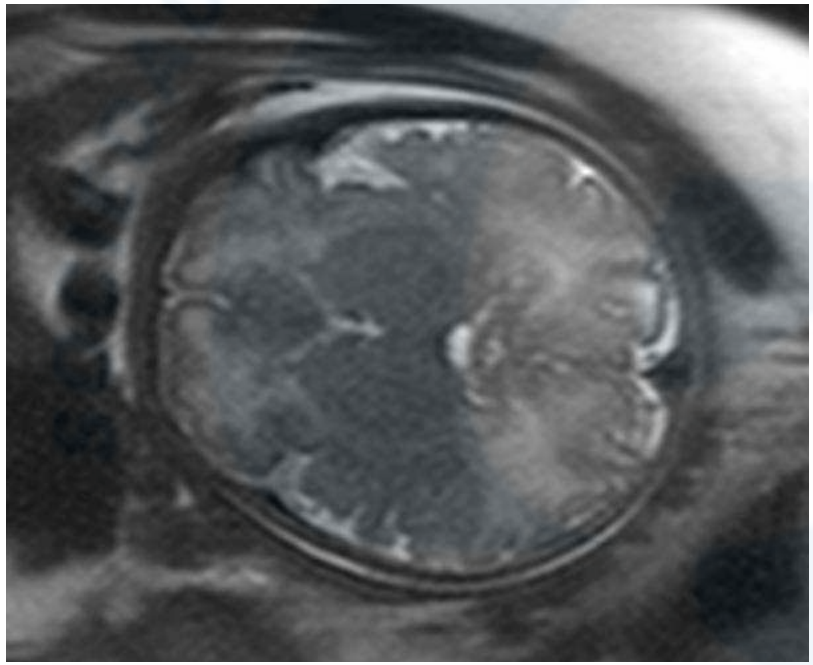
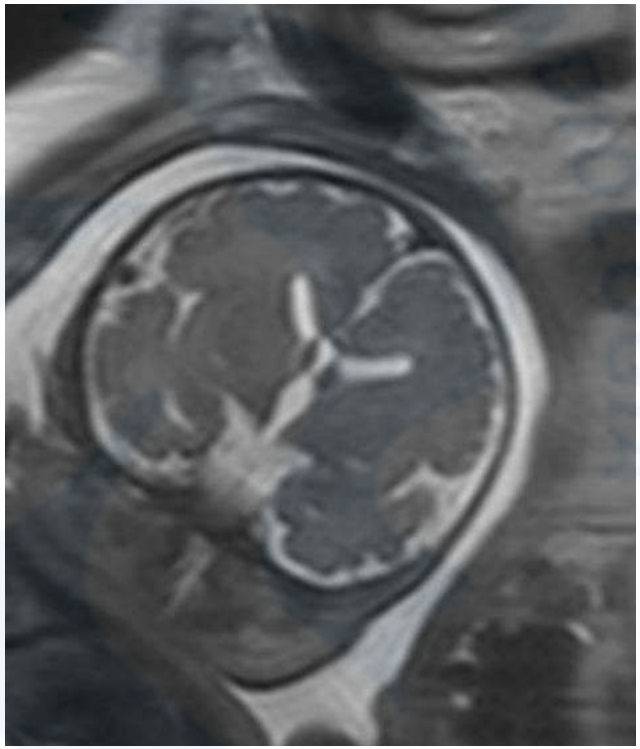
Fetal MR interpretation

Layer patter.





Up to 28 gestational weeks

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Indications of fetal MR

Primary indications for MRI include, but are not limited to:

A. Brain and Spine

1. Congenital anomalies of the brain suspected or not adequately assessed by sonography [3,7-30]. These include but are not limited to:
   a. Ventriculomegaly.
   b. Agenesis of the corpus callosum.
   c. Holoprosencephaly.
   d. Posterior fossa anomalies.
   e. Cerebral cortical malformations.

   In addition, MRI can be helpful in screening fetuses with a family risk for brain abnormalities such as tuberous sclerosis, corpus callosal dysgenesis, or lissencephaly.

2. Vascular abnormalities of the brain suspected or not adequately assessed by sonography [31,32]. These include, but are not limited to:
   a. Vascular malformations.
   b. Hydranencephaly.
   c. Infarctions.
   d. Monochorionic twin pregnancy complications.

3. Congenital anomalies of the spine suspected or not adequately assessed by sonography [18,33-40]. These include, but are not limited to:
   a. Neural tube defects.
   b. Sacrococcygeal teratomas.
   c. Caudal regression/sacral agenesis.
   d. Sirenomelia.
   e. Vertebral anomalies.

B. Skull, Face, and Neck

1. Masses of the face and neck suspected or not adequately assessed by sonography [22,41-45]. These include, but are not limited to:
   a. Venolymphatic malformations.
   b. Hemangiomas.
   c. Goiter.
   d. Teratomas.
   e. Facial clefts.

2. MRI can be helpful in assessing airway obstruction that may impact parental counseling, prenatal management, delivery planning, and postnatal therapy [41-45].

ACR 2010

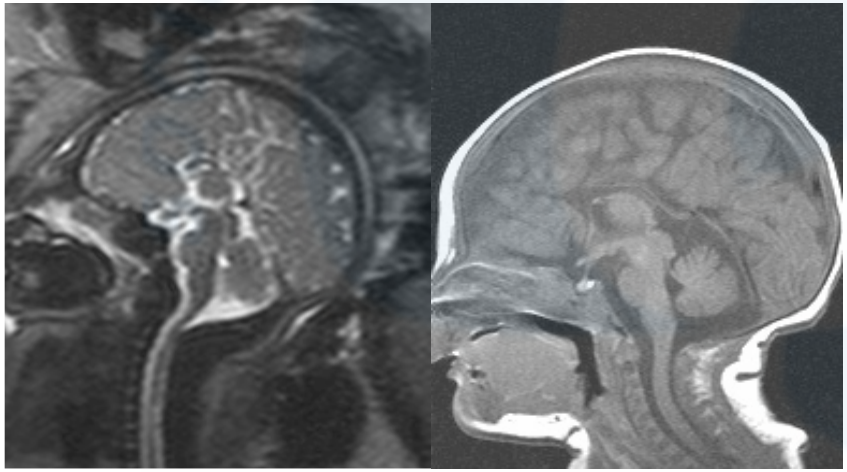
Indications of fetal MR

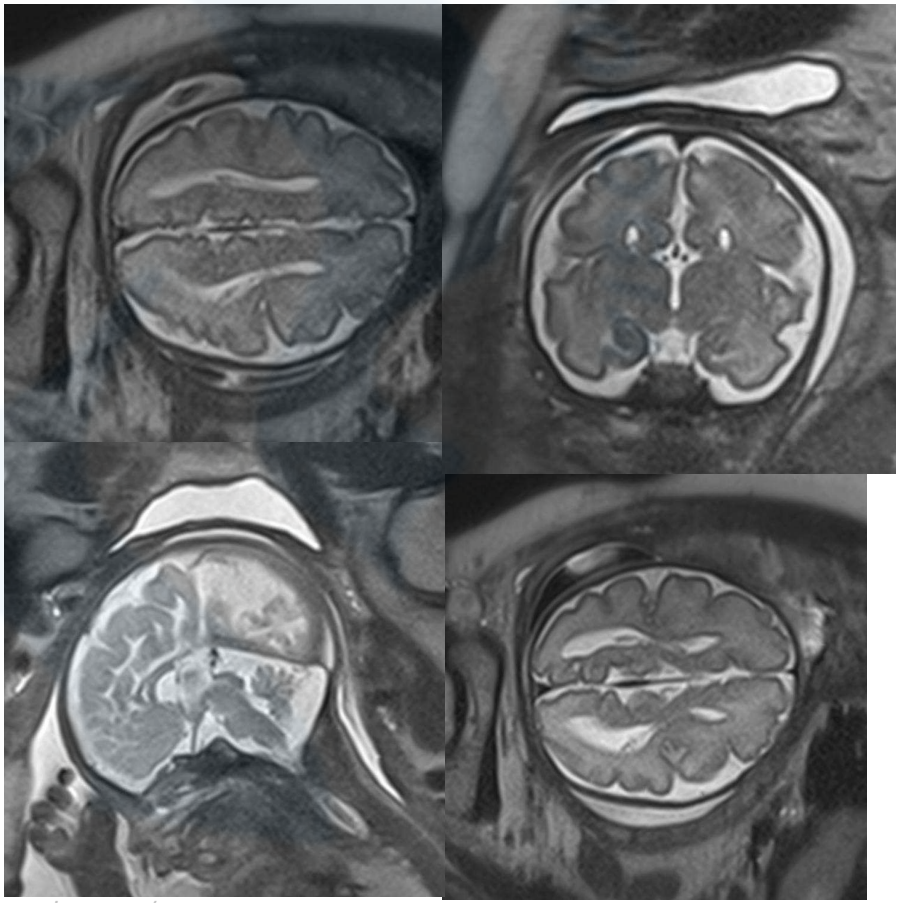
- History of severe fetal abnormality in a previous pregnancy, but with normal US (ventriculomegaly, corpus callosum agenesis).
- Anomaly identified in US but that can not be detailed by technical problems. (Additional information).

- In situations where there is high risk of cranial anomalies, for example fetal infections (cytomegalovirus, toxoplasmosis or chickenpox) or ischemia (intrauterine death or monochorionic twin transfusion syndrome.

Congenital anomalies.
Middle line malformation.

- Agenesis of corpus callosum





More sensible that US.

