

# Radiologia de Fusão



## RM Fetal

### Temas de Investigação Atual

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# Outline

- Guidelines ISUOG
- **Temas de Investigação Atual**
- Segurança
- *Technicalities*
- *Motion Correction*
- Estudos cerebrais
  - MRS
  - DWI / DTI
  - rs-fMRI
- Estudos Cardíacos

# Guidelines para RM Fetal



- *Clinical Standards e Educational Recommendations, 2017*

**Table 2** Steps in performance of fetal magnetic resonance imaging (MRI)

Indication	Dependent on quality of previous ultrasound examinations, clinical question and gestational age
Counseling of pregnant woman	Explanation of indication, performance, expected outcome and consequences of the procedure, information about the possibility of an accompanying person, discussion with respect to contraindications and claustrophobia and sedative drug prescription if necessary
Prerequisites for MRI unit	Written referral with clear indication of clinical question(s), ultrasound report and images (if possible), gestational age confirmed/determined by first-trimester ultrasound
At the MRI unit	Clarification of possible contraindications, comfortable positioning of woman (either supine or lateral decubitus position), adequate coil positioning, performance of examination according to pertinent protocol <b>Otimização de seqüências; redução de artefatos; 30' tempo scan; 3T</b>
After examination	Inform patient about when the report will be ready; in the case of immediate consequences resulting from MRI examination, information regarding results should be provided promptly to the referring physician
Storage of images, report	Electronic storage of images, analysis of images, structured reporting (Table 3)

# Segurança

## • Ruído Acústico:

- Correntes alternadas no Sistema Vestibular
- Organ de Corti. “(...) *unclear* be applied to the fetus (...) *cochlea is developed* middle ear cavity are fluid-filled (...)”
- Health and Safety Experts (HSE)/ Am.Acad.Pediatrics: **INCONCLUSIVO** – biótipo materno; vol. líquido amniótico; seq. efetuadas e tempo de scan
- Glover *et al.* (...) *microphone into the fluid-filled stomach of a volunteer, and found a >30 dB attenuation. This provides some reassurance that a level close to the instantaneous damage threshold (120 dB) could be reduced to an acceptable level (<90 dB) (...)*

[Safety of MR Imaging at 1.5 T in Fetuses: A Retrospective Case-Control Study of Birth Weights and the Effects of Acoustic Noise.](#)

Strizek B, Jani JC, Mucyo E, De Keyzer F, Pauwels I, Ziane S, Mansbach AL, Deltenre P, Cos T, Cannie MM.

Radology. 2015 May;275(2):530-7. doi: 10.1148/radiol.14141382. Epub 2015 Jan 7.

PMID: 25575119

[Similar articles](#)

[A review of the current use of magnetic resonance imaging in pregnancy and safety: implications for the fetus.](#)

De Wilde JP, Rivers AW, Price DL.

Prog Biophys Mol Biol. 2005 Feb-Apr;87(2-3):335-53. Review.

PMID: 15556670

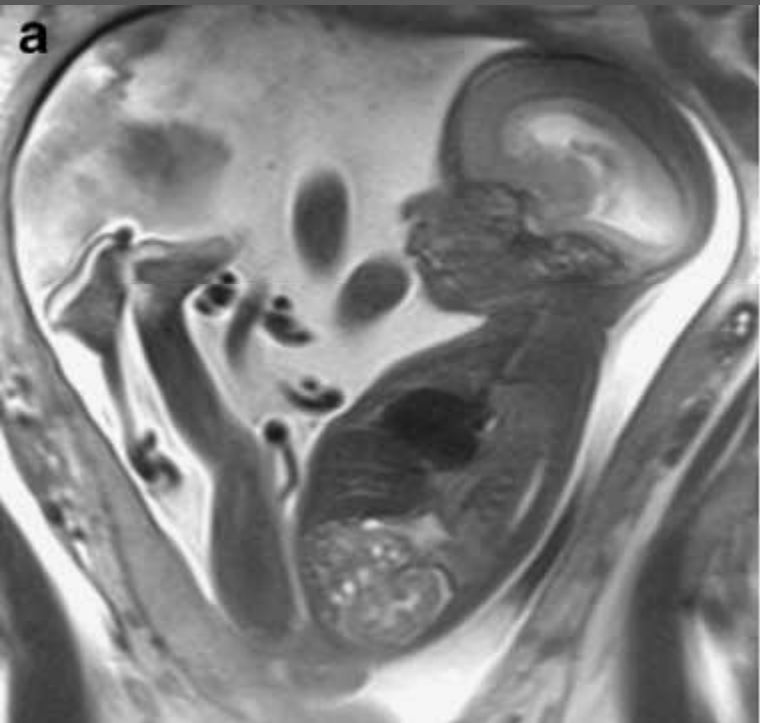
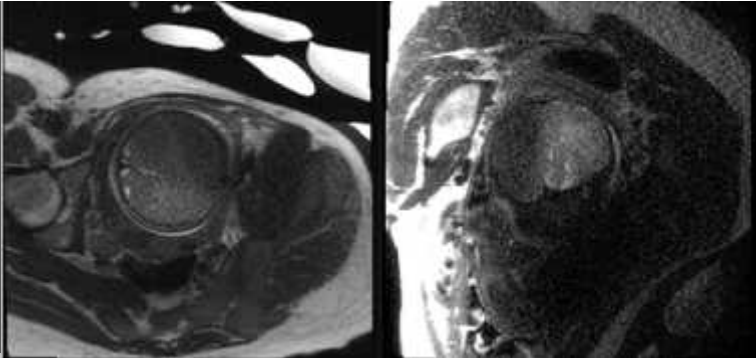
[Similar articles](#)

# Segurança

- **Exposição à RF:** hipertermia a B0, B1, biótipo mãe, resistência tecidos, t. de scan
  - Alteração temperatura 0.5°C mãe: feto < 38°C
- **IEC 60601-2-33: pregnant women (...) normal operating mode  $\leq$ wbSAR is limited to 2 W/kg**
- *the fetal whole body SAR was less than 1.24 W/kg and 1.14 W/kg at 1.5 and 3T, respectively. Based on these findings, they suggested limiting continuous RF exposure to 7.5 min*

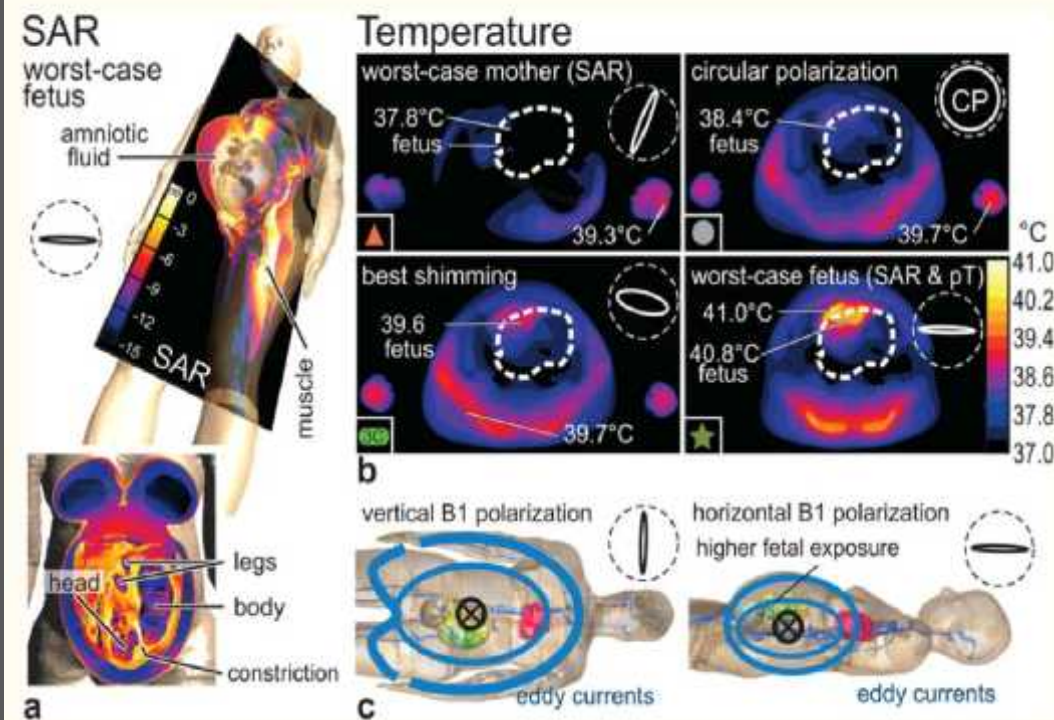
*Concepts Magn Reson 2014;43(6):237-66; Topics in MRI 2011;22(3):119-31; Phys Med Biol. 2010;55(4):913-30*

