MUSCULOSKELETAL ULTRASOUND

- Basic Physics
- Ultrasound Equipment
- Scanning Technique
- Common Scanning Areas
ULTRASOUND: BASIC PHYSICS

- Sound is a mechanical, longitudinal wave

- Period, Frequency, Amplitude (db), Power, Intensity ($P/\text{beam area}$), Propagation Speed, and Wavelength (longitudinal res./image quality)

- Speed of Sound: lung (air) 0.5 < fat 1.45 < muscle 1.6 < bone 3.0 [mm/us]
Sound Propagates as a Wave

- Sound waves propagate as longitudinal waves.
- Requires a medium, cannot propagate in a vacuum.
- Speed of sound propagation depends upon the material properties.
- Typically, speed of sound in human body is 1540 m/s.
ULTRASOUND: BASIC PHYSICS

- Impedance-associated with a medium; impedance increases when the density increases or propagation speed increases.
- Reflection occurs when some of the propagating sound energy strikes a boundary between two media and returned to the transducer.
- Reflection of an ultrasound wave depends upon a difference in the acoustic impedances at the boundary between the 2 media.
Sound is reflected at the interface between two materials of different density and/or speed of sound.

Acoustic Impedance = \( \text{density} \times \text{speed of sound} \)
### TYPICAL VALUES FOR ACOUSTIC IMPEDANCE

- Larger the difference in acoustic impedance between two tissue types, the stronger the reflection at the interface.

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>ACOUSTIC IMPEDANCE (kg.m(^{-2}).sec(^{-1})X10(^{-4})</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR</td>
<td>0.0004</td>
</tr>
<tr>
<td>FAT</td>
<td>1.38</td>
</tr>
<tr>
<td>WATER</td>
<td>1.5</td>
</tr>
<tr>
<td>BLOOD</td>
<td>1.61</td>
</tr>
<tr>
<td>KIDNEY</td>
<td>1.62</td>
</tr>
<tr>
<td>SOFT TISSUE</td>
<td>1.63</td>
</tr>
<tr>
<td>SPLEEN</td>
<td>1.64</td>
</tr>
<tr>
<td>LIVER</td>
<td>1.65</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>1.7</td>
</tr>
<tr>
<td>BONE</td>
<td>6.1</td>
</tr>
</tbody>
</table>
Refraction is a change in direction of wave propagation when traveling from one medium to another.

Direction can change with angulation of the transducer.
ULTRASOUND: BASIC PHYSICS

- Anisotropnic effect
- Tissue not imaged perpendicular to the sound beam
- Appears artifactually hypoechoic
- May simulate pathology
- Tendon, ligament, muscle
RT SST LONG IR/EXT
ULTRASOUND: BASIC PHYSICS

- **Attenuation**: A decrease in intensity, power and amplitude as a sound wave travels.
- Depends upon the wave’s frequency. In soft tissue, higher frequencies attenuate more; thus high frequency = diminished depth.
- **GOAL**: Use the highest frequency that still allows us to image to the depth of the structures of clinical interest.
ULTRASOUND: BASIC PHYSICS/EQUIPMENT

- The Transducer works from a piezoelectric crystal:
- Electricity converted to vibrations
- Sound wave reflects at interfaces
- Bright echo: high impedance differences
- Bone-soft tissue/Air-soft tissue
- Crystal receives echo > image
ULTRASOUND: BASIC PHYSICS/EQUIPMENT

- The Transducer, aside from the machine, is key. Technology is much improve. For MSUS one would want from 6/7.5 MHz to 10-15MHz; should be of the Linear Array Type
- Frequency determines resolution
Quality of an Ultrasound Transducer

Long-duration ring or high "quality"
"Narrowband"
Terrible for imaging

Short-duration ring or low "quality"
"Broadband"
Great for imaging
ULTRASOUND: BASIC CONCEPTS/EQUIPMENT

- Imaging is accomplished with a pulse echo technique
- The pulses of ultrasound are generated by a transducer and sent into the patient
- Echoes are produced at organ boundaries and within tissues
ULTRASOUND: BASIC CONCEPTS/EQUIPMENT

- The echoes return to the transducer, where they are detected and imaged on an instrument.
- The transducer generates the ultrasound impulses and detects the returning echoes.
- The ultrasound equipment processes the echo information and generates appropriate dots, which form the sonogram on display.
The signals returning from the transducer are extremely weak. The receiver boosts the strength of these signals, processes them and prepares them for display by the system.

Amplification allows one to make the signals returning from the transducer larger, so that they may be processed by the rest of the electronics. The amplification affects the brightness of the entire image.
ULTRASOUND: BASIC CONCEPTS/EQUIPMENT

- Imaging depth decreases as frequency increases because attenuation increases.

- Thus ultrasound of the musculoskeletal system has improved with the linear ray (good cross-sectional area image) high frequency and high resolution sonographic equipment.
ULTRASOUND: BASIC CONCEPTS/SCANNING TECHNIQUES

- Select appropriate transducer
- Coupling gel: transducer and skin
- Stabilize transducer:
- Anchor hand/transducer with 5th finger on patient
- Move focal zone on screen to level at area of interest
The focal zone is the region surrounding the focus where the beam is narrow and the picture is quite good.

TGC: since attenuation is strongly related to path length, echoes returning from great depths have lower amplitudes than those returning from shallow depths.
Lateral Resolution Depends Upon Focusing

Lateral resolution is typically 1~5 mm
ULTRASOUND: BASIC CONCEPTS/SCANNING TECHNIQUES

- TGC: the time gain compensation makes all echoes from similar reflectors appear identical regardless of the depth from which they return.
- When a higher frequency transducer is used, more attenuation occurs and, therefore, more TGC must be used.
ULTRASOUND: BASIC CONCEPTS/SCANNING TECHNIQUES

- Top of image: skin surface
- Bottom of image: deep away from transducer
- When imaging long axis of structure
- Left side of image: proximal
- Right side of image: distal
ULTRASOUND: BASIC CONCEPTS/SCANNING TECHNIQUES

- Structured Protocol:
- Specific sequences
- Checklist of structures
- Focused exam:
- Other joints and structures
- Signs and symptoms
ULTRASOUND: BASIC CONCEPTS/COMMON SCANNING AREAS

- **ECHOGENICITY** - a method of describing the reflecting echoes
  - *Hypoechoic/hypoechogenicity*
  - *Hyperechoic/hyperechogenicity*
Appearance of ultrasound images: Echogenicity and Echotexture

Weak scattering from blood and fluids $L << \lambda$

“Speckle” from scattering in tissue $L \approx \lambda$

Strong echoes from “mirror-like” interfaces $L >> \lambda$

Appearance of echoes depend upon the size of scatterers ($L$) relative to the ultrasound wavelength ($\lambda$).
Pros and Cons of Ultrasound

PROS
• Real-time imaging
• Portable, inexpensive, office-based
• Excellent spatial resolution
• Reasonable soft tissue contrast
• Visualization of tissue and blood flow
• Safe

CONS
• Technically challenging
• Operator dependent
• Limited field of view
• Not inherently 3D
In the year 2010 ... lawyers run loose in the streets. Health care is run by evil HMO empires. Fee for service doctors and nurses are rounded up nightly, tortured, and sent to managed competition camps. There is only one hope .............
THANK YOU