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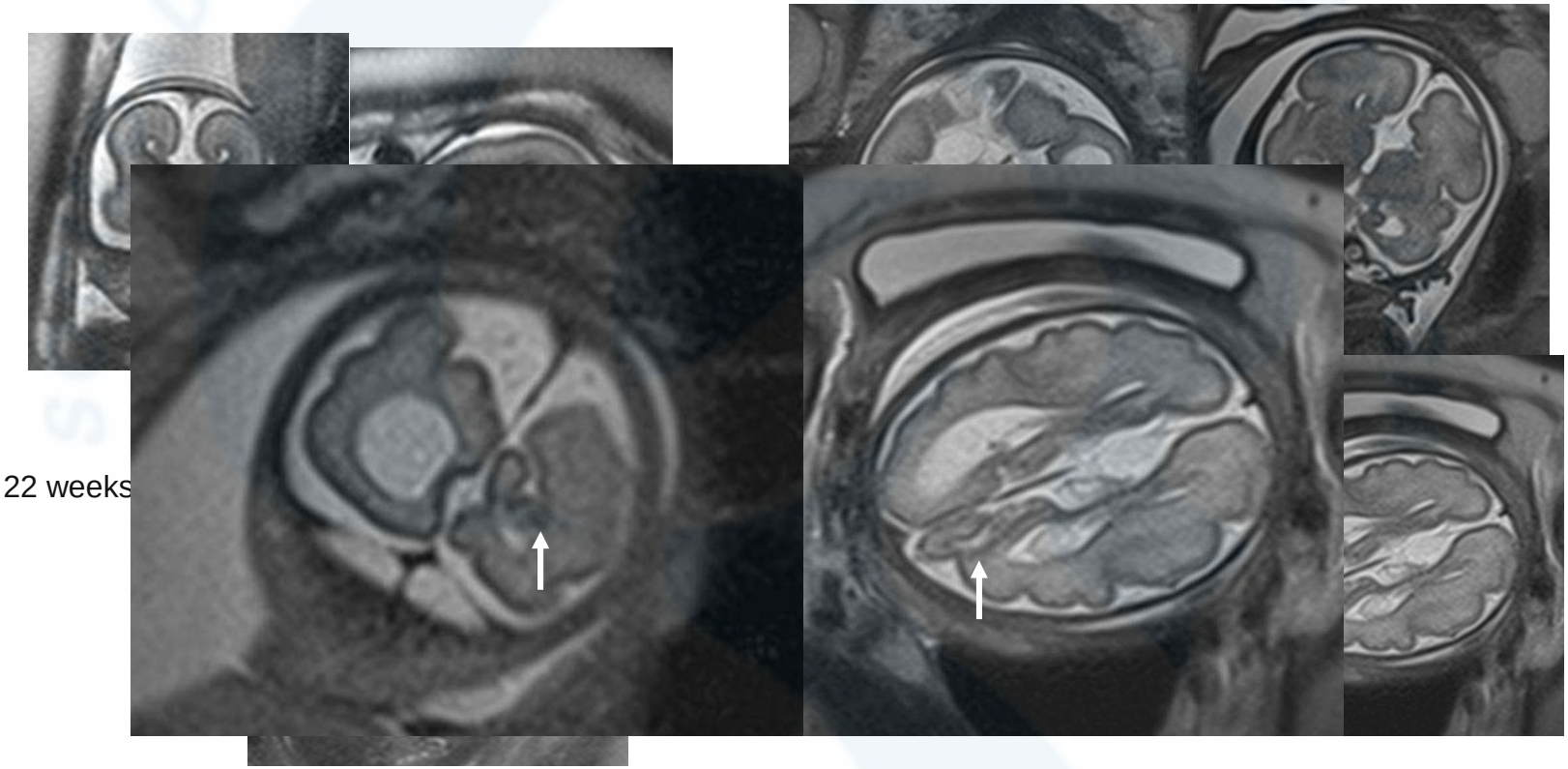
Congenital anomalies.

Middle line malformation.



22 weeks

28 weeks

Other associated malformation!!!

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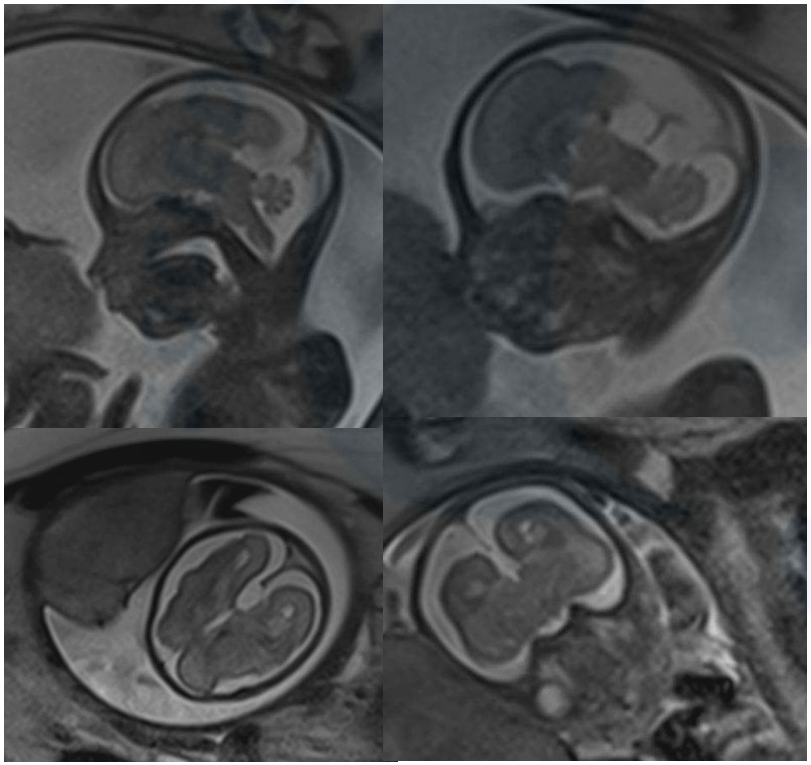
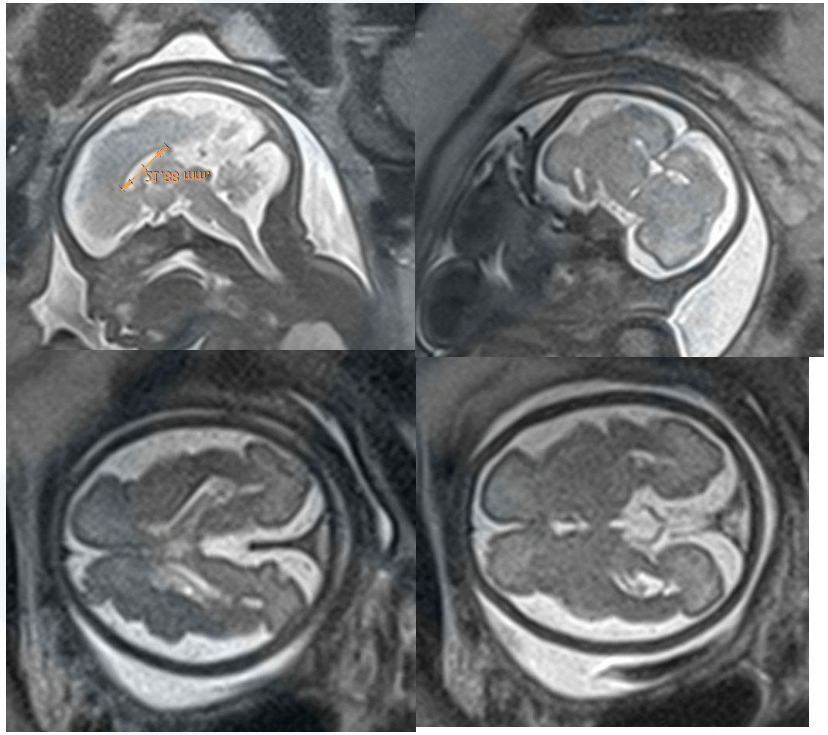
Congenital anomalies.

Middle line malformation.



26 w



34w

Other associated malformation!!!

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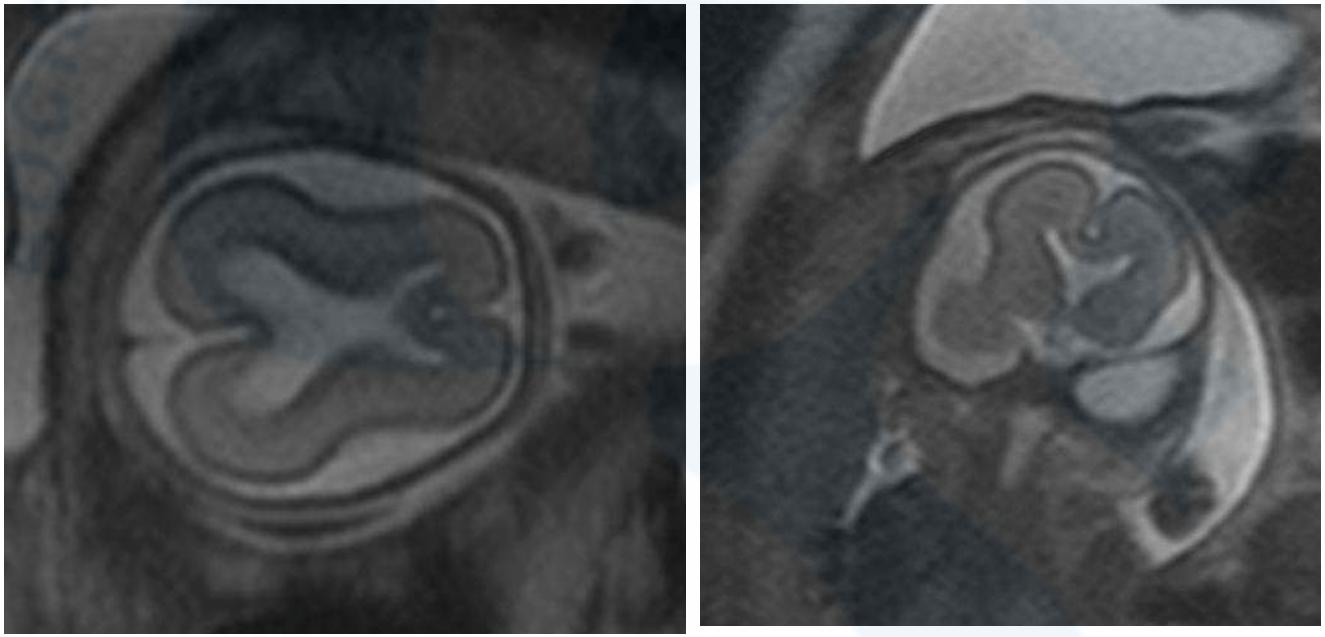
Congenital anomalies.
Middle line malformation.

