BIOMED 6505
Introduction to Fetal Medicine
Fetal Diagnosis and Imaging Ultrasound
12 February 2014
Ultrasonography and Invasive Diagnostic / Therapeutic Techniques

- How we do ultrasound
  - Ultrasound physics; machine components

- Why we do ultrasound
  - Image-based only
  - procedure guidance
  - Augment / replace other testing

- Examples, and to communicate findings
The Basics of Ultrasound

Definition

- The range of human hearing
  - 20 Hz to 20 KHz
- Medical ultrasound
  - 1MHz to 10 MHz

Penetration vs. Resolution

- Low frequencies (longer wavelengths) penetrate better, but have less resolution
- Higher frequencies (shorter wavelengths) have better resolution, but less penetration
How Ultrasound Works

- Make a ping
- Send it out
- Time the round trip
  - Distance = speed x time
    - Velocity of sound in tissue: averages 1540 m/sec
- Measure the strength of the ping when it gets back
- Paint the dot on the screen
  - Bright: dense target; soft: less dense target
- Repeat this a lot and REALLY FAST!
Generating an Ultrasound Ping

The piezoelectric effect
The Components of the Machine

- Transducer
  - Current technology: hand held
  - Format: linear, curved, curvilinear

- Display

- Signal Transduction and Information Processing
  - CPU and processing power
The Transducer

- **Transducer**
  - Lots and LOTS of small crystals in that hand-held array
  - “Fire” the crystals in different order to “Steer” the beam

- Paint the dots in 2D and get a “slice-of-bread” picture

- Interpret **volume** data and get pseudo-3D

- Interpret volume data **REALLY** fast and get real time pseudo-4D
2D Ultrasound

“Slice of Bread” View
3D Ultrasound

Surface Rendering
Biomechanical Effects and Ultrasound Safety

Tissue Effects

- Ever heard of thermodynamics?
  - Put energy into a system, and it’s got to come out somewhere, some how. The energy version of tight clothes – you can squeeze it in here, but it comes out somewhere else!

- Tissue heating

- Cavitation

- Increased sister chromatid exchange (bad if you’re a frog)
Why We Do Ultrasound: Indications for Ultrasound in Pregnancy

- ACOG: only when indicated
  - Indications: there are 28 of them
    - Uncertain LMP
    - Size: dates discrepancy
    - Viability
    - Maternal medical illness
    - Fluid assessment
    - Bleeding
    - Anatomy

- The rest of the world
Indications for Ultrasound in Pregnancy

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  - Indications: there are 28 of them
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    - Size: dates discrepancy
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    - Fluid assessment
    - bleeding

- The rest of the world
  - Indication: only one
    - She’s pregnant
How could you prove routine ultrasound in pregnancy is worthwhile?
How Could you prove routine ultrasound is worthwhile?

Randomized trial: the RADIUS Trial

- Two groups:
  - Group 1: Automatically get two scans
  - Group 2: scan only if indicated

- Results:

NO DIFFERENCE!!!*

* TRAINING, TRAINING, TRAINING!!!
First Trimester
- How many fetuses are there, where are they, how far along in pregnancy are they, and are they alive
- Adnexae

Second/Third Trimester
- Number, location and viability
- Placental location, fluid volume
- Anatomic examination
Ultrasound Content

- Structure / function dichotomy
  - If it looks out of the ordinary it probably won’t work as it should
  - Even if it looks as it should, it STILL may not work as it should.

- Ultrasound speaks to conformation primarily, and usually only indirectly to function
## Sensitivity of Ultrasound Study

<table>
<thead>
<tr>
<th>Study</th>
<th># Anomalies</th>
<th># Anomalies Detected</th>
<th>% anomalies Detected</th>
<th>Detection rate per 1000</th>
<th>Prevalence per 1000</th>
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<tbody>
<tr>
<td>Brocks</td>
<td>81</td>
<td>44</td>
<td>54.3</td>
<td>3.08</td>
<td>5.67</td>
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<tr>
<td>Levi</td>
<td>259</td>
<td>54</td>
<td>20.8</td>
<td>3.36</td>
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<td>RADIUS</td>
<td>187</td>
<td>31</td>
<td>16.6</td>
<td>3.97</td>
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<td>Helsinki</td>
<td>45</td>
<td>18</td>
<td>40.9</td>
<td>4.42</td>
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<tr>
<td>Luck</td>
<td>67</td>
<td>41</td>
<td>61.2</td>
<td>4.81</td>
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<td>Shirley</td>
<td>84</td>
<td>51</td>
<td>60.7</td>
<td>8.25</td>
<td>14.39</td>
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<td>Roberts</td>
<td>218</td>
<td>96</td>
<td>44.0</td>
<td>8.45</td>
<td>19.29</td>
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<tr>
<td>Chitty</td>
<td>125</td>
<td>93</td>
<td>74.4</td>
<td>11.03</td>
<td>14.82</td>
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<tr>
<td>Anderson</td>
<td>157</td>
<td>93</td>
<td>60.0</td>
<td>11.80</td>
<td>19.80</td>
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Sensitivity and Specificity of Ultrasound in Detecting Fetal Structural Anomalies