3T



# “Technicalities”

*Magn Reson Med.* 2017; 77(5): 2048–56



## Pregnant women models analyzed for RF exposure and temperature increase in 3T RF shimmed birdcages.

Murbach M, Neufeld E, Samaras T, Córcoles J, Robb FJ, Kainz W, Kuster N.  
*Magn Reson Med.* 2017 May;77(5):2048-2056. doi: 10.1002/mrm.26265. Epub 2016 May 13.  
 PMID: 27174499 [Free PMC Article](#)  
[Similar articles](#)

## Local SAR enhancements in anatomically correct children and adult models as a function of position within 1.5 T MR body coil.

Murbach M, Cabot E, Neufeld E, Gosselin MC, Christ A, Pruessmann KP, Kuster N.  
*Prog Biophys Mol Biol.* 2011 Dec;107(3):428-33. doi: 10.1016/j.pbiomolbio.2011.09.017. Epub 2011 Sep 22.  
 PMID: 21964524  
[Similar articles](#)

## Thermal thresholds for teratogenicity, reproduction, and development.

Ziskin MC, Morrissey J.  
*Int J Hyperthermia.* 2011;27(4):374-87. doi: 10.3109/02656736.2011.553769. Review.  
 PMID: 21591900  
[Similar articles](#)

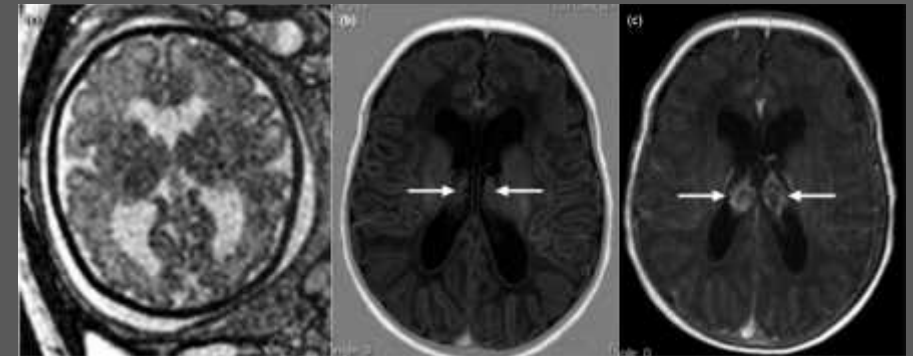
## Numerical study of RF exposure and the resulting temperature rise in the foetus during a magnetic resonance procedure.

Hand JW, Li Y, Hajnal JV.  
*Phys Med Biol.* 2010 Feb 21;55(4):913-30. doi: 10.1088/0031-9155/55/4/001. Epub 2010 Jan 20.  
 PMID: 20090188  
[Similar articles](#)

*Concepts Magn Reson* 2014;43(6):237-66; *Topics in MRI* 2011;22(3):119-31; *Phys Med Biol.* 2010;55(4):913-30

# Segurança

- **Administração do Gadolínio:**
  - Medicamento da classe C em grávidas
  - Sem indicações documentadas
  - Estudos animais: morte fetal e anomalias congénitas



**CFP·MFC** Official Publication of The College of Family Physicians of Canada

Can Fam Physician. 2006 Mar 10; 52(3): 309-310.

### Safety of gadolinium during pregnancy

Facundo Garcia-Bourmissen, MD, Alon Shrim, MD, and Gideon Koren.

### Guidelines

The European Society of Radiology has issued a guideline<sup>19</sup> on the use of iodinated and gadolinium contrast media during pregnancy and lactation. Their conclusion is that gadolinium is probably safe because small quantities are not expected to cross the placenta or to be toxic to the fetus. The guidelines also state that, given that gadolinium is mainly distributed to the placenta and rapidly eliminated by the kidney, in the unlikely event that some gadolinium would be rapidly eliminated into urine.<sup>19</sup>

Go to: (v)

The use of iodinated and gadolinium contrast media during pregnancy and lactation.

Webb JA, Thomsen HS, Morcos SK, Members of Contrast Media Safety Committee of European Society of Urogenital Radiology (ESUR). Eur Radiol. 2005 Jun; 15(6):1234-40. [PubMed] [Ref list]

### Intravenous Gadolinium Contrast for Fetal MRI

There are no absolute fetal or placental indications for the administration of intravenous gadolinium contrast agents (category C drug) and therefore administration of these agents for these specific indications is not usually indicated. While there is a report of a small number of patients administered gadolinium contrast in the first trimester, with none having experienced congenital defects, there is no literature to prove its fetal safety [28]. Gadolinium agents are not known at this time to be teratogenic [29-34]. However these agents do enter fetal-placental circulation and amniotic fluid potentially creating an environment where dissociation of toxic free gadolinium may occur by way of delayed excretion [35-37].

Please note that gadolinium contrast agents may be considered in the rare instance of a serious maternal indication, a discussion beyond the scope of this section.



*Comparing 1<sup>st</sup>-trimester MRI (n = 1737) to no MRI (n = 1 418 451): NO SIG DIFFERENCE OR ASSOCIATION/ORatio.*

*The risk was also not significantly higher for congenital anomalies, neoplasm, or vision or hearing loss.*

*Comparing gadolinium MRI (n = 397) with no MRI (n = 1 418 451), the hazard ratio for NSF-like outcomes was*

*not statistically significant*



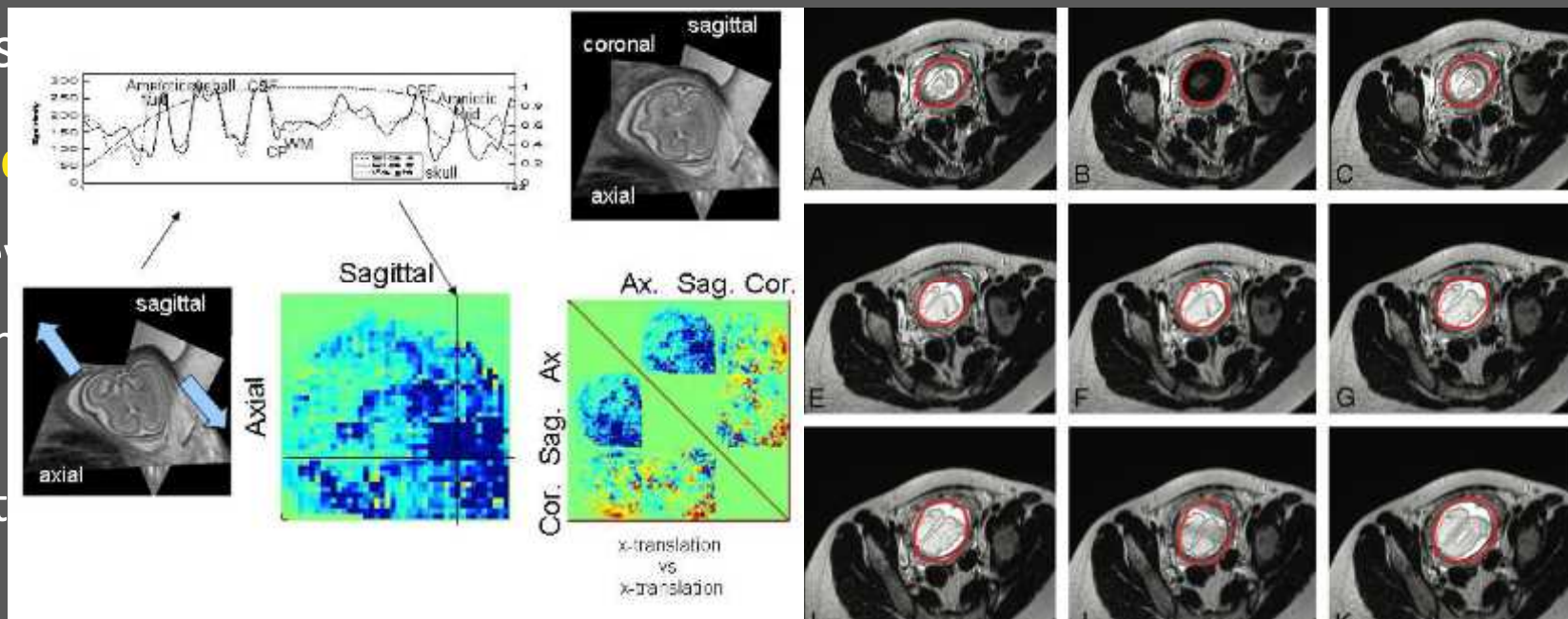
**Conclusions and Relevance** Exposure to MRI during the first trimester of pregnancy compared with nonexposure was not associated with increased risk of harm to the fetus or in early childhood.