- Lobar Holoprosencephaly- Septo-optico dysplasia/ agenesis of septum pelucimum



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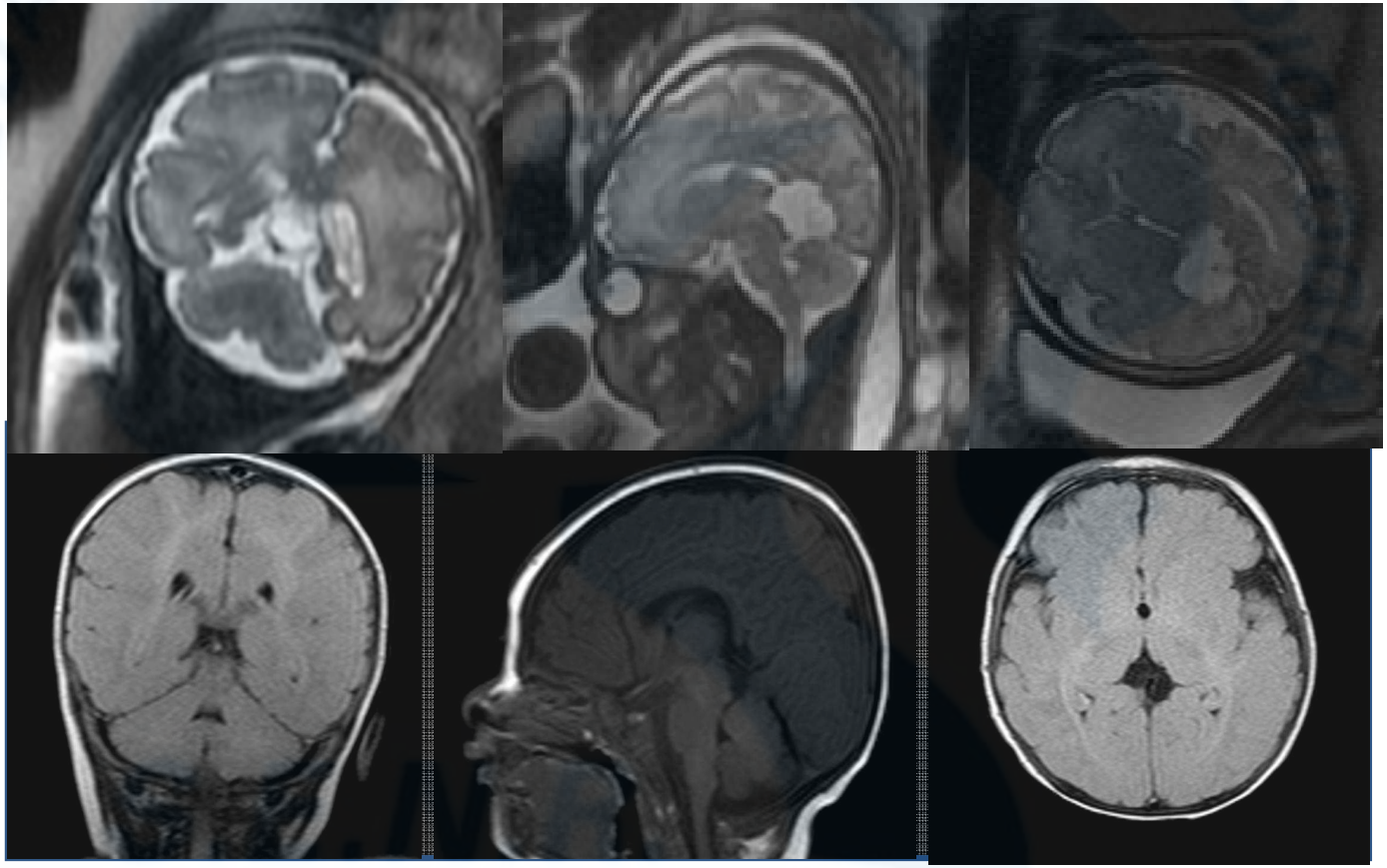
Congenital anomalies.
Middle line malformation.

- Middle line cysts



Aracnoid cyst of the velum interpositum

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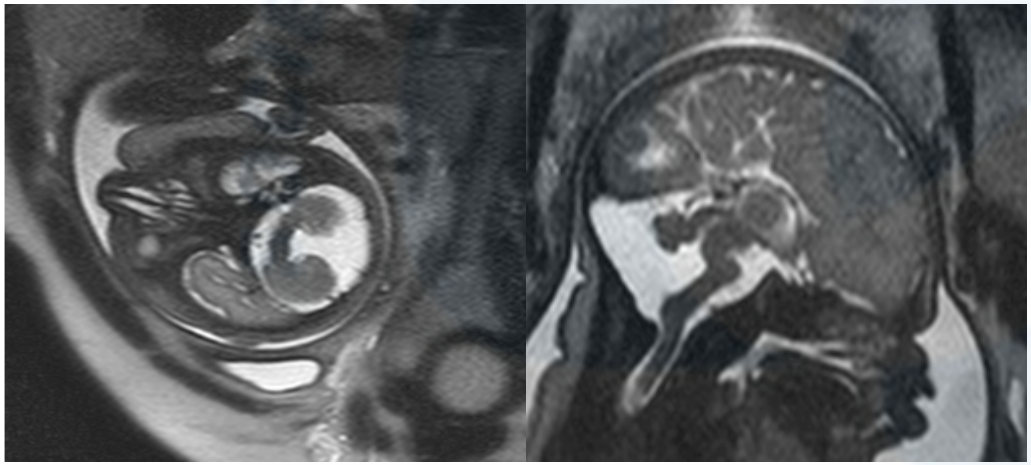
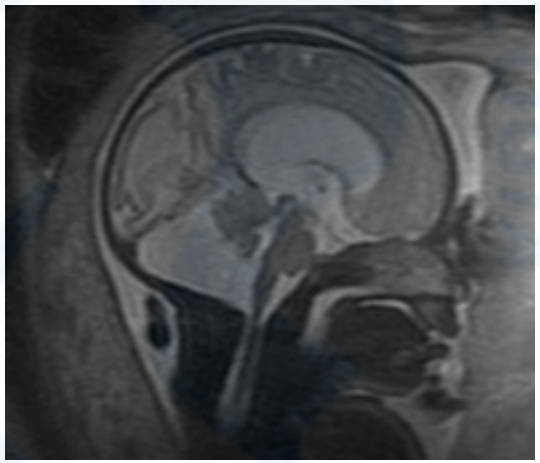
Congenital anomalies.

Posterior fossa malformations.

- Dandy Walker complex syndrome



Dandy-Walker Sd



Dandy-Walker Variant

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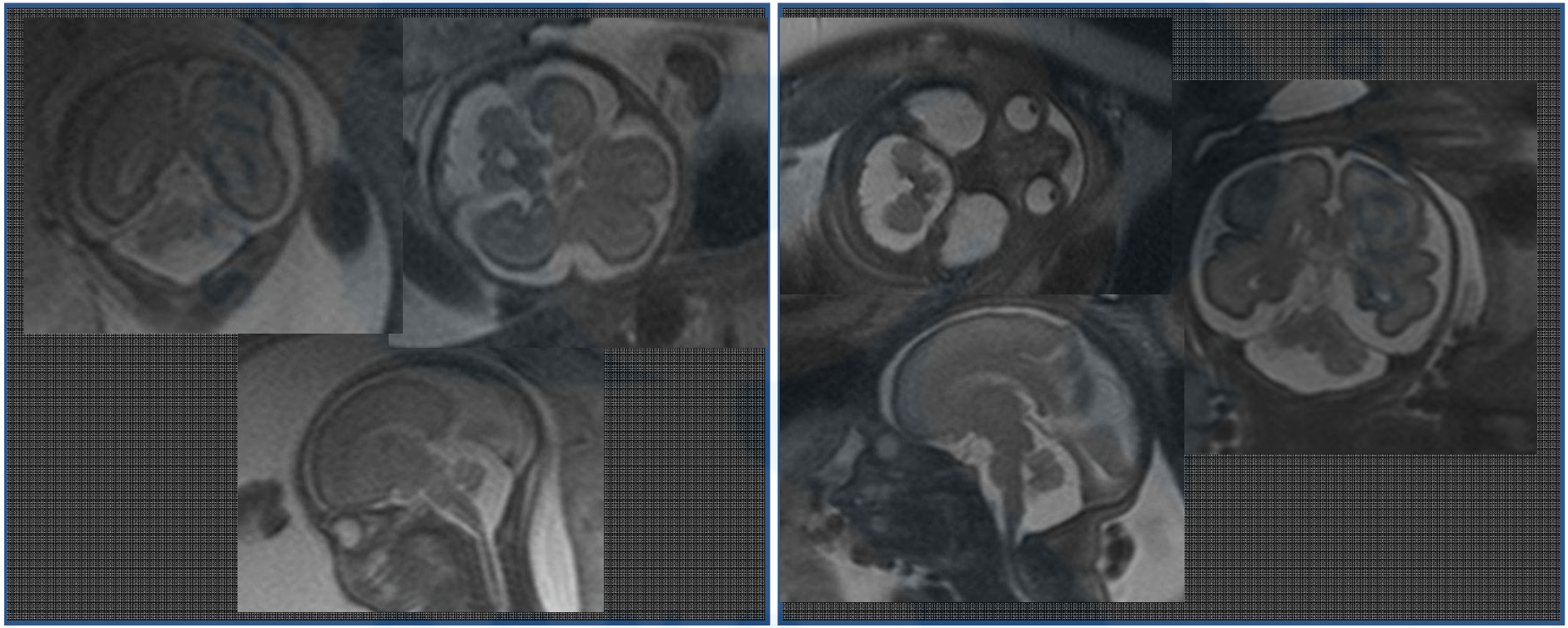
Congenital anomalies.
Posterior fossa malformations.

- Cerebelum hypoplasia vs aracnoid cyst.



21 w.

