Optimising MR Imaging protocols

Dr Christina Malamateniou
Lecturer in Perinatal Imaging, King’s College London, christina.malamateniou@kcl.ac.uk
Honorary research fellow, Hammersmith Hospital, Imperial College London, cm1@imperial.ac.uk
Study group: fetal patients

• Lies at the extreme of any other paediatric population
• It is perhaps the most difficult case to optimise MRI for.
• Fetal neuro focus
Fetal MRI

- Fetal MRI introduced in 1983 (Smith FH et al, Lancet)
- A useful diagnostic tool, complimentary to obstetric ultrasound (Whitby et al., 2001; Levine et al., 2003; Coackley et al, 2004, Dietrich et al., 2006)
- Structural MRI for congenital abnormalities (T1w, T2w)
- Quality of fetal MRI scans is vital for diagnosis
T2-weighted as the mainstay fetal brain MRI tool
Learning objectives

• 1. What makes these patients a unique population?
• 2. Which are the challenges associated with fetal MRI optimisation?
• 3. Which are the remedies?
• 4. An example of optimising fetal brain MRI.
Why is this population unique?

- Anatomy of interest is very small
- Fast developing
- Motion in unpredictable and uncontrollable
- Inside maternal body → in-homogeneity of surrounding tissues including maternal fat, amniotic fluid, maternal soft tissue
Fetal MRI challenges
Image quality optimisation process in MRI

- Time
- Resolution
- Contrast

SNR

Artefacts

Safety limits: SAR, acoustic noise
Challenges

• **Poor Signal to Noise Ratio**
  – Minute fetal anatomy in coils designed for adult anatomy
  – Coil positioning relative to position of the anatomy of interest (often uncertain and variable)

• **Motion artefacts**
  – Maternal motion
  – Fetal motion
Signal to Noise Ratio (SNR) issues
Signal to noise ratio considerations

• For a given field strength
  – Receiver coil type
  – Coil positioning
  – Maternal size and distance from brain
  – Fetal presentation and positioning
  – Scan parameters
Coils used

Multi-channel phased array or cardiac surface coils

Sense Cardiac Coil with five elements
Signal-to-noise in fetal MR

T2 weighted images

1. Patient presentation
2. Head deep in pelvis
3. Maternal BMI > 40

c/o Georgia Lockwood-Estrin, PhD student
Coil Placement, maternal anatomy, fetal size

AIM: To have good signal to noise ratio (SNR)
Coil Placement

c/o Amy Mc Guinness, Research Radiographer
Maximising SNR

• Optimal coil positioning
• Reposition coil after first scan, if required

• Use of spin echo acquisitions where feasible
• Minimum TE
• More signal averages (NSA, NEX etc..)
Patient motion and associated artefacts
Motion in fetal MRI: negative effects

Motion artefacts may:
- degrade image quality
- overlap with normal anatomy
- hide or mimick pathology
- decrease diagnostic confidence
- may turn images non-diagnostic

MILD

MODERATE

SEVERE
Maternal motion characteristics

- Voluntary (Bulk) motion
- Involuntary
  - Breathing
  - Peristalsis
Maternal breathing during MRI scan
What may provoke maternal motion

- Uncomfortable positioning
- Poor communication
- Maternal stress
Fetal motion characteristics

- Unpredictable (baby “chasing”)
- Uncontrollable
- Within flowing/moving maternal tissues
- Three-dimensional
- Substantial, considering relative sizes
A good T2-weighted examination
A poor T2–weighted examination
Fetal motion during MRI scan

Motion compensation techniques in neonatal and fetal MRI: a review, AJNR, e-pub May 10th 2012
Repertoire of fetal motion

Hayat T et al, 2011, AJNR
Fetal motion considerations

- Gestational age
- Range of neurological abnormalities
- Fetal presentation
- Maternal stress?
- Maternal nutrition?
Gestational age

18 GW

25 GW

36 GW

Courtesy Tayyib Hayat, PhD candidate, Robert Steiner MRI Unit
Aim to investigate factors influencing fetal head motion

A pre-scan motion assessment was conducted on all women undergoing a fetal MRI between November 2010 and July 2011

<table>
<thead>
<tr>
<th>Gestational age</th>
<th>Reason for scan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal BMI</td>
<td>Twins compared to singletons</td>
</tr>
<tr>
<td>Maternal temperature (before and after scan)</td>
<td>Time point during scan</td>
</tr>
<tr>
<td>Music listened to during scan</td>
<td>Controls compared to clinical scans</td>
</tr>
<tr>
<td>Fetal gender</td>
<td>Maternal exercise before scan</td>
</tr>
<tr>
<td>Fetal lie (breech, cephalic)</td>
<td>Maternal food intake before scan</td>
</tr>
<tr>
<td>Maternal anxiety (before and immediately after scanning)</td>
<td>Maternal caffeine intake before scan</td>
</tr>
</tbody>
</table>

c/o Georgia Lockwood-Estrin, PhD student
Motion Assessment - results

1. More head motion with younger gestation (p=0.01)

2. Control subjects have significantly less head motion than clinical. N.B. control data n = 7.

3. No significant correlation between fetal head motion and any other studied factor

4. No obvious method to decrease motion

120 mothers with pre-scan motion assessment.

c/o Georgia Lockwood-Estrin, PhD student
Maternal Anxiety

1. Anxiety scores reduced immediately after the scan, but before results are given
2. Anxiety reduced in patients coming for a repeat scan
3. No difference in anxiety scores between controls and clinical subjects.