Gadolinium MRI at any time during pregnancy was associated with an increased risk of a broad set of rheumatological, inflammatory, or infiltrative skin conditions and for stillbirth or neonatal death. The study may not have been able to detect rare adverse outcomes.

JAMA 2016;316(9):952-61

# Motion Correction

- Incons
- Estrat
- Pre
- Min
- Det

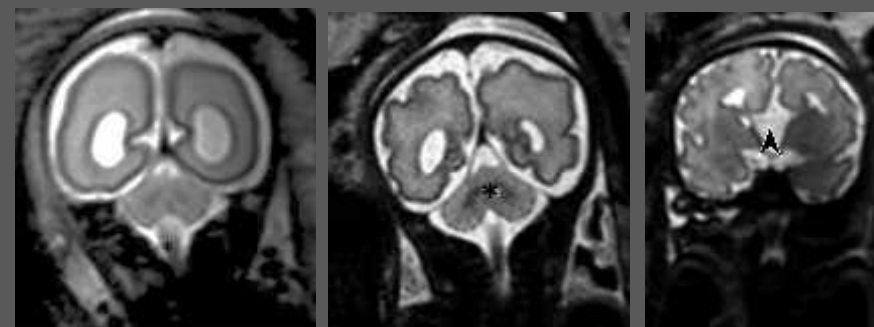
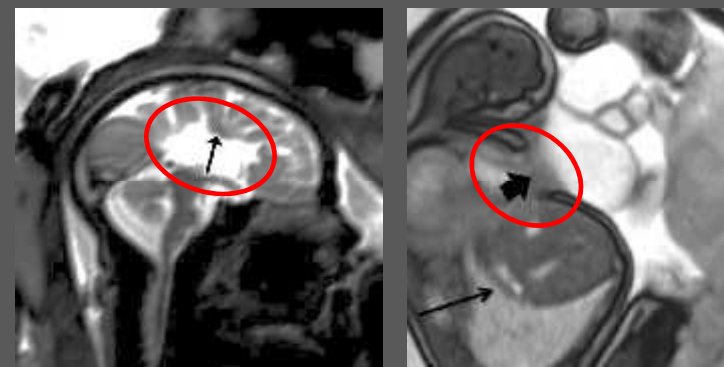
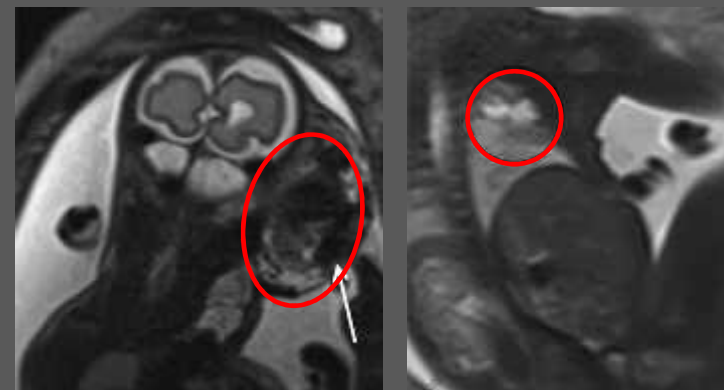


- **Pós-processamento:** algoritmos que compensam movimentos de rotação e translação, *in-plane*, *through plane*

Annu Rev Biomed Eng. 2011;13:345-68; AJNR. 2013;34(6):1124-36

# Indicações para RM Fetal

- Pescoço; Pat. Malformativa **Cardíaca** (*triggering*); Tórax; Abdómen
- Teratoma Sacrococcígeo; Malformações vertebrais/medulares (mielomeningocelo)
- Anomalias craniofaciais
- **SNC:** ventriculomegalia; anomalias do CC; hemorragia; padrão sulcação; heterotopias, charneira CCervical



*La radiologia medica*;2018;123:271-85; *Hong Kong Med J* 2016;22:270-8; *J. of Adv Research* 2014;5:507-23

