Objectives

- Presentation of cases of fetal malformations
- Cases examined by both ultrasound and fetal MRI
- Highlight the strengths and limitations of each imaging modality
- Emphasize the complementary nature of the techniques

Fetal MRI - How Does It Work?

Basic MRI Principles

Detected Energy Exchange (RF Signal) Between External Magnetic Fields and Hydrogen Nuclei

1. Spinning protons align with static magnetic field
2. RF pulse causes magnetic moments to flip
3. RF pulse stops - magnetic moments re-align to field
4. Released RF energy detected by tuned RF coils and encoded into image according to signal strength
5. Magnetic field relaxation times allow display of different tissue types (contrast)
Free Induction Decay Signal

Fast Fourier Transform

MRI Image

magnetism growth (z-axis)
magnetism decay (xy plane)
Relaxation

Process by which protons release energy that are absorbed from RF pulse

T1 Relaxation Time

T2 Relaxation Time

Tissue Type

<table>
<thead>
<tr>
<th>T1 (msec)</th>
<th>T2 (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Matter</td>
<td>510 67</td>
</tr>
<tr>
<td>Gray Matter</td>
<td>760 77</td>
</tr>
<tr>
<td>Edema</td>
<td>900 126</td>
</tr>
<tr>
<td>CSF</td>
<td>2650 180</td>
</tr>
</tbody>
</table>

T1 and T2 Values for Brain Tissues at 1.5 Tesla

Adapted from Stark DD and Bradley WG (eds). Magnetic Resonance Imaging, 3rd edition, 1999

Fetal MRI - Is It Safe??

Static Magnetic Fields

<table>
<thead>
<tr>
<th>Magnetic Source</th>
<th>Magnetic Field Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnet for Junk Cars</td>
<td>3,000 gauss</td>
</tr>
<tr>
<td>Household Refrigerator Magnet</td>
<td>10-100 gauss</td>
</tr>
<tr>
<td>Earth's Magnetic Field (Equator)</td>
<td>0.3 gauss</td>
</tr>
<tr>
<td>Earth's Magnetic Field (Poles)</td>
<td>0.7 gauss</td>
</tr>
<tr>
<td>Clinical MR Scanners</td>
<td>15,000 - 30,000 gauss</td>
</tr>
</tbody>
</table>

1 Tesla = 10,000 gauss

Static Magnetic Field

Time-Varying Magnetic Gradient Fields

Pulsed-Radio Frequency Fields

biological effects
miscarriage
heating effects
acoustic noise exposure

A review of the current use of magnetic resonance imaging in pregnancy and safety implications for the fetus

J.P. De Wilde*, A.W. Rivers, D.L. Price
Department of Biomedical Engineering, Imperial College, Exhibition Road, South Kensington, London SW7 2AZ UK

Static Magnetic Field

biological effects
miscarriage
heating effects
acoustic noise exposure

Prog Biophys Mol Biol 2005;87:335-53
Fiberoptic probes did not indicate significant heating in amniotic fluid or tissues using MR HASTE pulse sequences.
“During pregnancy, other imaging procedures not associated with ionizing radiation (e.g. ultrasonography, MRI) should be considered instead of X-rays when appropriate. Ultrasonography and MRI are not associated with known adverse fetal effects.”

ACOG Committee Opinion, Guidelines for Diagnostic Imaging During Pregnancy, 2004


Summary Points

Pregnant healthcare practitioners permitted to work in and around MR environment throughout all stages of their pregnancy.

MRI scans can be performed at any stage of pregnancy if risk-benefit ratio for the patient warrants that the study be performed.

MR contrast agents should not be routinely administered during pregnancy, but based on risk-benefit ratio for a given patient.

Written informed consent is recommended to make sure the patient understands the risks and benefits to the procedure.

AJR 2007;188:1-27

Fetal MRI - Selected Indications

- CNS abnormalities
- Chest Masses
- Facial Anomalies
- Gastrointestinal Anomalies
- Functional Assessment

Basic MRI Sequences

- Ultra fast spin echo T2
- T1
- DWI
- Gradient echo, sensitive to blood products (T2*)
- MRS
- DTI

CNS Abnormalities

Case 1
22 Week 3D Scan

Sagittal multiplanar reconstruction
Original plane of acquisition: transverse
Is the corpus callosum normal?

22 Week 3D Scan

All planes shown now...
Does your diagnostic impression change?

22 Week 2D Scan

Axial
Coronal

T2 HASTE

Axial

T2 HASTE

Coronal

Neonatal Findings

- CT
  - Dilatation of the occipital horn and posterior temporal horns, more on the left side
  - Agenesis of the corpus callosum
- EEG
  - Beta waves present on right but not left side of the brain
  - Asynchronicity consistent w/ agenesis of the corpus callosum
Case 2

19.0 weeks

24.6 weeks

T2 Axial MR Scan

4 mm slices 3 mm slices

Clinical Course

- Complications: none
- Delivery Route: vaginal
- Gestational Age: 37.7 weeks
- Birth Weight: 2,830 grams
- Gender: male
- Apgars: 9/9

Postnatal MRI

- closed lip schizencephaly (frontal cortex to superior right lateral ventricle)
- absent septum cavum pellucidum
- normal optic nerves and pituitary gland
- hyperintense linear areas (T1 sequence)
  - posterior left lentiform nucleus
  - deep white matter adjacent to right lateral ventricle
- no diffusion weighted imaging abnormalities
Case 3

