Basic Fetal MRI: Techniques, Protocols, Philosophy

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Carol E. Barnewolt, MD
Department of Radiology
Boston Children’s Hospital
Harvard Medical School

The Advanced Fetal Care Center
No Disclosures
Techniques of the past........

Fetography
Amniography
Peritomeography
1970s (Pre-Sonography)

Fetal Radiograph          Post Mortem Radiograph

c/o Dr. Thorne Griscom
1980: Fetal Ascites
Fetal MRI: Return of the Pediatric Radiologist!

Neonatal and pediatric specialists have insight and experience that is unique in:

- Management of the transition from fetal to neonatal physiology.

- Understanding of the short and long term consequences of congenital abnormalities.
US vs MRI

1. Fetal MRI should never be performed in a vacuum.

2. Up-to-date US information is necessary for planning your MRI technique and establishing the focus of your search.

3. Performing MRI improves your US technique AND performing US improves your MR technique.

4. Allows correlation with up-to-date biometrics.

5. A chance to talk to the patient, establish a relationship and get more history.
US vs MRI

- Images created by you.
- Images available to you.
- Report available to you.
US \(\text{vs}\) MRI

- Images created by you.
- Images available to you.
- Report available to you.
- None of the above?
  - Go for it anyway!!
The Goal:
Accurate and Complete Prenatal Diagnosis

- Look at the big picture.
- How was gestational age established?
Basics of Fetal MRI
Basics of Fetal MRI

(Fetal MRI for the Humanities Major)
General Considerations

- Consent (+/-)
- Screening Forms
  - (pregnant pt and her partner)
Addressing Fetal Motion

– In Boston, we do not require a maternal NPO prep.

– Timing: Image as late in gestation as you can (while still providing relevant data).

– Chemical immobilization should be for rare, extreme circumstances. We have NEVER done this at BCH.
Length of MRI-Exam

- 45 minutes of “table time” at BCH (formerly 30 minutes)
- Consider comfort and safety
- “Blow-by” oxygen
Table Weight Limits

Generally in the range of 250 – 350 lbs.
(Stick to it!)
Bore Size:

1.5 T Magnet
Average diameter: 60cm
Length varies: 120 to 180 cm

“Open” Magnet
Theoretically desirable, but signal-to-noise may be unacceptably lower.
Claustrophobia

- Headphones / music
- Accompanying partner
- Relaxation techniques
- Feet first vs. Head first
Coil Selection

- It has to fit!
- Flexibility helps.

-at BCH:

GE (8 ch)
Siemens (up to 24 ch)
Philips (32 ch)
Our technologists now consider this routine.
Patient Positioning

- Underwire bra & snaps OFF.
- Comfort first.
- Supine vs decubitus.
Multiple Gestations

Decubitus Position
Coil Position

Too High:                      Just Right:
First Trimester

Gadolinium
Pediatric Radiologist (Dr. Susan Connolly) at the console.
<table>
<thead>
<tr>
<th>Year</th>
<th>Time Duration</th>
<th>Sequence Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>10-15 minutes</td>
<td>(spin echo)</td>
</tr>
<tr>
<td>1990</td>
<td>3-4 minutes</td>
<td>(fast spin echo)</td>
</tr>
<tr>
<td>2000</td>
<td>30 seconds</td>
<td>(single shot FSE)</td>
</tr>
<tr>
<td>2010</td>
<td>15 seconds</td>
<td>(“super-de-duper” fast)</td>
</tr>
</tbody>
</table>
The Basic Sequences

- **T2:**
  Half Fourier Single Shot Turbo (Fast) Spin Echo

- **T2-like:**
  Steady State Free Precession (Gradient Echo)