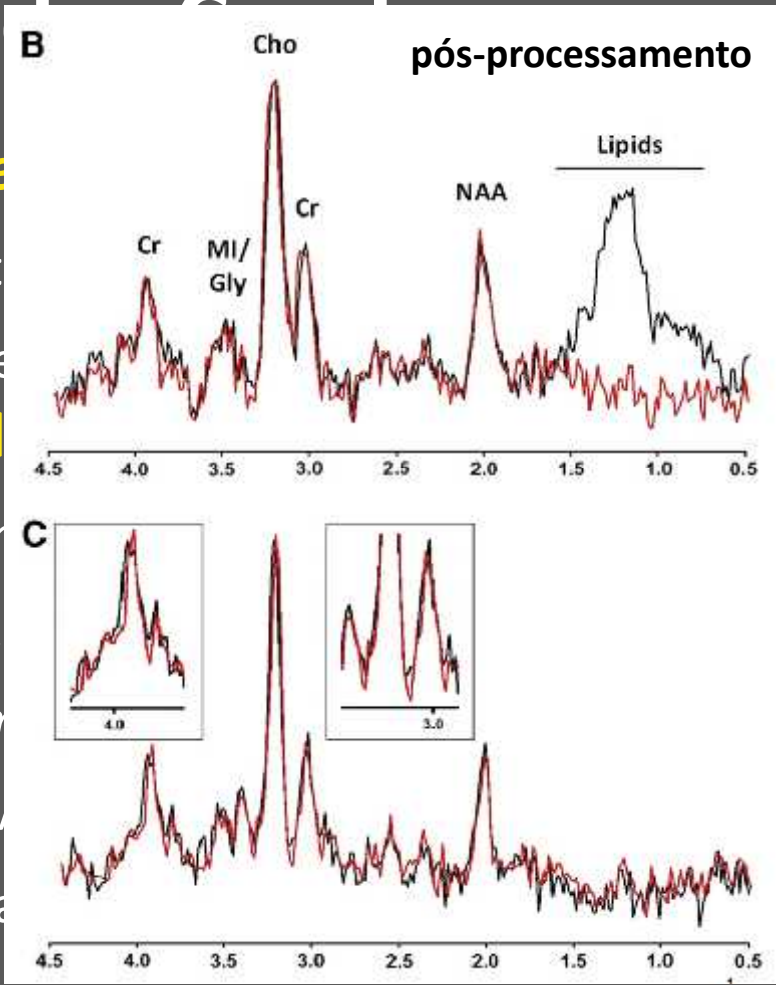
# Estudo de caso

- **MRSpe**

- Mat
- Encé

- **Qualid**

- Hom
- SNR
- *Shim*
- Mov
- Seda



*AJOG 2015;213(5):741-2*

*Concepts Magn Reson 2014;43(6):237-66*



*AJNR 2013;34(2):424-31*

ORIGINAL RESEARCH  
**PEDIATRICS**

## MR Spectroscopy of the Fetal Brain: Is It Possible without Sedation?

V. Berger-Kulemann, P.C. Brugger, D. Pugas, M. Krssak, M. Weber, A. Wielandner, and D. Prayer

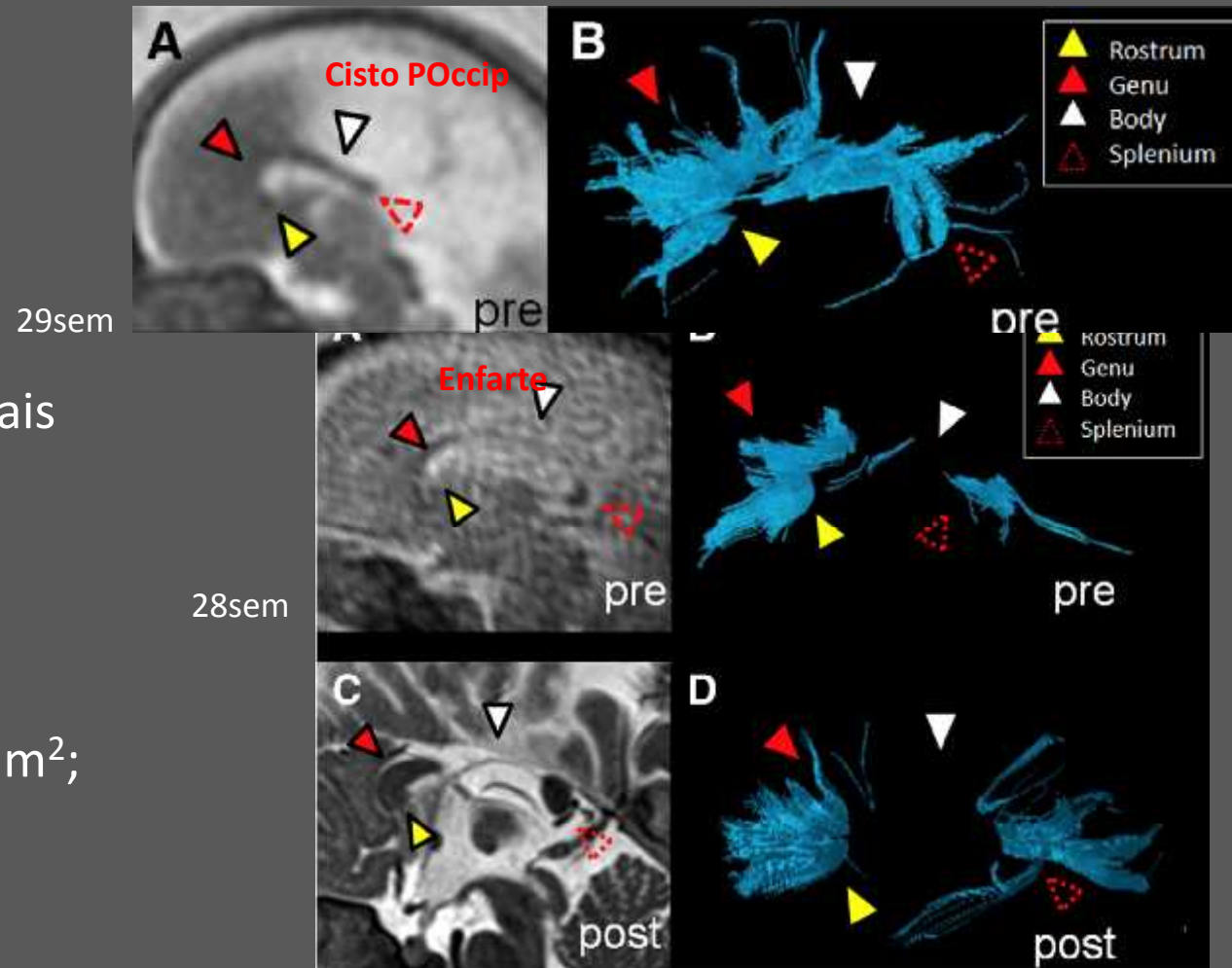
Peak	Position	SNR	width	height	FWHM	Area	AUC	Peak	Position	SNR	width	height	FWHM	Area	AUC
NAA	2.017	3.4	0.107	1.628	1.882	0.273	1.987	Cho	3.244	3.2	0.107	1.073	1.186	0.194	1.186
Cho	3.244	3.2	0.107	1.073	1.186	0.194	1.186	Cr	3.921	3.7	0.102	1.166	0.987	0.209	1.273

entação)

# Estudos Cerebrais

## • DWI/DTI

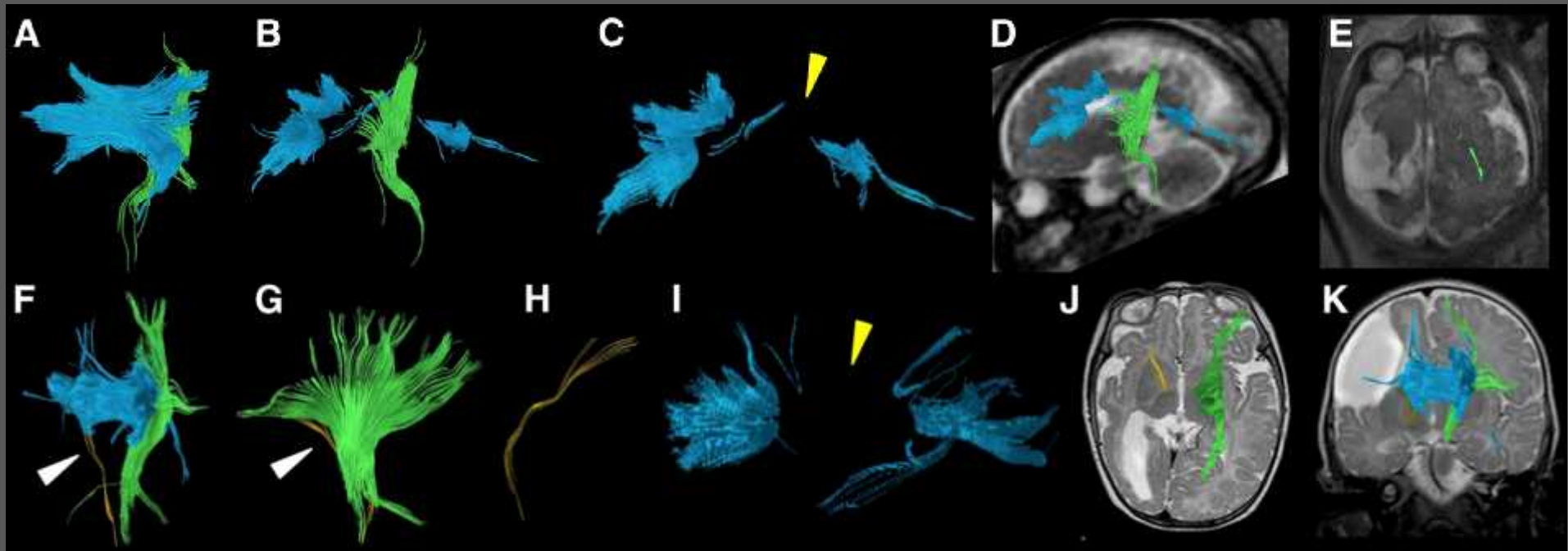
- Predição de consequências funcionais de alterações estruturais
- Arquitetura de malformações complexas
- Song *et al.* (2018): 12 casos; DTI 16 direções; b-values 0,700s/mm<sup>2</sup>; thick 3mm; 1:16min; algoritmo determinístico