35 Week Scan - Fetal Growth

Head Circumference 33.1 cm @ the 75th pct for EDC

T2 HASTE
Neonatal US Findings

- Dilatation of lateral ventricles
  - especially left temporal and occipital horns
- Left intraventricular hemorrhage
- Cystic areas in left frontoparietal lobe
  - likely representing encephalomalacia

Chest Abnormalities

Case 4

Ultrasound Presentation

Patient: 26 year old gravida 3
Scan Indication: Referred for Chest Mass
Gestational Age: 25.7 weeks
Past History: Rheumatoid Arthritis

Dilated SVC
Right Adnexal Mass "17 cm"

Differential Diagnosis

- Klippel-Trenaunay-Weber Syndrome
- Lymphatic Malformation

Fetal 3D Ultrasonography
Delivery Information

Gestational Age: 37.3 weeks
Delivery Route: Cesarean Section
Birth Weight: 2014 gm
Pathology: Corpus luteum cyst

Vascular Malformations - Classification

Simple
- capillary malformation
- venous malformation
- arterial malformation
- lymphatic malformation

Combined
- arteriovenous malformation
- capillary-venous malformation
- lymphatico-venous malformation


Case 5

Patient: 18 year old gravida 1
Scan Indication: Abdominal mass adjacent to stomach and spleen
Gestational Age: 30 6/7 weeks
Differential Diagnosis

- Bronchogenic cyst
- Esophageal duplication cyst
- Neuroenteric cyst

Patient delivered elsewhere
Baby doing well
No neonatal imaging studies performed
Face Abnormalities

Case 6

Normal Amniotic Fluid Volume

20.4 weeks
Flipped Face View

Tomographic Ultrasound Imaging

Tomographic Ultrasound Imaging

Mandibular Width
Maxillary Width

3.23
2.52 = 1.28

Inferior Facial Angle - Retrognathia

Normal 29 weeks
Current Case
Pregnancy Outcome

- Cesarean delivery at term gestation
- Failure to progress
- 3,709 gram male, normal 46 XY
- Pierre Robin Sequence
  - micrognathia
  - obstructive apnea
  - soft cleft palate
- Prone position - oxygen for desaturation
- Elective ventilation for surgery Day 31
- Extubated and weaned to room air Day 40
- Discharged on Day 45

GI Abnormalities

Case 7

GI Anomalies - Bowel
Third Trimester US

32.1 weeks 35.1 weeks

3D Inversion Mode

T2-Weighted MRI

T1-Weighted MRI
Additional Topics of Interest

- migrational anomalies (n = 4)
- porencephaly (n = 4)
- hypoplastic corpus callosum
- microcephaly
- kinked brain stem
- cerebellar hypoplasia
- congenital infarction

What Does Magnetic Resonance Imaging Add to the Prenatal Sonographic Diagnosis of Ventriculomegaly?


4 year review of 26 fetuses who underwent ultrasonography and MRI

Table 3. Comparisons of Fetuses With and Without Additional Findings on MRI

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No Additional Findings on MRI</th>
<th>Additional Findings on MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCA and other findings on sonography*</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>MCA and other findings on MRI</td>
<td>25.8 ± 6.3 (17-31)</td>
<td>24.9 ± 7.1 (16-40)</td>
</tr>
</tbody>
</table>

*P < .05 compared to Table 2. **No significant differences.

Real-time fetal magnetic resonance imaging for the dynamic visualization of the pouch in esophageal atresia

L. J. SALOMONé, P. SIGNORET, F. ORT, Y. VIREL and F. BRUNELLE

EMIOT-UMR CS 470, UFR d'Ingenierie Bionique et Biologique de Langue Française, ENS de Cachan, France.
Comparisons - Fetal Ultrasound vs MRI

<table>
<thead>
<tr>
<th></th>
<th>Ultrasound</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>Bedside</td>
<td>Shielded Room</td>
</tr>
<tr>
<td>Cost</td>
<td>Inexpensive</td>
<td>Expensive</td>
</tr>
<tr>
<td>Safety</td>
<td>Longer History</td>
<td>Shorter History</td>
</tr>
<tr>
<td>Noise</td>
<td>Quiet</td>
<td>up to 140 dB</td>
</tr>
<tr>
<td>Technical</td>
<td>Fat/Bone - Shadowing</td>
<td>Fat/Bone - Fewer Limitations</td>
</tr>
<tr>
<td>Movement</td>
<td>Real-Time</td>
<td>Limited 4D</td>
</tr>
<tr>
<td>Calcium</td>
<td>Better Detection</td>
<td>Poorer Detection</td>
</tr>
<tr>
<td>Functional</td>
<td>Doppler</td>
<td>MRS, DWI</td>
</tr>
</tbody>
</table>

Fetal MRI - Future Directions

Functional MR Imaging: Blood oxygen level dependent contrast perfusion and diffusion weighted sequences magnetic resonance spectroscopy

Magnetic Resonance Spectroscopy

Fetal Brain MRS

Measures concentrations of chemicals within tissues

MR Spectroscopy

Fetal MRI

- Complementary diagnostic imaging modality
- No adverse bioeffects documented during pregnancy
- Especially useful for CNS lesions and chest masses
- Future applications
  - Noninvasive assessment of fetal metabolites
  - Functional MRI
  - Congenital heart disease