28 w

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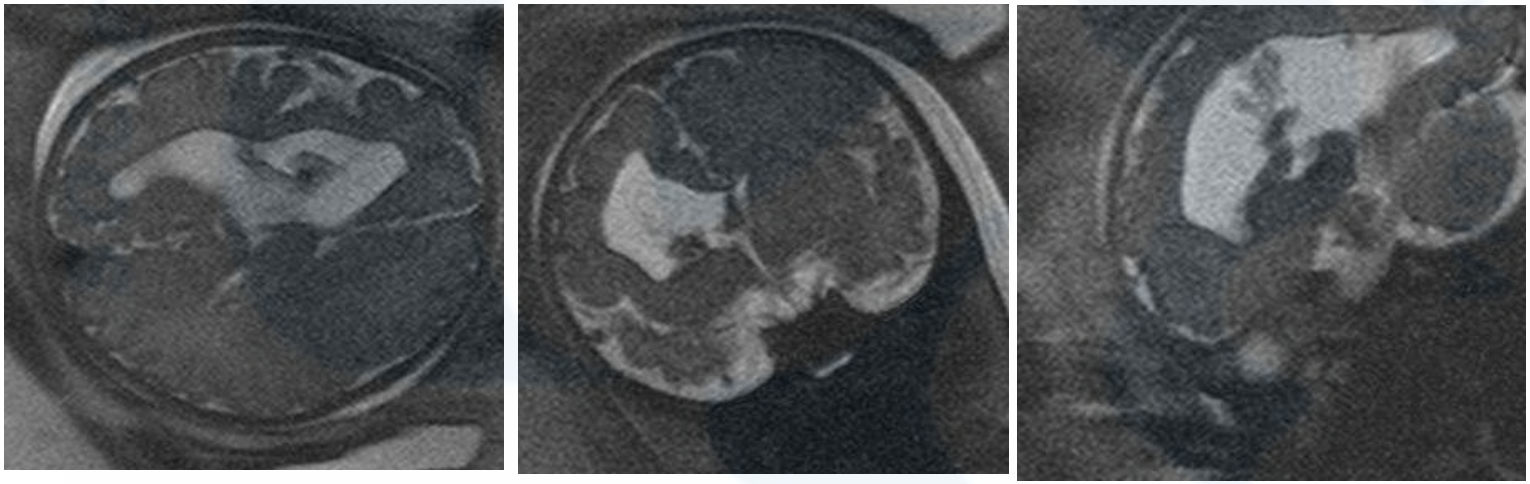
Congenital anomalies.

Neuronal migration, surcation and cortical development malformations.



Neuronal proliferation disorders (hemimegancephaly)

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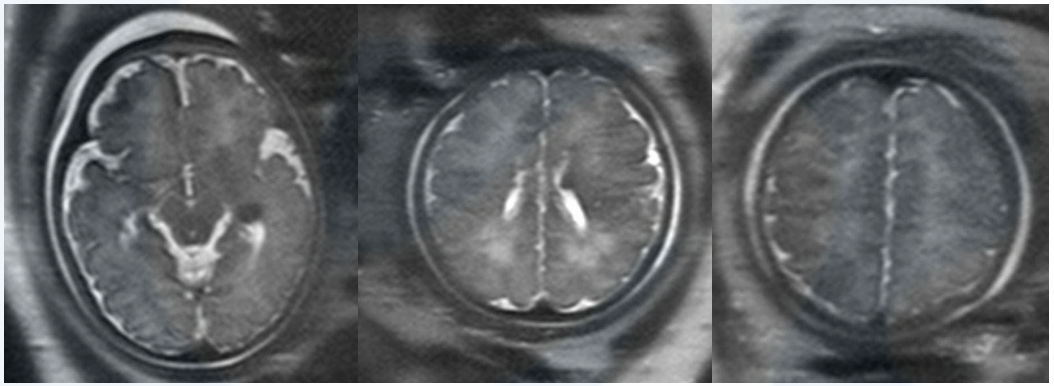
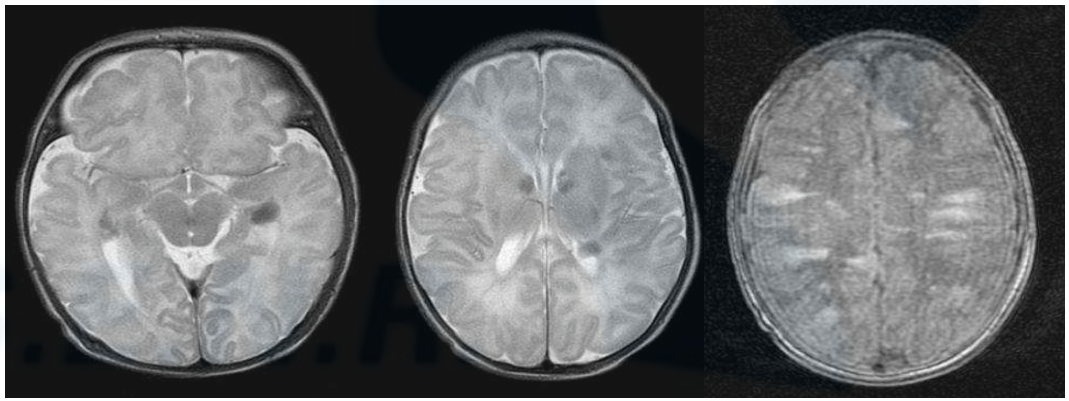
Congenital anomalies.

Neuronal migration, surcation and cortical development malformations.

- Tuberous sclerosis.





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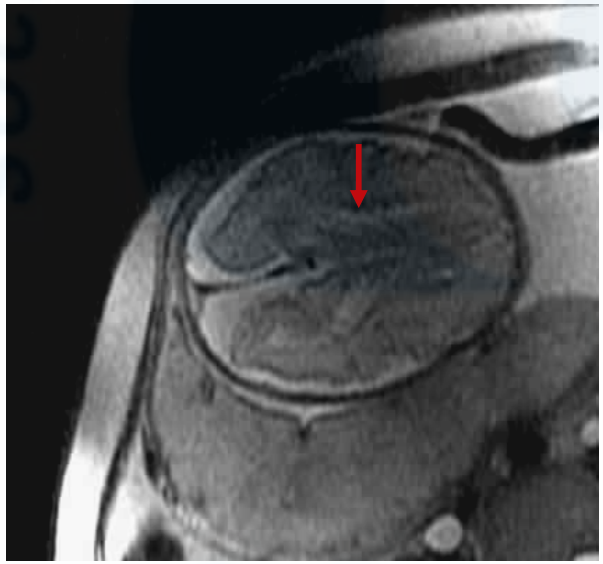
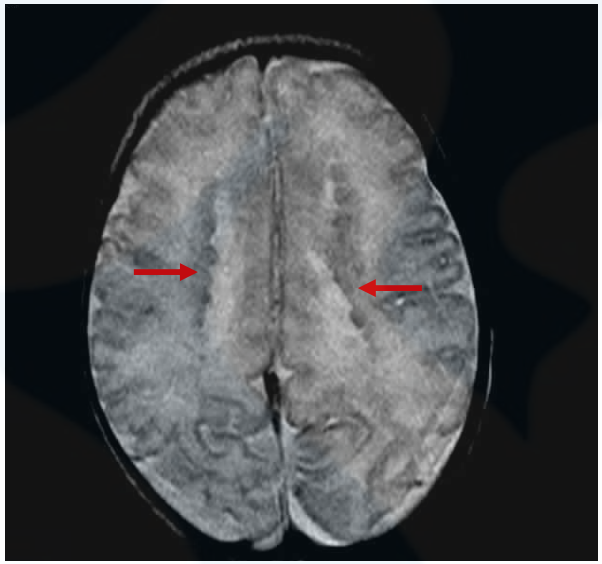
Congenital anomalies.
Neuronal migration, surcation and cortical development malformations.

- Periventricular heterotopia

New born MRI





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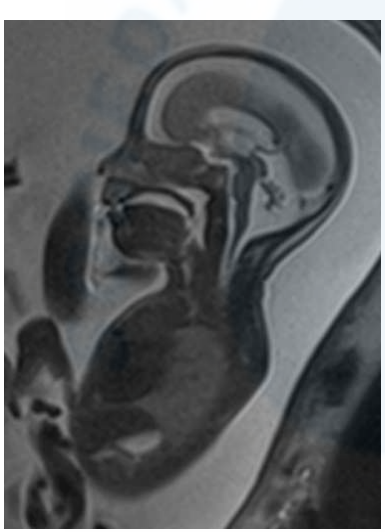
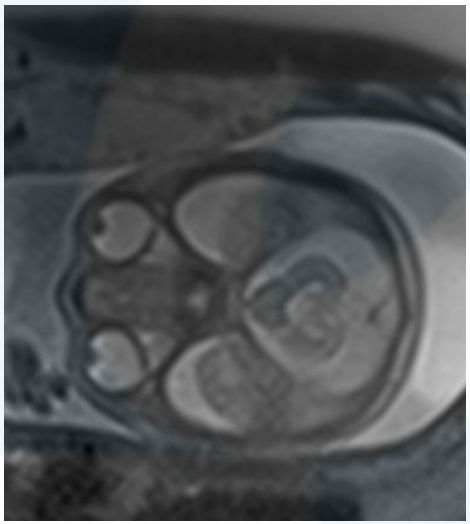
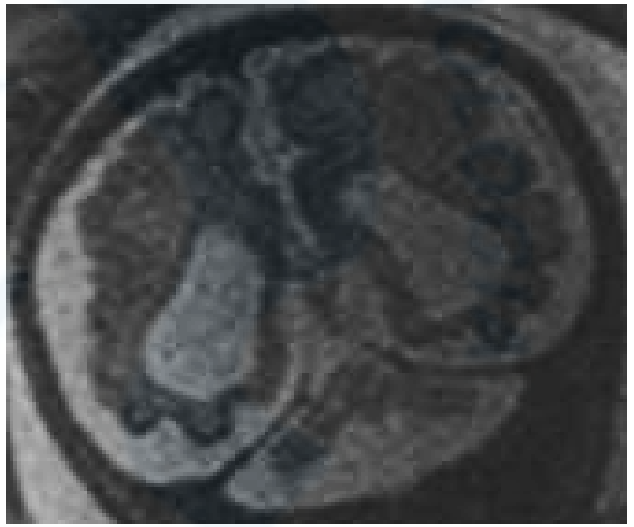
Congenital anomalies.

Surcation and cortical development malformations.







Very often associated with other malformation!!!.