# Estudos Cerebrais

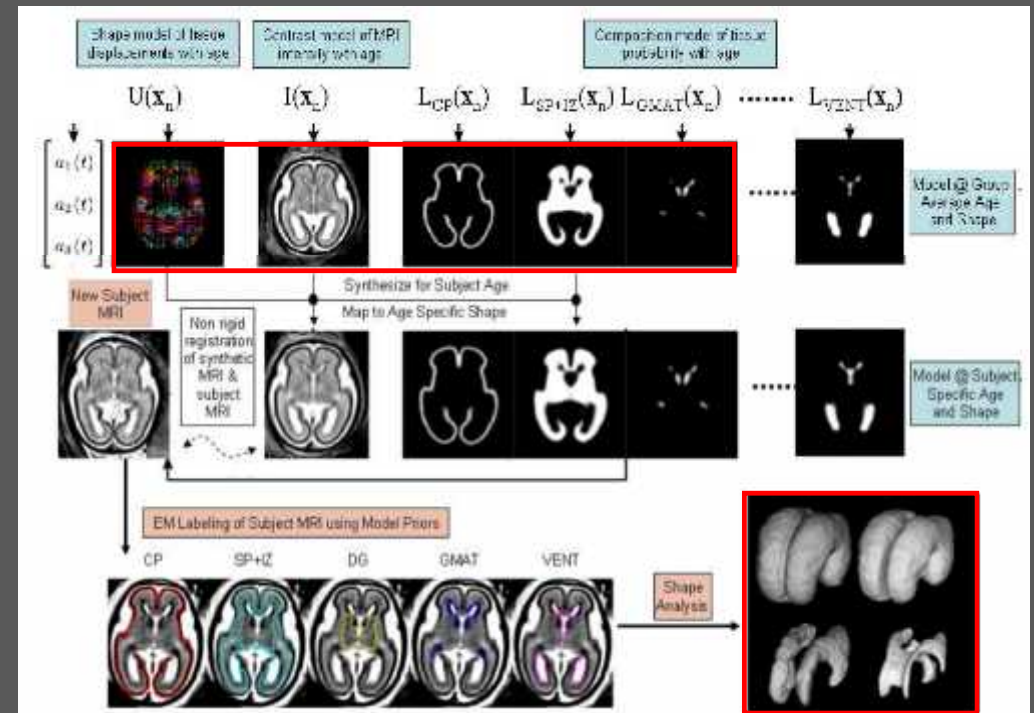
	Corpus callosum				Corticospinal tracts	
	Rostrum	Genu	Body	Splenium	Right	Left
Positive predictive value	100.0%	100.0%	50.0%	87.5%	100.0%	88.9%
Negative predictive value	33.3%	25%	80.0%	50.0%	50.0%	33.3%
Accuracy	66.7%	75.0%	75.0%	66.7%	91.7%	75.0%

33sem



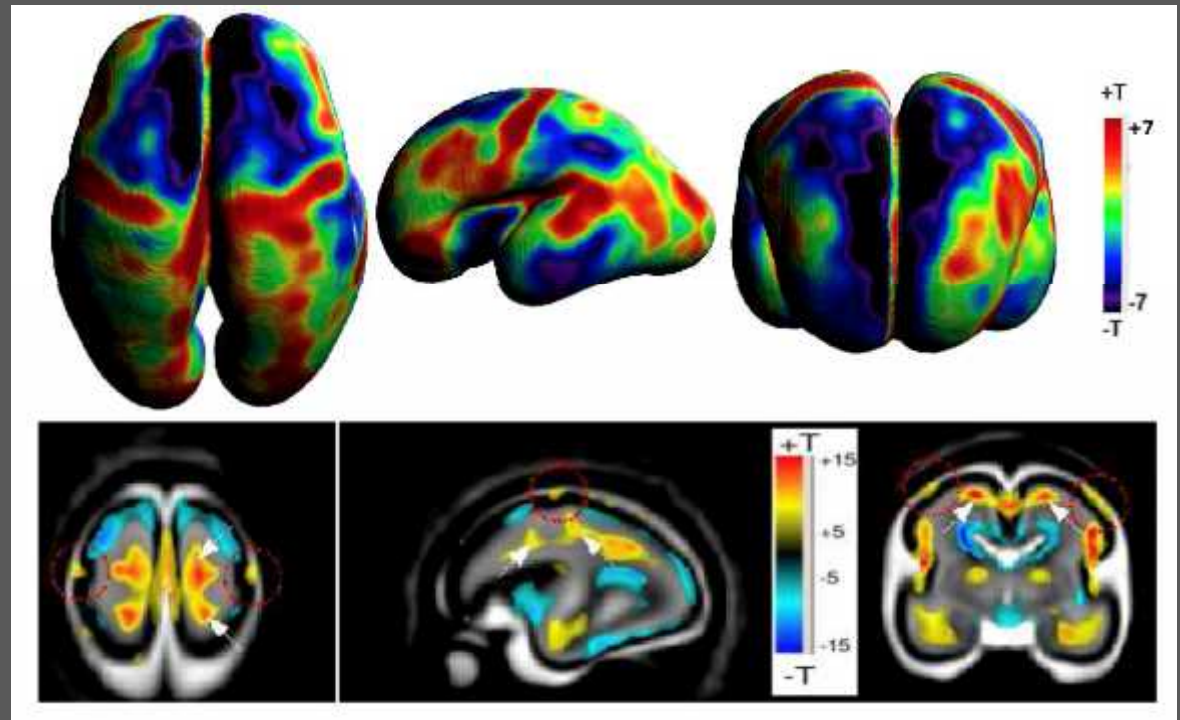
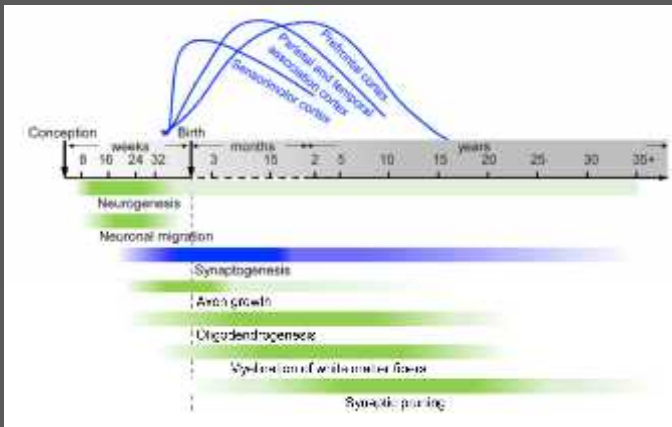
# Estudos Cerebrais

- **Mapping do Desenvolvimento Fetal** (imagens estruturais)
- **Mapas paramétricos probabilísticos** das áreas cerebrais em desenvolvimento para a idade gestacional

