Image Optimization and Interpretation

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Outline:
• Basic Physics
• Ultrasound Equipment
• Scanning Technique
• Image Interpretation
• Pathology Examples

Sound Wave Frequencies
• Human hearing: 20 Hz to 20KHz
• Low frequency, low intensity treatment: 40 KHz
  – Non-contact wound treatment
• Low intensity pulsed (1.5 MHz): bone healing
• High intensity focused ultrasound: HiFU
  – 200 KHz – 4 MHz: tissue necrosis
• Diagnostic imaging: 1 – 20 MHz

Sound Wave
• Reflection:
  – Specular: mirror-like
  – Scattering or diffuse
• Refraction
• Absorption
• Attenuation

Probe: 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

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Equipment: probe selection
• Frequency determines resolution
  – High frequency = high resolution
  – Poor depth penetration
• Superficial structures: 10 – 17 MHz
  – Distal extremities and peripheral nerves
• Deep: 5 – 7 MHz linear or curvilinear
  – Thigh or hip

Ultrasound Probes

Ultrasound Probes

12 - 5 MHz
Linear

15 - 7 MHz
Compact linear

9 - 4 MHz
Curvilinear

Normal Thigh Musculature

Linear 12 MHz
Curved 7 MHz

Scanning: basics
• Holding transducer:
  – Anchor hand/transducer
  – 5th finger or hand on patient
• Coupling gel
• Imaging plane:
  – Long axis of transducer
Scanning: basics

- Beam is focused
  - Narrower than transducer width
  - < 2 mm
- Sweep transducer slowly
  - Only millimeters at a time

1. Select appropriate transducer
2. Adjust depth
3. Optimize focal zone location
4. Adjust gray scale gain

Adjust Depth

Adjust Focal Zones

Adjust Gray Scale

Image Appearance:

- 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
**Ergonomics**
- Transducer hand lower than shoulder
- Elbow near side (arm not extended)
- Hand touching patient
- Chair
- Monitor with 45 degrees of patient to avoid excessive back torsion

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**Ultrasound Appearance:**
- Tendon: *hyperechoic*, fibrillar
- Muscle: relatively *hypoechoic*
- Bone cortex: *hyperechoic*, shadowing
- Fluid: *anechoic*, posterior enhancement

**Artifacts:**
- Anisotropy
- Shadowing
- Attenuation
- Reverberation
- Increased through transmission
- Refraction

**Anisotropic Effect:**
- Tendon not imaged perpendicular to sound beam
- Appears artifactually hypoechoic
- May simulate pathology
- Tendon, ligament, muscle

**Long Head of Biceps Brachii Tendon**
- Short Axis
- Long Axis
**Scanning: basics**
- Heel-toe maneuver
  - Evaluating long axis of tendon
  - Eliminate anisotropy

**Anisotropy:** supraspinatus

**Shadowing**
- Occurs at interface with high impedance differences
- Surface of object is irregular
- Sound beam is absorbed
- Bone, calcification, gas
- Foreign bodies

**Attenuation**
- Occurs where soft tissues are dense or many interfaces
- Sound beam is partially absorbed
- Fibrous tissue
- Fatty infiltration of muscle
- Consider low frequency transducer

**Reverberation**
- Occurs when sound beam hits smooth surface
- Sound beam reflected back and forth between object and transducer
- Ring down linear echoes
- Metal, glass, bone cortex
Increase Through Transmission

- Occurs when sound beam passes through fluid or homogeneous mass
- Sound beam brighter deep to object
- Fluid
- Solid mass: nerve sheath tumor, metastasis, etc.

Refraction

- Occurs when sound beam hits edge of tendon at site of tear
- Oblique shadow
- Patellar and Achilles tendon tears

Color and Power Doppler

- Increased blood flow or hyperemia
  - Neovascularity: tumor, tendinosis
  - Inflammation
- Not seen in normal tendon, ligament, or peripheral nerve
- Pitfall:
  - Avoid too much transducer pressure
  - Obscure flow

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Color Doppler Imaging

- Vascular Tumor
- Synovitis

Tendon: supraspinatus

- Tear
- Normal
Muscle: triceps

Tear | Normal

Ligament: anterior talofibular

Tear | Normal

Bone: greater tuberosity

Fracture | Normal

Take Home Points

• Optimize image
• Scanning technique:
  – Stabilize transducer on patient with hand
  – Move transducer small amount at a time
  – Beware: anisotropy

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