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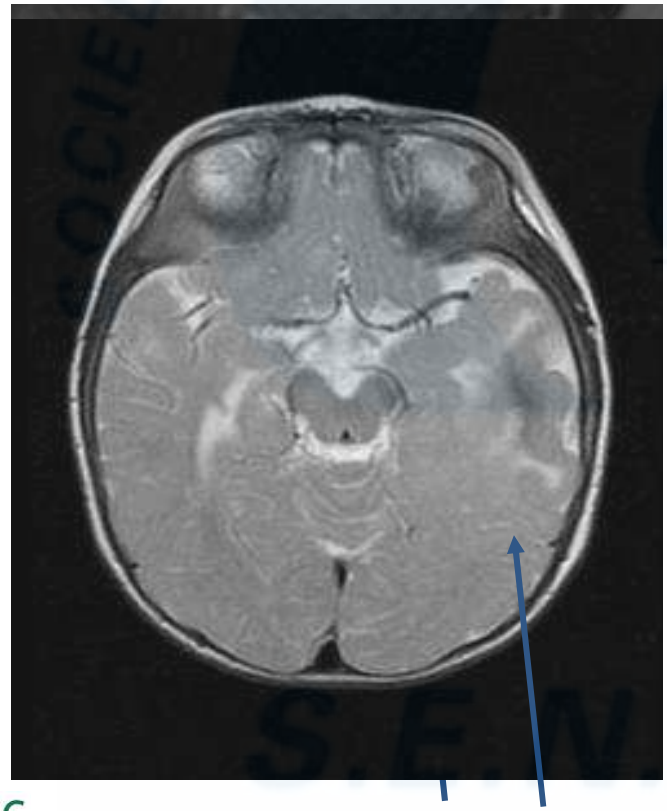
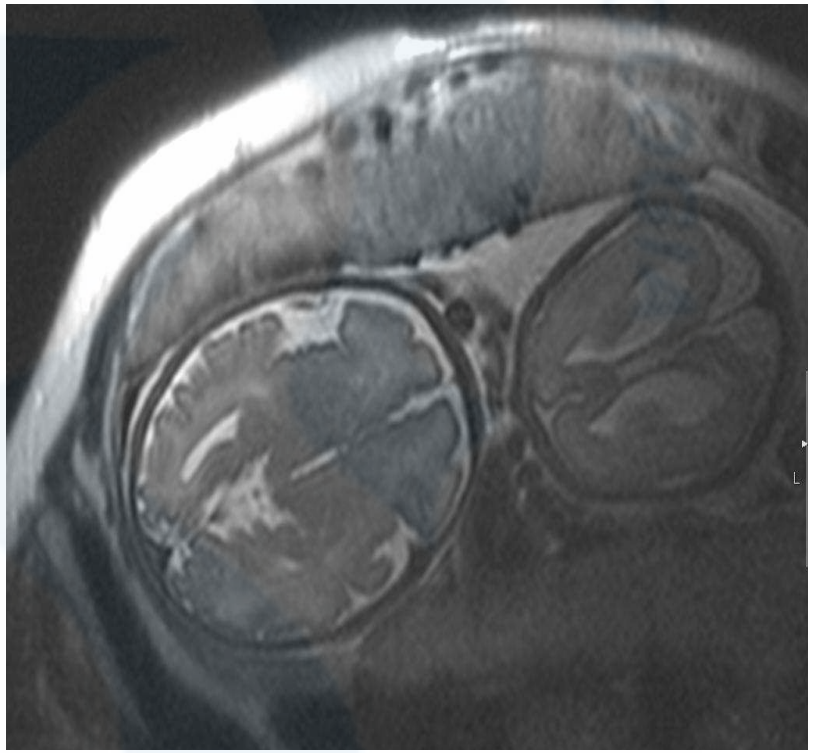
Congenital anomalies.

Surcation and cortical development malformations.

- Cortical dysplasia



- Delayed surcation



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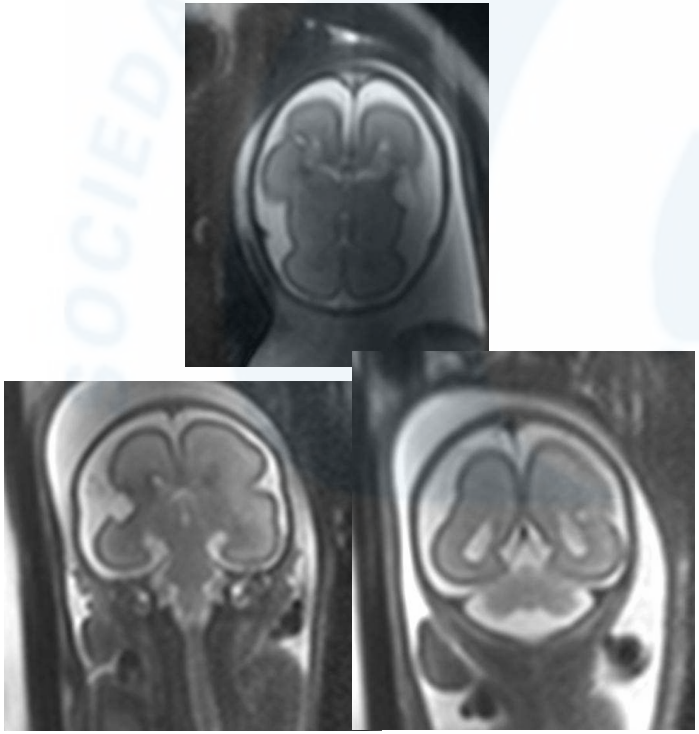
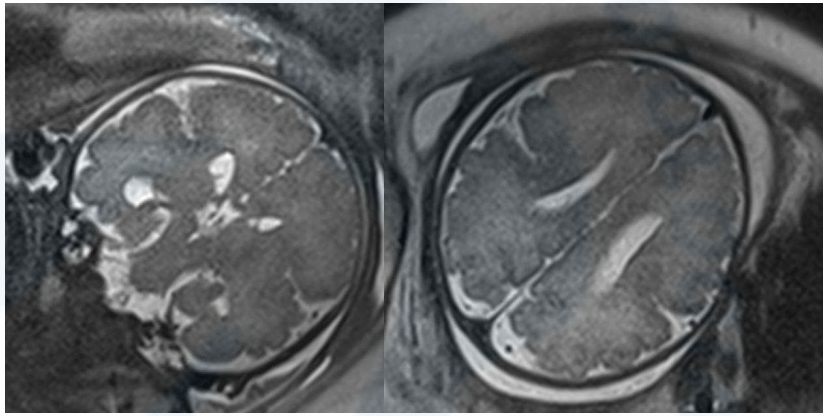
Congenital anomalies.

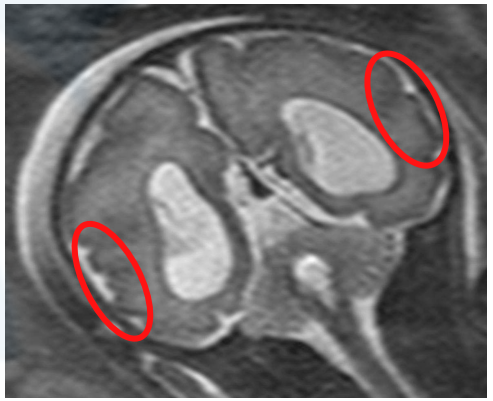
Surcation and cortical development malformations.



Squizencephaly



Perirolandic dysplasia



Focal polimicrogyria

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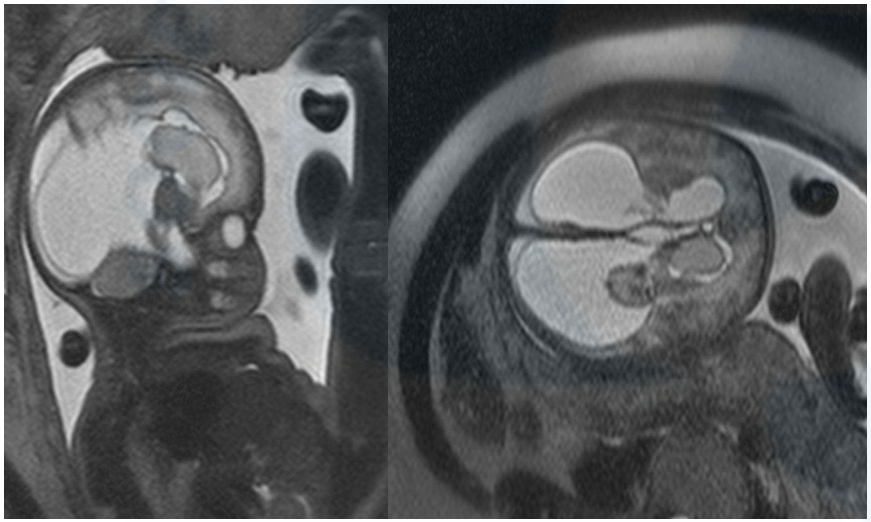
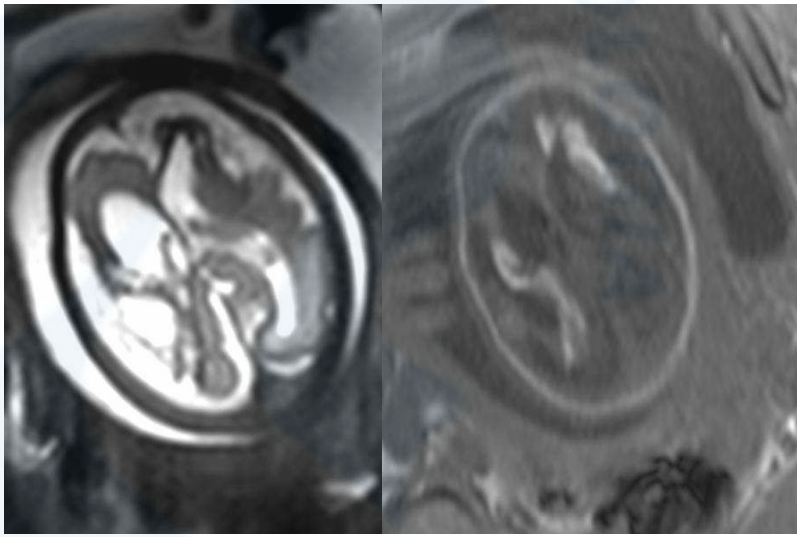
Acquired pathology with brain destruction

- Hemorrhagic lesions:



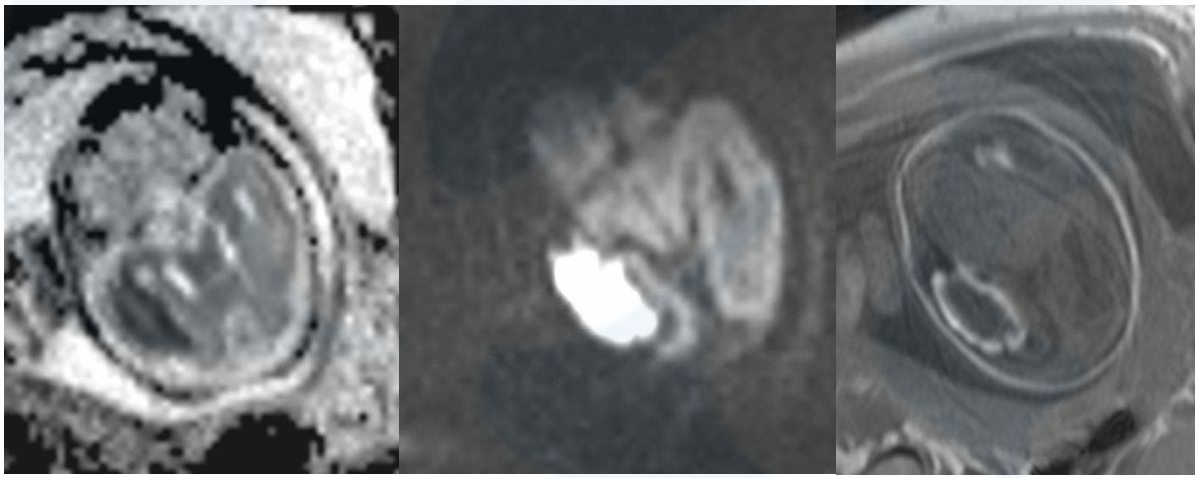
Germinal matrix hemorrhage with intraventricular contamination and ventriculomegaly



Brain hemorrhage (monochoriotic twin Sd)

Acquired pathology with brain destruction

Ischemic lesions



Ischemic infarct with hemorrhagic transformation.