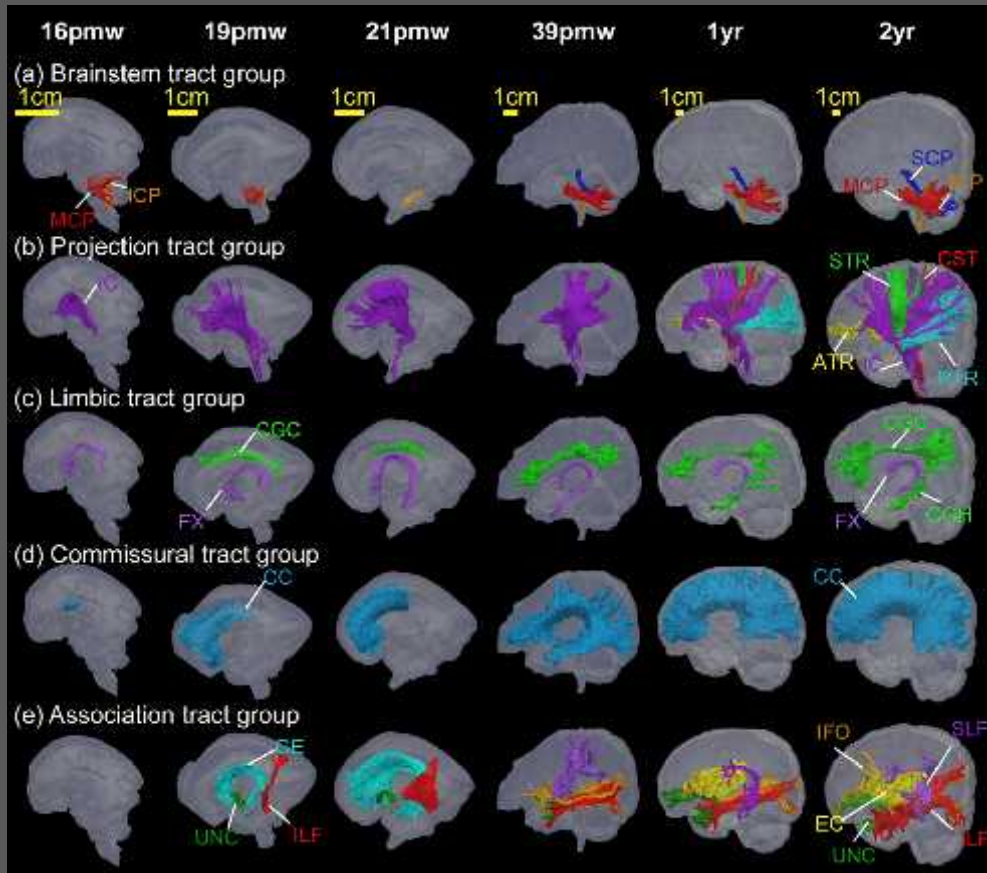


# Estudos Cerebrais

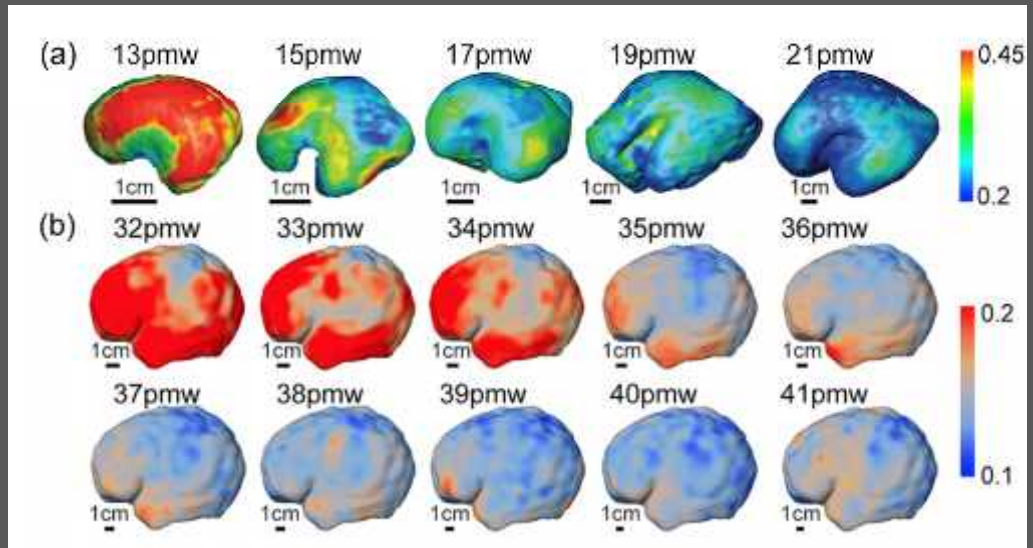
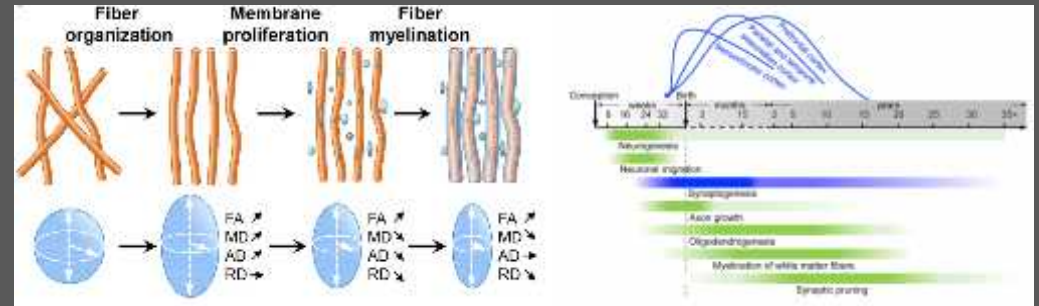
(...) **Tensor Based Morphometry** to detect the locally varying pattern of expansion of tissue (regions that grow faster or slower than the overall brain), indicating where additional cortical complexity is being added. (...)



• **Mapping do Desenvolvimento Fetal (DTI)**



Maturação cerebral – mielinização

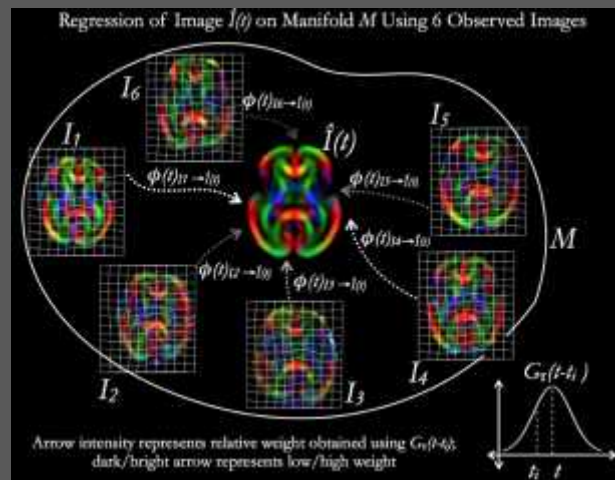


Mapping of FA onto the cortical surface

Neuroimage 2018 April 23; Neuroimage. 2018 Apr 12

# Motion Correction

- Khan *et al.* (2018):
  - 7(60 datasets) casos; DTI 12 direções; b-values 0,500s/mm<sup>2</sup>; thick 2-4mm; 3-10min
  - *Motion-correction post processing*




NeuroImage: Clinical 15 (2017) 611–612

Contents lists available at ScienceDirect

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NeuroImage: Clinical

journal homepage: [www.elsevier.com/locate/ynicl](http://www.elsevier.com/locate/ynicl)

**In utero diffusion tensor imaging of the fetal brain: A reproducibility study** 

András Jakab<sup>a,b,\*</sup>, Ruth Tuura<sup>a</sup>, Christian Kellenberger<sup>c</sup>, Ianina Scheer<sup>c</sup>

**A B S T R A C T**

Our purpose was to evaluate the within-subject reproducibility of *in utero* diffusion tensor imaging (DTI) metrics and the visibility of major white matter structures.

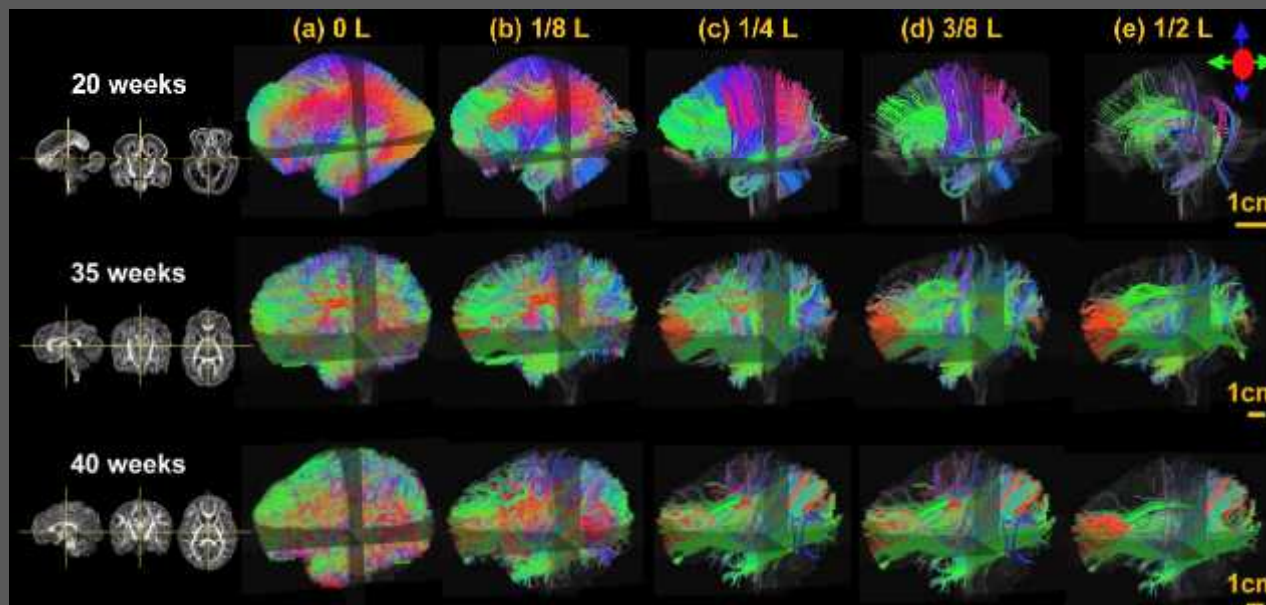
Images for 30 fetuses (20–33, postmenstrual weeks, normal neurodevelopment: 6 cases, cerebral pathology: 24 cases) were acquired on 1.5 T or 3.0 T MRI. DTI with 15 diffusion-weighting directions was repeated three times for each case, TR/TE: 2200/63 ms, voxel size: 1 × 1 mm, slice thickness: 3–5 mm, b-factor: 700 s/mm<sup>2</sup>. Reproducibility was evaluated from structure detectability, variability of DTI measures using the coefficient of variation (CV), image correlation and structural similarity across repeated scans for six selected structures. The effect of age, scanner type, presence of pathology was determined using Wilcoxon rank sum test.