- **T1:**
  Spoiled Gradient Echo
## Cross Vendor Lexicon

<table>
<thead>
<tr>
<th>Generic Category</th>
<th>Parameters</th>
<th>GE</th>
<th>Philips</th>
<th>Siemens</th>
<th>Hitachi</th>
<th>Toshiba</th>
<th>Picker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Shot Turbo/Fast Spin Echo</td>
<td>TR=4000-10000 TR=4000-10000 TE=80-130 FA (excitation)=90 FA(refocusing)=1 30-160</td>
<td>SSFSE</td>
<td>Single-Shot TSE</td>
<td>HASTE</td>
<td>Single Shot FSE</td>
<td>FASE</td>
<td>EXPRESS</td>
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<tr>
<td></td>
<td></td>
<td>GE</td>
<td>Philips</td>
<td>Siemens</td>
<td>Hitachi</td>
<td>Toshiba</td>
<td>Picker</td>
</tr>
<tr>
<td>Balanced Steady State Free Precession</td>
<td>TR=3.8-6.0, 1.5-4.0, 4.0 TE=1.5-4.0 FA=60-85</td>
<td>FIESTA</td>
<td>Balanced FFE</td>
<td>TrueFISP</td>
<td>BASG</td>
<td>True SSFP</td>
<td>CE FAST</td>
</tr>
<tr>
<td>Spoiled T1 Gradient Echo</td>
<td>TR=100-200 TE=3-8 FA=70-90</td>
<td>SPGR</td>
<td>T1-FFE</td>
<td>FLASH</td>
<td>GE/GFE</td>
<td>Field Echo</td>
<td>RF Spoiled FAST</td>
</tr>
<tr>
<td>Spoiled T2* Gradient Echo</td>
<td>TR=100-200 TE=20-30 FA=10-25</td>
<td>MPGR</td>
<td>T2-FFE; MPGR</td>
<td>FLASH, RF-spoiled GRE</td>
<td>GRE</td>
<td>Field Echo</td>
<td>T1-FAST, NOSE</td>
</tr>
<tr>
<td>3D-spoiled T1 Gradient Echo</td>
<td></td>
<td>LAVA</td>
<td>eTHRIVE</td>
<td>VIBE</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Parallel Imaging Technique</td>
<td></td>
<td>ASSET</td>
<td>SENSE</td>
<td>iPAT</td>
<td>RAPID</td>
<td>SPEEDER</td>
<td>SMASH</td>
</tr>
</tbody>
</table>
MRI Vendors / T2-Weighted Information

[Half Fourier Single Shot Turbo (Fast) Spin Echo]

- GE: SS-FSE
- Siemens: HASTE
- Philips: SS-TSE
- Hitachi: SS-FSE
- Toshiba: FASE
- Picker: EXPRESS
“MRU/MRCP” type technique

Thick slab: 2 cm.
SS-FSE T2: Long TR (>8000).
MRI Vendors / T2-Weighted Information

[Steady State Free Precession (Gradient Echo)]

- GE: FIESTA
- Siemens: TrueFISP
- Philips: Balanced-FFE
- Hitachi: SARGE
- Toshiba: True SSFP
- Picker: CE Fast
FIESTA-type Sequence

- Peculiar edge artifacts.
- Decreased SNR.
- Thicker slices.
- Loud/Harsh sound!
- Artifact related to Fe-supplements.
- Accentuates differences between fluid and soft tissues.
- Can acquire using Cine Technique.
FIESTA

Striking Fluid-Fluid interface around the palate
Movies!!!

20w0d
17w6d Confession/Disclosure

Polyhydramnios and “Stuck” Twin
Challenge: The frustratingly active fetus…

-Sometimes it takes longer to SET up the sequence than to RUN it!
-So, don’t set it up again….
Wrap Around Artifact and FOV
33w4d Gestation: GW Differentiation

SS FSE-T2

Fiesta
MRI Vendors / T1-Weighted Information

[Spoiled Gradient Echo]

- GE: SPGR (or IR-variation)
- Siemens: FLASH
- Philips: T1-FFE
- Hitachi: RF spoiled SARGE, RSSG
- Toshiba: Field Echo
- Picker: T1 fast, NOSE
Fast T1 Techniques