Acquired pathology .
Infecctions

Table 1 Indications of fetal brain MRI in infections (*CMV* cytomegalovirus, *PROM* prolonged rupture of membranes)

Infection	Number	Abnormal MRI (%)	Normal MRI
Toxoplasmosis	97	15 (15)	82
CMV	37	15 (39)	21
Varicella	17	3 (18)	14
Parvovirus	4	1 (25)	3
Rubella	3	1 (33)	2
Toxoplasmosis + HIV	3	1 (33)	2
CMV + HIV	3	1 (33)	2
HIV + hepatitis C	1	0	1
Toxoplasmosis + *E. coli*	1	1	0
Maternal acute hepatitis	1	0	1
Maternal herpetic encephalitis	1	0	1
Acute maternal infection	7, (Guillain Barre syndrome due to coxsackie in 1)	1 (16)	6
PROM and chorioamnionitis	3	1 (33)	2
Total	178 of 1,175 fetal brain MRI (14%)	41 (23)	137

A. James Barkovich
Nadine Girard

Fetal brain infections

Childs Nerv Syst (2003) 19:501–507

na.org/

Acquired pathology
Infecctions

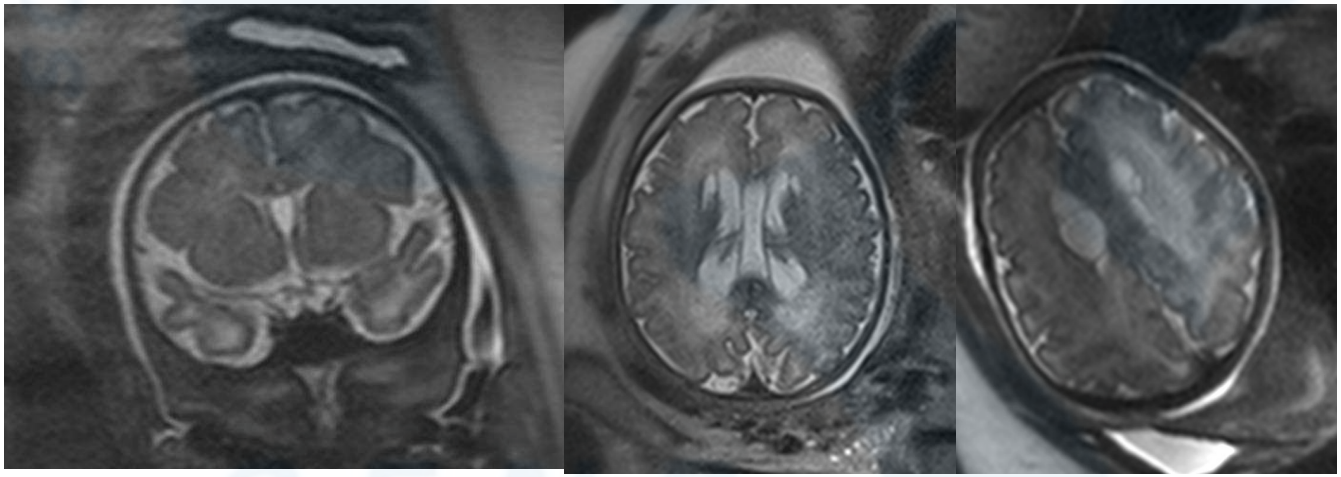
Table 2 MRI findings in fetal infections

	Infection % (178 patients)
Cerebral abnormality	23 (41)
Ventricular dilatation	85 (35)
Hemorrhage	4.8 (2)
Destructive brain	34 (14)
Calcifications	12 (5)
Malformation	22 (9)

Barkovich and Girard. 2003

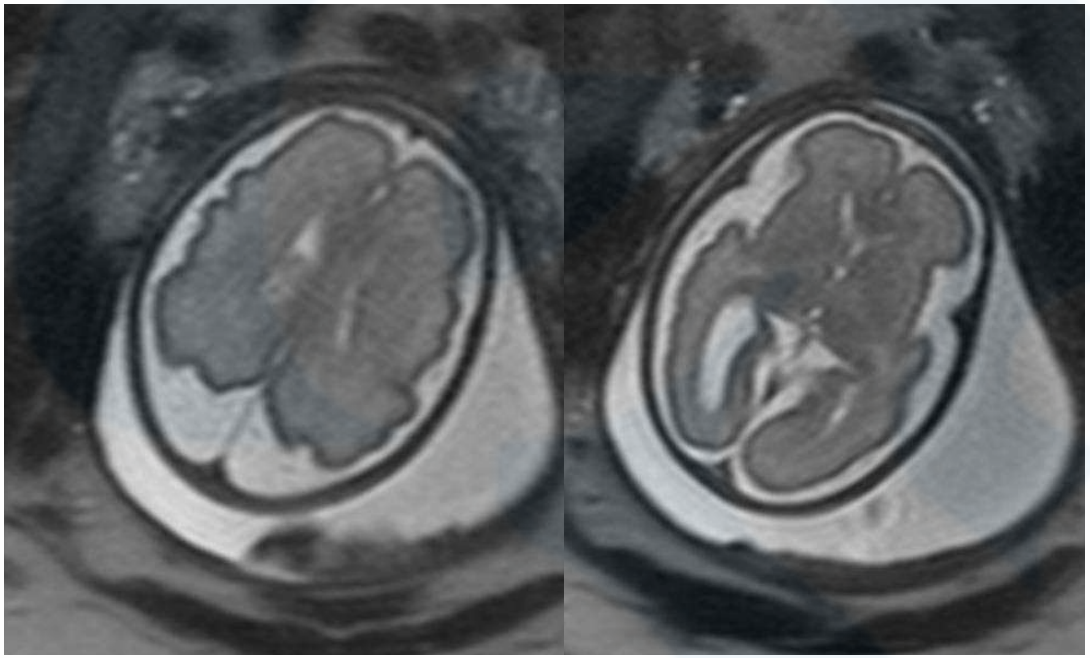
Acquired pathology.
Infections

- White matter high signal abnormalities (edema or gliosis).
- Periventricular cysts (germinolytic cyst).
- Ventricular cysts.
- Temporal pole high signal (CMV)



Acquired pathology
Infections

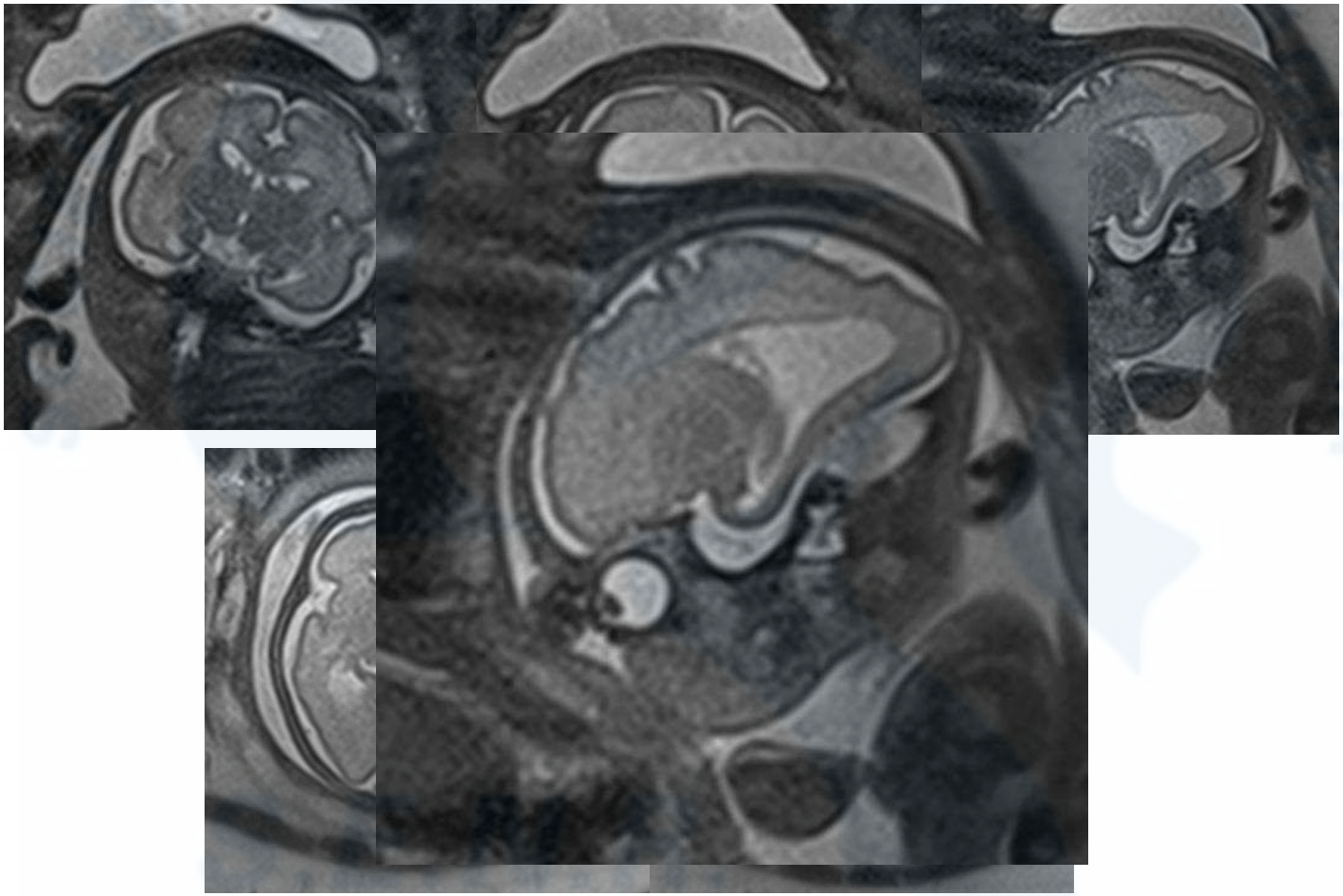
Herpes Zoster infecction.



