Functional MRI: basic concepts and applications in fetal imaging

Eduard Gratacos
Center of Maternal-Fetal Medicine and Neonatology
Hospitals Clinic & Sant Joan de Deu - University of Barcelona
www.medicinafetalbarcelona.org
1. Studying the fetal-neonatal brain is relevant

2. Methods for MRI brain evaluation

3. fMRI basics

4. Evidence in fetal medicine
1. Studying the fetal-neonatal brain is relevant

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3. fMRI basics

4. Evidence in fetal medicine
preterm/infection
IUGR/preeclampsia
cardiac defects
ART pregnancies
1. Studying the fetal-neonatal brain is relevant

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Sulcation

Voxel Deformation

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What is functional MRI (BOLD)?

Blood Oxygen Level Dependent

BOLD signal results from a complicated mixture of these parameters

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Stuart Clare, FMRIB Centre, University of Oxford
Types of fMRI

Task-evoked

Activation of specific brain areas

Baseline activity

Resting state

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fMRI: Task Evoked
fMRI: Resting state
Resting state: a pre-activated state
Correlation between structure and function
Resting state: a pre-activated state
Correlation between structure and function
Functional resting state networks to study brain connectivity

Seed-based analysis
Areas correlated with defined region of interest

Independent component analysis
- Default Mode Network
- Visual Network
- Somatosensory and motor Network
- Auditory Network
- Prefrontal Network

Connectomics
Resting state in cognitive disorders

Autism spectrum disorder

DMN is separated in different components
Less connectivity

Attention deficit hiperactivity disorder

Decreased connectivity in Putamen and changes in pattern of connection of this region

Internodal connectivity controls>ASD
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fMRI resting state in fetal / neonatal medicine

Opportunity:
resting state networks

Challenges:
- Movement (requires sedation/natural sleep)
- Task-evoked impossible
fMRI resting state in fetal / neonatal medicine

Opportunity:
resting state networks

Challenges:
• Movement (requires sedation/natural sleep)
• Task-evoked impossible
Neonates have resting state networks.

Primary visual areas

Somatosensory and motor

Auditory

Posterior lateral and cerebellum

Prefrontal

Fransson et al. PNAS. 2007

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There is a pattern of changes in network throughout neonatal and infant’s life
Resting state is different in preterm newborns

<table>
<thead>
<tr>
<th>Region</th>
<th>Early preterm</th>
<th>Preterm</th>
<th>Term equivalent</th>
<th>Term controls</th>
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<tbody>
<tr>
<td>Medial visual</td>
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<td>Lateral visual</td>
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<td>Auditory</td>
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<td>Cerebellum</td>
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<td>Brainstem-thalami</td>
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<td>DMN</td>
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<tr>
<td>Dorsal visual stream left</td>
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<tr>
<td>Dorsal visual stream right</td>
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<tr>
<td>Executive control</td>
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</tbody>
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Doria et al. PNAS. 2010,
Smyser et al Cerebral Cortex. 2010.

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Resting state connectomics different in IUGR newborns

- Structural MRI
- Brain parcellation

- Functional MRI

- Individual connectomes
  - Global characteristics
  - Regional characteristics

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Resting state connectomics different in IUGR newborns

Structural MRI

Brain parcellation

Functional MRI

Individual connectomes

Global characteristics

Regional characteristics

Global efficiency

Local efficiency

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Adjusted by GA delivery, gender, breastfeeding and age at MRI
IUGR newborns have different regional networks in resting state
IUGR newborns have different regional networks in resting state.

**NODAL EFFICIENCY AND NODAL STRENGTH**

Control > IUGR

IUGR > Control

$p < 0.05$
Resting state is also detectable in fetuses

Motor association cortex; peristriate cortex; primary visual and visual association cortex; inferior parietal lobule, primary motor and motor association cortex; right frontal cortex; left frontal cortex; left primary motor cortex; and right primary motor cortex and bilateral temporal lobe.
fMRI evaluates brain activity

Resting state networks correlate with neurostructure and are useful to compare subtle brain differences

Resting state occurs in fetuses and neonates and is different under pathological conditions

fMRI: promising tool for assessing impact of prenatal conditions. Requires research and technological evolution to be clinically relevant