- Fat, Hemorrhage, Calcium, Proteinaceous Fluid, meconium.
- Slower acquisition times.
- Less satisfactory SNR.
- Challenges of Motion Artifact.
GRE T1 (GE)

33w4d
Saturation Recovery Gold Standard vs IR-SSFSE T1-Weighting

++ TR = 500 ms
TI = 2 s
TI = 1.5 s
TI = 1 s

c/o Robert Mulkern, PhD
Inversion not exactly the same as Gold Standard Spin-Echo T1-weighting, but...

Saturation Recovery spin-echo

\[ S \propto 1 - \exp(-TR/T1) \]

Inversion Recovery single shot

\[ S \propto |1 - 2 \exp(-TI/T1)| \]

c/o Robert Mulkern, PhD
Referred at 26w2d for VM (LLV = 10.8 mm)
26w2d

IR fast T1
DOL 2 (born at 39 weeks gestation)
MPGR
36w5d: Referral DX = abdominal cyst
36w5d

SS FSE T2

FIESTA
36w5d

Adrenal Hemorrhage

IR fast T1
LAVA - ASSET (GE)

CDH with liver UP

-Parallel imaging, originally designed to perform dynamic contrast enhancement (fast T1).
Gradient Echo

GE T2* GRE  Siemens 2D FLASH
DWI and DTI
Echo Planar Imaging (GE)

20 week fetus (1/23/13)

SS FSE T2  45 sec  
FIESTA  45 sec  
EPI  12 sec

c/o Drs. Onur, Gholipour, and Warfield
What is going on here?

SS FSE T2    Fiesta    T2* GRE
Underwire Bra Artifact:

SS FSE T2  
Fiesta  
T2* GRE
It's all about SNR:
GE SS-FSE T2

4 mm

3 mm
It’s all about SNR:
Siemens HASTE

4 mm

3 mm
Philips TSE:

32 channel coil, 2 mm
21w4d Gestation: GW Differentiation

SS FSE-T2 (4 mm)
Works in progress: Reduced FOV SS-FSE T2

40 sec                             9 sec

PI: Robert Mulkern, PhD
Quantification Techniques
Ready (or just about ready) for fetal prime time:

• Mathematical conversion of 2D data sets into 3 orthogonal planes
• Motion reduction techniques (propeller, etc…)
• Continued creative “tweaking” of all tools
• The Scientists: Drs. Simon Warfield, Ali Gholipour, and Onur Afacan at BCH.
Motion-Robust Super-Resolution MRI
Dr. Ali Gholipour

3T: -Safety (heat, noise)
-Artifacts (dielectric effect, susceptibility, chemical shift)
Don’t forget the corners of the film:
“Established” Applications of Fetal MRI

- Brain and associated spinal cord abnormalities (formational, hemorrhage, stroke).
- Craniofacial malformations.
- Chest “masses” (including CCAM, sequestration, diaphragmatic hernia).
- Airway compromise (cervical teratoma, vascular anomalies).
- Baseline when considering fetal procedure (cord ligation, MMC patch).
Evolving Applications

- Gastrointestinal/Abdominal Wall Defects
- Complex genitourinary
- Musculoskeletal
- Vascular/Cardiovascular
- ???
Focus of Search

• State your *focus* from the outset.
• Answer those questions to the best of your ability.
• Fetal Brain (consider parallel reporting between subspecialties).
• We do not “screen” the entire fetus, but we do look at the entirety of the field of view after acquisition.
• KEEP AN OPEN MIND.
The Final Product: Reporting

• If you don’t communicate with the people who need to know, the best history, imaging, reporting, and counseling is for naught!

• Failure to communicate creates conflict, mistrust, and anguish for all involved.
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30w: The Cloacal Malformation
Referral DX: Diaphragmatic Hernia

Don’t forget to look for associated structural anomalies
Fryns Syndrome