Microcephaly with enlargement of subarachnoid space.

Acquired pathology
Infections

CMV infection



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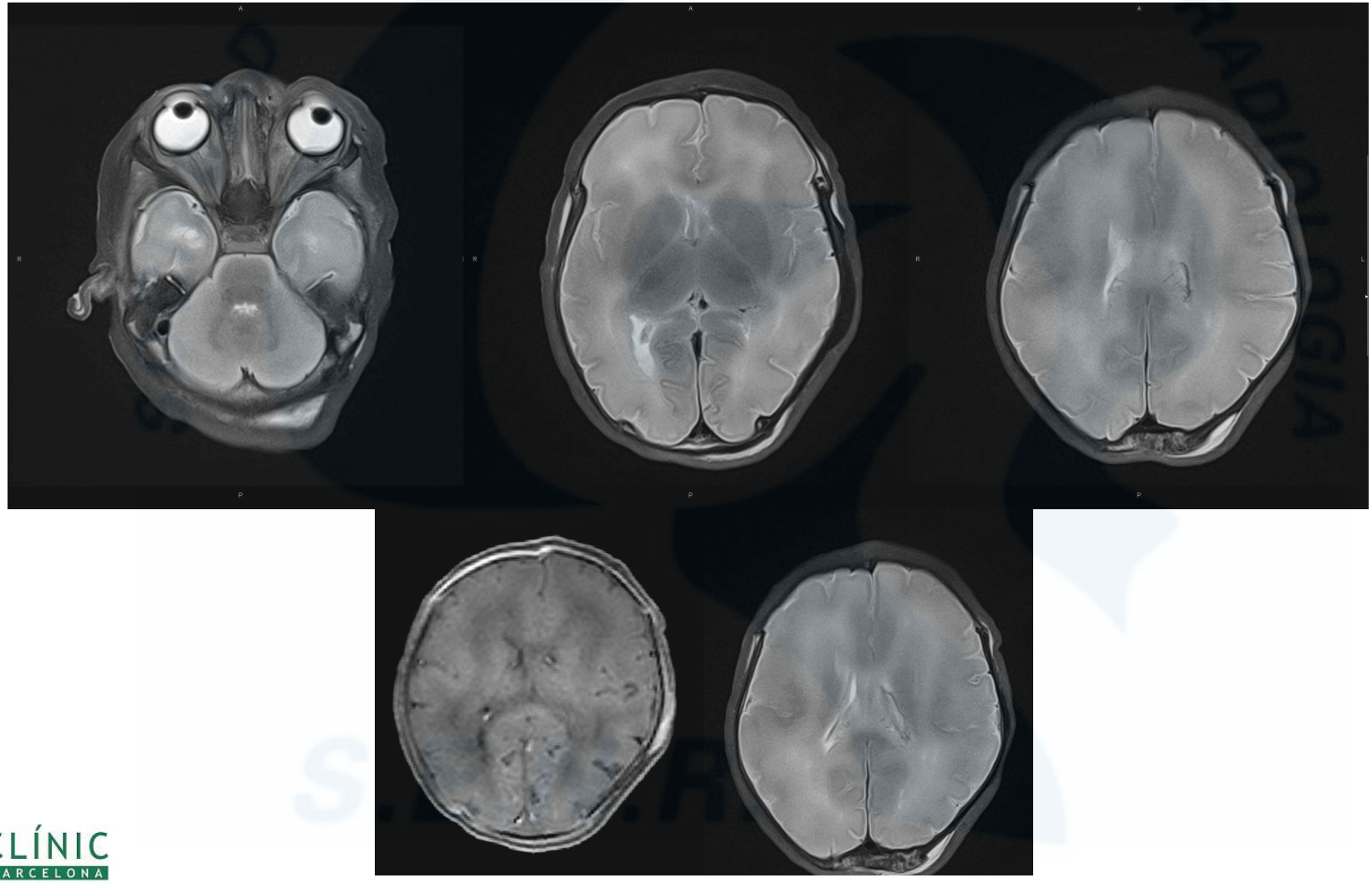
Acquired pathology
Infections

MR autopsy



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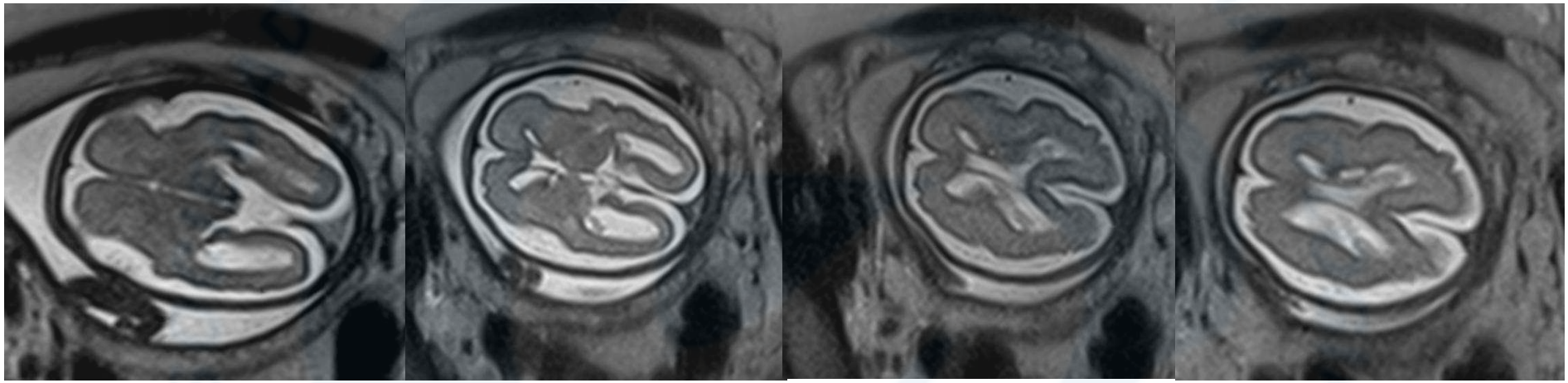
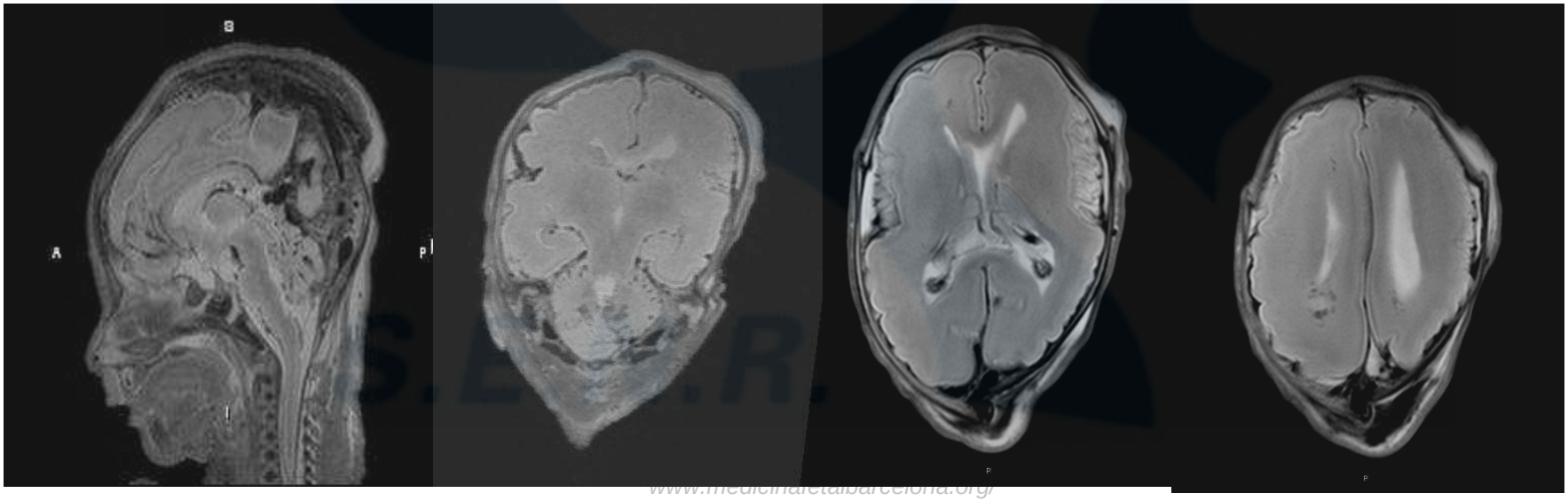
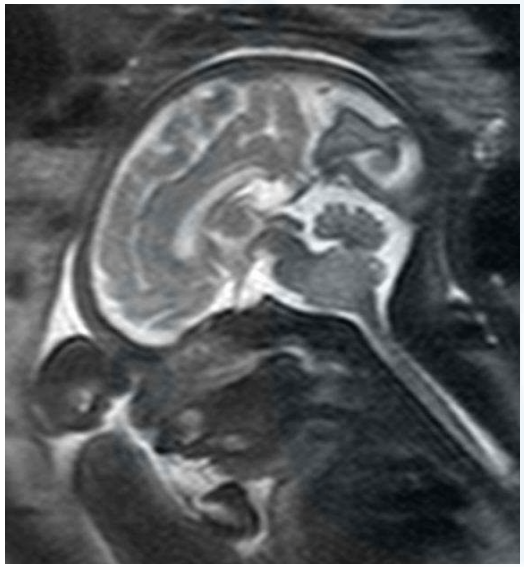
Acquired pathology
Infections