White matter structures were detectable in the following percentage of fetuses in at least two of the three repeated scans: corpus callosum genu 76%, splenium 64%, internal capsule, posterior limb 60%, brainstem fibers 40% and temporooccipital association pathways 60%. The mean CV of DTI metrics ranged between 3% and 14.6% and we measured higher reproducibility in fetuses with normal brain development. Head motion was negatively correlated with reproducibility, this effect was partially ameliorated by motion-correction algorithm using image registration. Structures on 3.0 T had higher variability both with- and without motion correction.

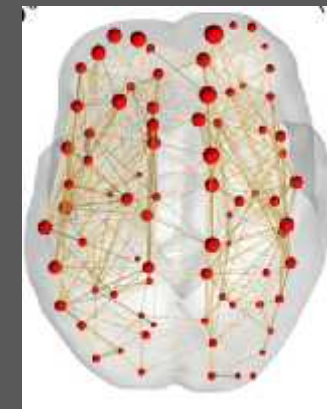
Fetal DTI is reproducible for projection and commissural bundles during mid-gestation, however, in 16–30% of the cases, data were corrupted by artifacts, resulting in impaired detection of white matter structures. To achieve robust results for the quantitative analysis of diffusivity and anisotropy values, fetal-specific image processing is recommended and repeated DTI is needed to ensure the detectability of fiber pathways.

# Fetal Brain Structural Connectome

(Oct 2017)



*b-values 0 e 1000 s/mm<sup>2</sup>; 30 dir; 11min*



# Fetal Brain Functional Connectome

- **resting-state fMRI**

- *Fetal rs functional connectivity (...) advance knowledge of human neurodevelopment and even predict, birth outcomes and child psychopathology in utero*
- *fetal functional connectivity development may follow both medial-to-lateral and posterior-to-anterior patterns of development*

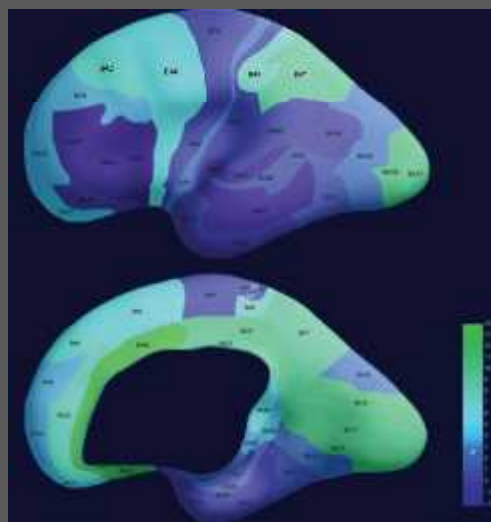
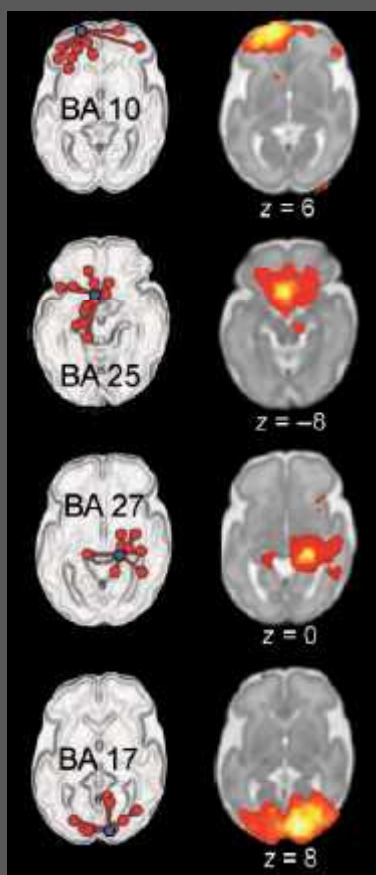