Concern about the MR examination itself causes maternal anxiety

To decrease anxiety, we produced a short film - http://vimeo.com/37368763 - explaining the examination procedure.

c/o Georgia Lockwood-Estrin, PhD student
Fetal Presentation

Courtesy Tayyib Hayat, PhD candidate, Robert Steiner MRI Unit
Coping with motion
What to do about motion artefacts?

• Understand
• Minimise
• Correct
• Accept but re-orientate
• Accept and recognise (it may be useful!)
Motion artefact compensation strategies

• Patient preparation
• Optimisation of image acquisition
  – Fast acquisitions
  – Motion resistant acquisitions
  – Scanning Time reducing strategies
• Advanced Image Post-processing

Motion compensation techniques in neonatal and fetal MRI: a review, AJNR , e-pub May 10th 2012
I. Patient preparation: keeping moms happy and comfy!

- Nutrition,
- Fluids to a minimum,
- Empty bladder
- Acoustic noise reduction
- Comfortable (pillows, foam pads)
- Temperature maintained 24º degrees (fan, barefoot)
- Clear instructions
- Interpreter, if required
- Music, if requested
- Partner in room, if requested
Positioning

- 20º tilt on left side (inferior vena cava syndrome)
II. Data acquisition

– Fast imaging
  • Shortening scanning time by reducing TR, # of phases, # of averages
  • Half scan
  • Inherently faster sequences (FSE, EPI, Single shot etc)

– Different data sampling strategies
  • Radial
  • Spiral
  • PROPELLER/BLADE/Multi-VANE

– Parallel imaging (SENSE, GRAPPA, ASSET)

– Dynamic scans

– Navigators

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Multi-shot FSE vs Single-shot FSE

Multi-shot

Single-shot
An example of optimisation in the fetal MRI context

• Snapshot Inversion Recovery=SNAPIR
Coronal T1 w GRE
T1 FLAIR
axial T1 weighted on a 32 week fetus
Prayer D, 2004, Ped Rad

Coackley FV, 2004, AJR
Levine D, 2006, JMRI
Brunel H et al, 2004, J Neuror
Single shot inversion recovery: different TIs

(i) 200 msecs
(ii) 400 msecs
(iii) 600 msecs
(iv) 800 msecs
(v) 1000 msecs
(vi) 1200 msecs
Spatial resolution

1x1x4mm³
Snapshot Inversion Recovery

Conventional T1-weighted

Optimised SNAPIR
Snap IR

Conventional T1-weighted

Optimised SNAPIR

Malamateniou C, Mc Guinness AK, Allsop JM, O'Regan D, Rutherford MA, Hajnal JV, Radiology, 2011,
An Optimized Single-Shot T1-weighted Inversion-Recovery Sequence for Improved Fetal Brain Anatomic Delineation
## Protocol parameters

<table>
<thead>
<tr>
<th></th>
<th>SNAPIR</th>
<th>Standard T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence</td>
<td>SNAPIR</td>
<td>Standard T1</td>
</tr>
<tr>
<td>Breath hold</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>TE (msec)</td>
<td>8-9</td>
<td>6</td>
</tr>
<tr>
<td>(minimum)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR (msec)</td>
<td>20000 – 22000</td>
<td>142</td>
</tr>
<tr>
<td>(shortest)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOV (mm)</td>
<td>320 x 340</td>
<td>320 x 300</td>
</tr>
<tr>
<td>Resolution (mm)</td>
<td>1 x 1</td>
<td>1.2 x 1.6</td>
</tr>
<tr>
<td>Slice Thickness</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of slices</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>SENSE factor</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Half Fourier</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Water-Fat shift</td>
<td>0.75</td>
<td>0.921</td>
</tr>
<tr>
<td>(pixels)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Time</td>
<td>40 sec</td>
<td>17 sec</td>
</tr>
</tbody>
</table>
Neonatal SNAPIR

Ederies C et al, ISMRM 2011

McGuinness C et al, ISMRM 2011
III. Data reconstruction

- registration,
- realigning,
- reject analysis,
- thresh-holding techniques
- Advanced methods
  - Snapshot-to-Volume Reconstruction or SVR,
    » Rousseau F et al, Academic Radiology, 2006
33 weeks gestational age

4 transverse loops

Registered and reformatted

Ex utero 3 Tesla preterm infant 33 weeks

Jiang et al, IEEE TMI 2007
Conclusion I

• Fetal MRI is perhaps the most challenging area for patient motion
• Optimisation important in terms of
  – Patient preparation
  – Patient/coil positioning
  – Image protocol choice and optimisation
  – Image quality analysis
• Since there is currently not a single way to address the fetal motion problem interdisciplinary team work and effective communication of all medical imaging professionals is essential for a successful scan
Conclusion II

• Image quality is governed by many factors, often competing with each other
• Optimisation should take into account all these different factors but focus on the ones that really matter for the clinical case
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