CMV infecction

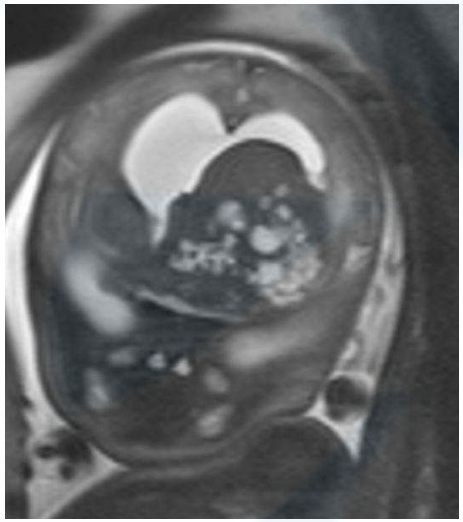


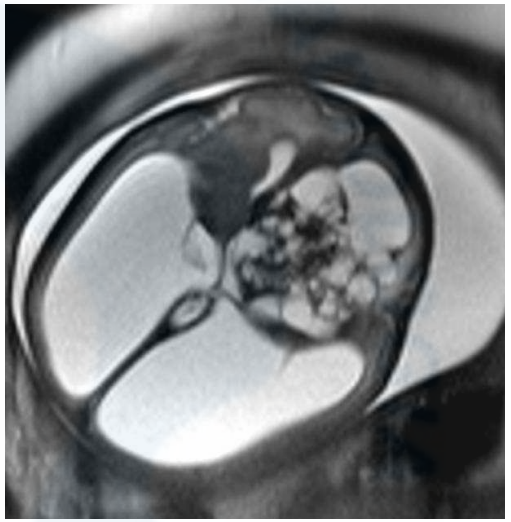


Acquired pathology
Tumors



Brain stem astrocytoma





Giant cell subependimal astrocytoma

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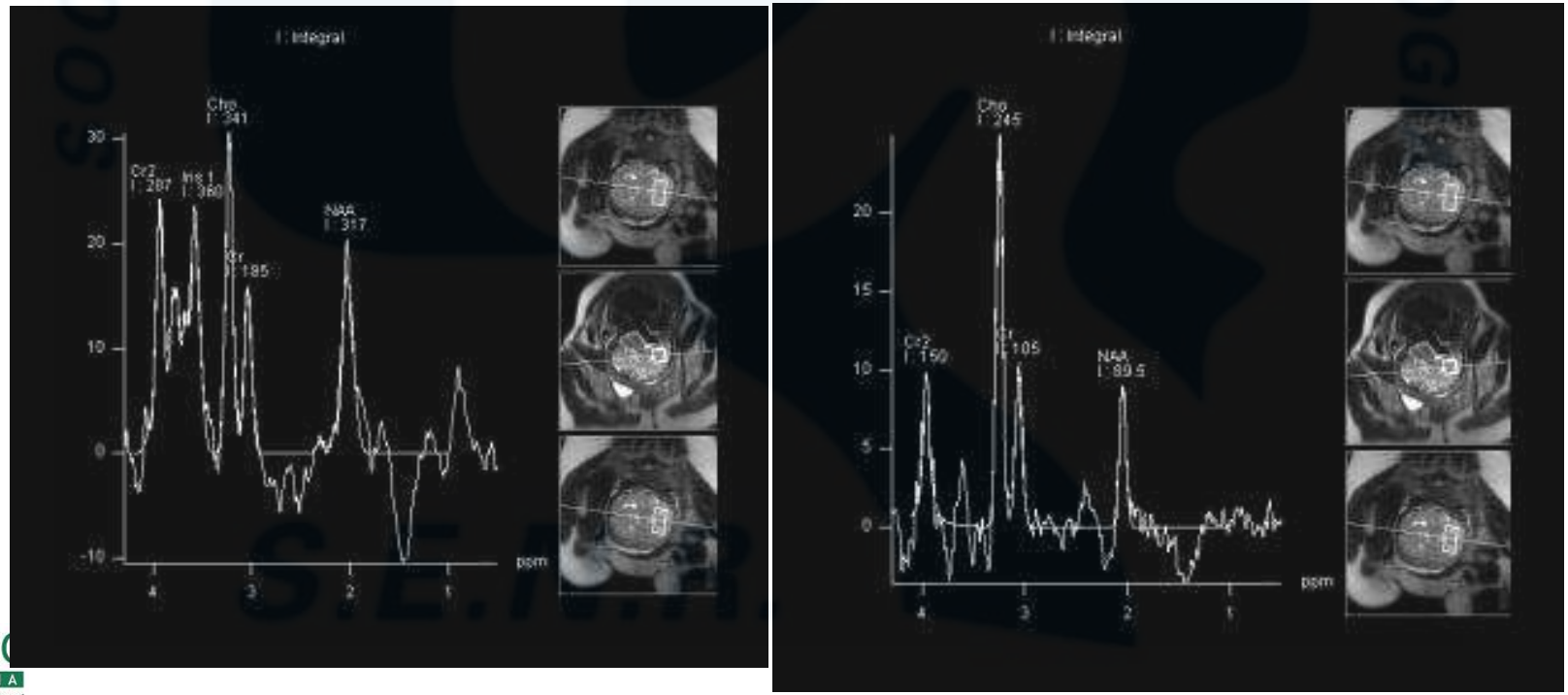
Journal of Pediatric Neuroradiology 1 (2012) 225–251
DOI 10.3233/PNR-2012-031
IOS Press

Advanced fetal MRI: Diffusion tensor imaging, spectroscopy, dynamic MRI, resting-state functional MRI

Salil Soman[a], Gregor Kasprian[b], Veronika Schopf[b], Vanessa Berger-Kulemann[b], Ursula Nemec[b], Christian Mitter[b] and Daniela Prayer[b,*]
[a]*Department of Radiology, Neuroradiology Section, Stanford University, Stanford, CA, USA*
[b]*Department of Radiology, Division of Neuro- and Musculoskeletal Radiology, Medical University of Vienna, Vienna, Austria*

Spectroscopy



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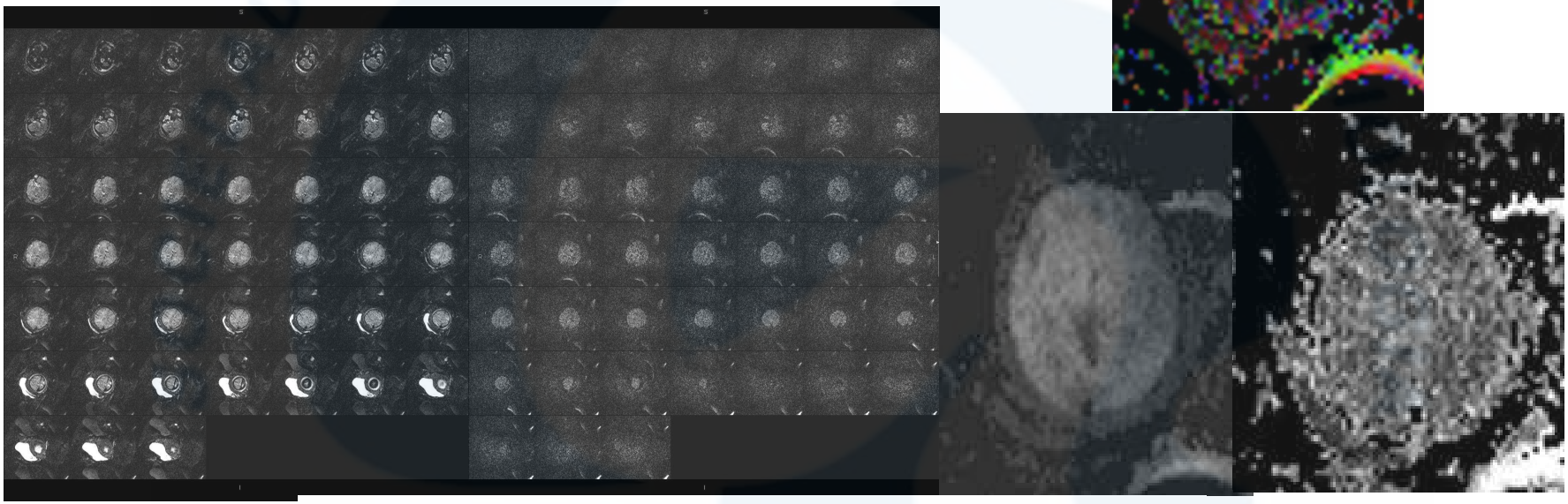
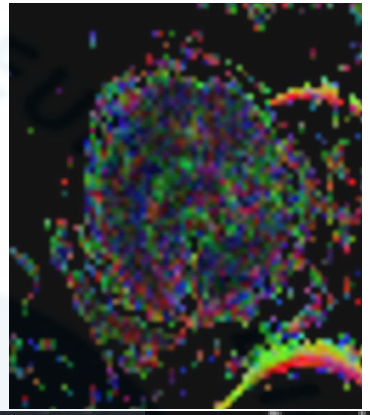
- Difusion tensor imaging





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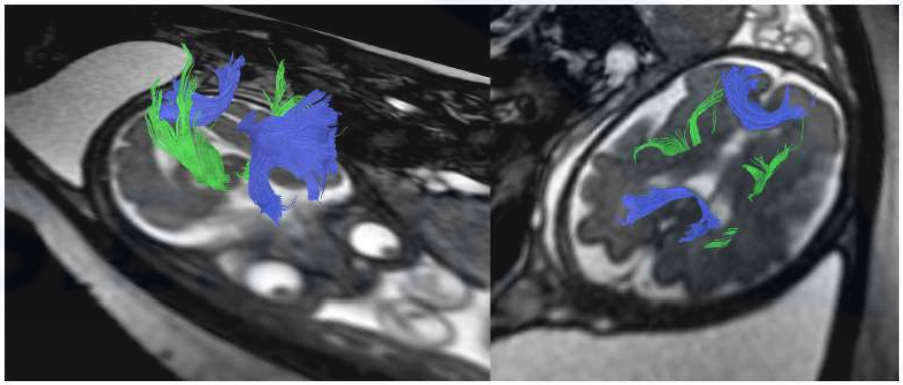

Fig. 3. Fetal diffusion tensor imaging demonstrating corpus callosum (blue) and sensorimotor tract (green) fibers in a 28 wk old fetus in utero.

Summary.

- Fetal MRI is a complementary diagnostic tool for CNS fetal abnormalities.
- Is very sensible to detect anomalies related to infections or monochorial twins pathology and has to be performed when the US is normal.
- More sensible that US in detecting abnormalities related to migration , surcation and cortical organization.
- Advances sequences as DWI can help to detect acute ischemic lesions. Although other sequences are difficult to applied due to movements artefacts.

Molto Obligado

Muchas Gracias

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