*Trends Cogn Sci. 201620(12):931–9*

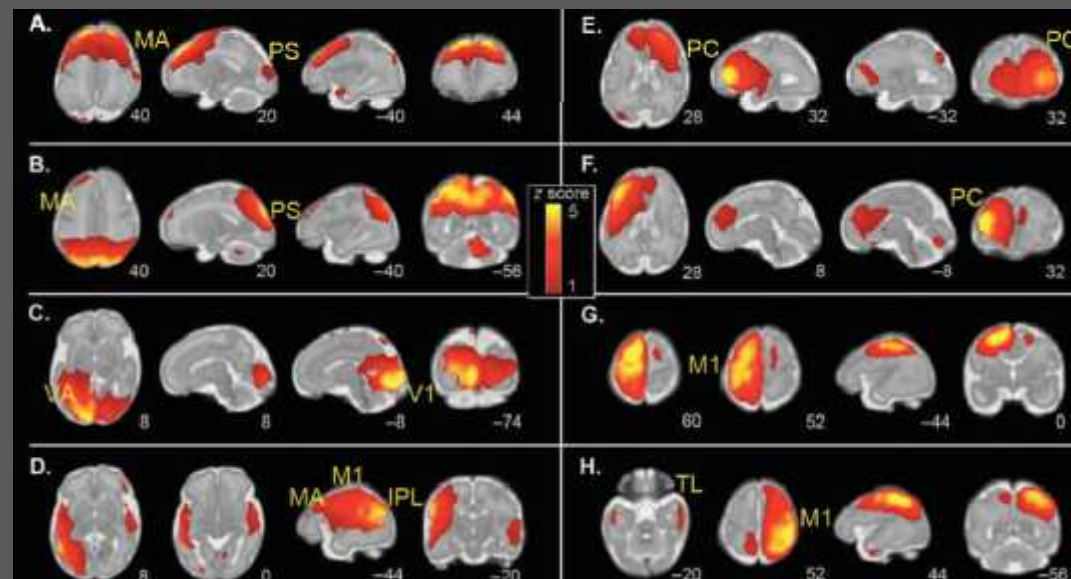
# Fetal Brain Functional Connectome

seed areas functional connectivity maps

BA = area funcional do mapa de Brodman



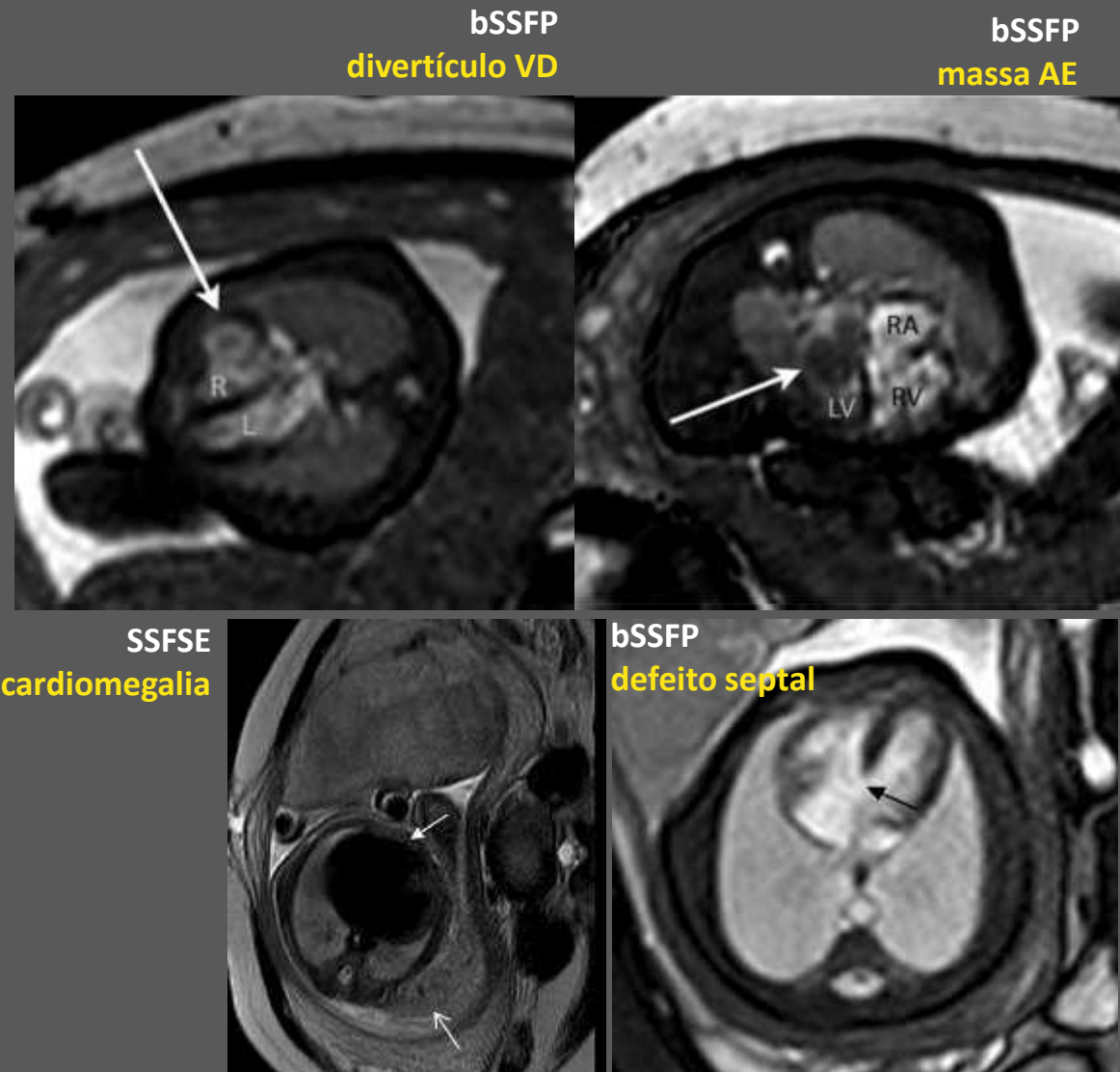
Group ICA of spontaneous fMRI activity patterns in 25 fetuses (24 to 28 weeks of gestation)



Sci Transl Med. 2013;5(173):173ra24.

# Estudos Cardíacos

- Fogel MA *et al.* 2005
- **Desafios Técnicos**
  - Ausência de sinal ECG para sincronizar as sequências
  - Movimento incoerente e imprevisível do feto
  - Tamanho ↓
- **Imagens estáticas**
- **Sequências SSFP sem *trigger***

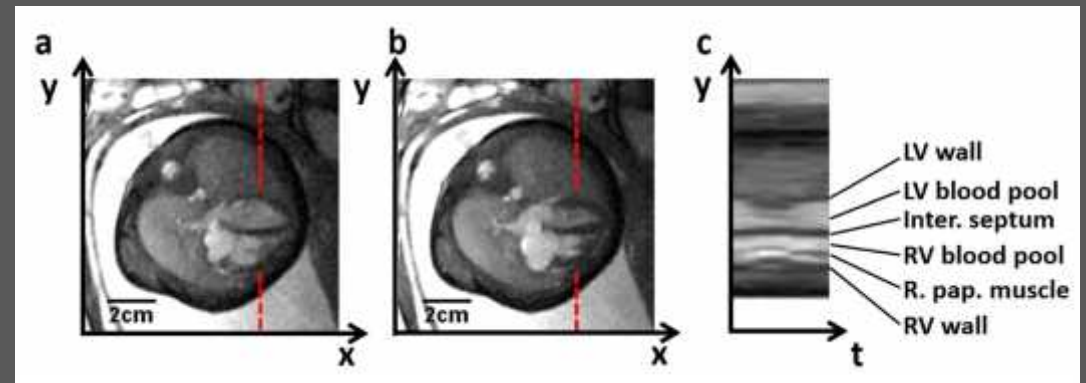
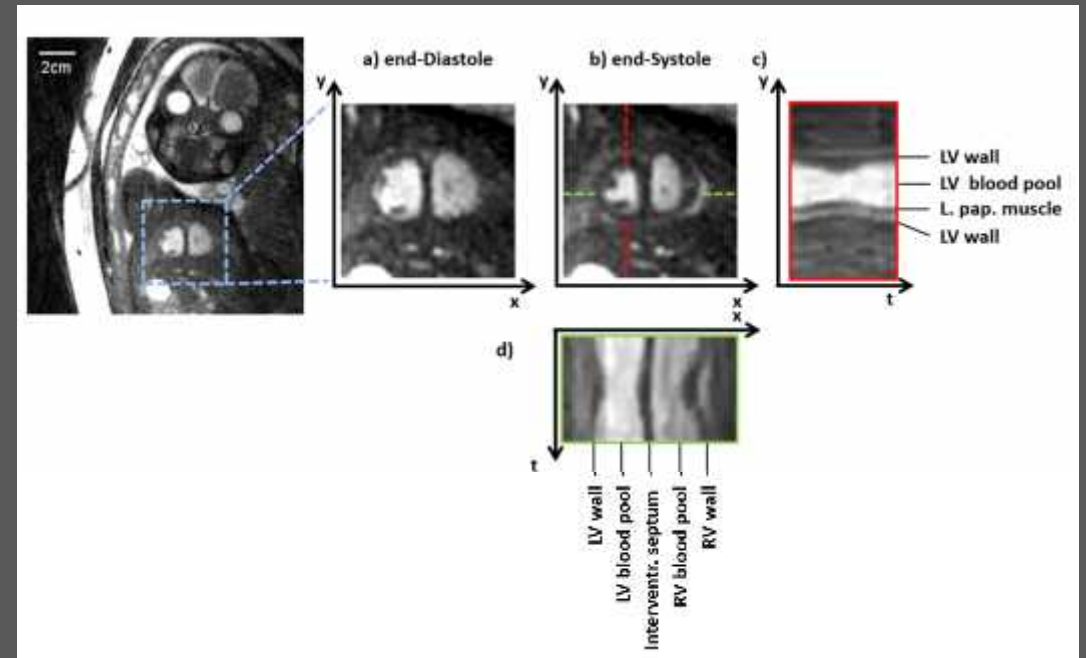


Springerplus. 2016 Jul 29;5(1):1214; Springerplus. 2016;29;5(1):1214

# Estudos Cardíacos

- **Self-gating: detetar as contrações tendo como base info das imagens**

- Modulação da amplit. do sinal no centro do k-space
- *Metric Optimized Gating*: estimar iterativamente o ECG ao minimizar a entropia relacionada c/ artefatos *ghosting*
- *Self-gated retrospective* (Chaptinel *et al.* 2017)



Nature Scientific Reports 2017;7(15540)

# Conclusões

- Movimento fetal é um *major issue*
- Sequências rápidas, fator de aceleração
- *Hardware*
- Utilização clínica generalizada: **PÓS-PROCESSAMENTO**