- **Low Risk Populations**
  - Sensitivity 17-35% 
  - Specificity > 90% 

- **High Risk Populations**
  - Sensitivity 90% 
  - Specificity > 90%
Ultrasound as Guidance for Invasive Diagnostic/Therapeutic Techniques

Amniocentesis

- Take an aliquot of amniotic fluid
  - Grow amniocytes and determine karyotype
  - Test fluid itself
- Indications
  - Abnormal serum screen, advanced maternal age, family history of heritable disease, abnormal anatomy
Amniocentesis: Technique

- **Timing**
  - 15-16 weeks
    - Procedure-related pregnancy loss rate
      - At 15-16 weeks: 0.5 – 1.0%
      - At 13-15 weeks: 7.6%
        - Higher incidence of club foot – 1.3%

- **Ultrasound Guidance**

- **Equipment**
  - Ultrasound machine, 22 gauge needle, 20 cc syringe, and ultrasound gel
Chorionic Villus Sampling

- Take a sample of chorion frondosum
  - Grow trophoblast and determine karyotype
- Indications
  - Advanced maternal age, elevated nuchal translucency, family history of heritable disease, abnormal anatomy
CVS: Technique

- **Route**
  - Transcervical versus transabdominal

- **Timing**
  - 10 – 12 weeks

- **Procedure-related pregnancy loss rate**
  - Exceeds procedure-related pregnancy loss rate for second trimester amniocentesis by 0.5 – 1.0%

- **Limb reduction defects**
  - 1% - 2% if CVS is done < 10 weeks EGA

- **Confined Placental Mosaicism**: mutation in trophoblast cells; seen in 1% of CVS samples
CVS: Technique
CVS: Technique
Percutaneous Umbilical Blood Sampling

- **Purpose**
  - Determine Hgb / Hct, acid-base status, or determine karyotype from lymphocytes

- **Indications: fewer and fewer!**
  - Isoimmunization, hemoglobinopathies, NAIT, fetal hydrops

- **Technique**
  - Timing: after 19 – 20 weeks EGA
  - Ultrasound guided
  - Equipment
What do we get from it?

- Fetal RBC’s, lymphocytes, and serum

Risks: 1.1% per procedure

- The \textit{a priori} risk is higher because these fetuses are already at risk
PUBS : Technique
Therapeutic US-Guided Procedures

- Vesico-amnionic shunt
- Thoraco-amnionic shunt
- Ventriculo-amnionic shunt
- Cardiac valvulotomy
- Laser ablation for TTTS
- Tracheal occlusion
Can Non-Invasive Testing Supplement Invasive Testing?

Nuchal Translucency Measurements
## Can Non-Invasive Testing Supplement Invasive Testing?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Likelihood Ratio</th>
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<tbody>
<tr>
<td>Nuchal fold ≥ 6 mm</td>
<td>11-19</td>
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<tr>
<td>Echogenic bowel</td>
<td>5.5-6-7</td>
</tr>
<tr>
<td>Short femur</td>
<td>2.2</td>
</tr>
<tr>
<td>Short humerus</td>
<td>2.3</td>
</tr>
<tr>
<td>EIF</td>
<td>2.0</td>
</tr>
<tr>
<td>Mild hydronephrosis</td>
<td>1.5</td>
</tr>
<tr>
<td>No anomalies</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Can Non-Invasive Testing Replace Invasive Testing?

Non-Invasive Assessment of Risk for Significant Fetal Anemia
Carr’s Rules
(Aw, crap! When is he going to show some pictures?)

- Describe the methodology (transvag, etc)
- Describe the fetal plane you’re in
- Describe what body area you’re in
- Give dimensions
- Give description of echodensity
- Describe the location or relationship to a nearby structure
- Describe nearby anatomy
- NAME THAT ANOMALY!!! (or give a Ddx)
Examples

- Bad: “there’s a thing near the other thing over there on the fetus”
- Better: “there’s a dark area near the fetal bladder.”
- Good: “On transabdominal scan, transverse images of the fetal pelvis reveal a 1 x 2 x 3cm echolucent structure located immediately ventral to the fetal bladder. The fetal bladder and kidneys appear normal in location, conformation and echotexture. The Ddx includes......”
Shakespeare on Ultrasound

For naught so vile that on the earth doth live
But to the earth some special good doth give.
Nor naught so good but, strained from that fair use
Revolts from true birth, stumbling on abuse

Romeo and Juliet
Act 2, Scene 3

Shakespeare on Ultrasound