Image Optimization and Interpretation

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Ultrasound versus MRI:
• Inexpensive
• Examine multiple joints
• Better tolerated by patient
• Higher resolution
• Guide needle aspiration
• Improved evaluation of distal extremities

MRI versus Ultrasound:
• Examine entire joint
• Intraarticular assessment
  – Cartilage
• Intraosseous abnormalities
• Deep structures
• Less operator dependent

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

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
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

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

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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
- 12 - 5 MHz Linear
- 15 - 7 MHz Compact linear
- 9 - 4 MHz Curvilinear

Normal Thigh Musculature
- Linear 12 MHz
- Curved 7 MHz
**Equipment: cart-based**
- Advantages:
  - Powerful: fast, software
  - High resolution: 15 – 17 MHz
- Disadvantages:
  - Not portable
  - Relatively expensive

**Equipment: portable**
- Advantages:
  - Small size
  - Less expensive
- Disadvantages:
  - Possible decreased resolution of superficial structures

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

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

Adjust Depth

Adjust Focal Zones

Adjust Gray Scale

Supraspinatus
Long Axis
**Scanning Technique**
- Structured protocol:
  - Specific sequence
  - Checklist of structures
  - Rotator cuff
- Focused exam:
  - Other sites
  - Signs and symptoms
  - Do not focus exam too much!

**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 hyperechoic
- 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

Scanning: basics
• Heel-toe maneuver
  – Evaluating long axis of tendon
  – Eliminate anisotropy
• Toggle
  – Evaluating short axis of tendon
  – Help identify tendon
  – Eliminate anisotropy

Anisotropy: supraspinatus tendon

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

Anisotropy: supraspinatus

Longitudinal
**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

**Tendon: supraspinatus**
- Deltoid
- Humerus
- Normal
- Tear

**Muscle: triceps**
- Normal
- Tear
Ligament: anterior talofibular

Tear  Normal

Bone: greater tuberosity

Fracture  Normal

Hyaline Cartilage: hypoechoic

*Hyperechoic surface layer = glycosaminoglycan depletion
From: Han TS et al. Ultrasonography 2015; 34:115

Normal Peripheral Nerve

• Ultrasound appearance:
  – Hypoechoic nerve fascicles
  – Hyperechoic connective tissue
• Short axis:
  – Honeycomb appearance

Ulnar Nerve Entrapment: elbow

Compression  Normal

Abscess: shoulder

Short Axis  Long Axis
**Color and Power Doppler**

- **Color Doppler:**
  - Blood flow direction relative to transducer
  - Red (toward) and blue (away) colors
- **Power Doppler:**
  - Direction independent
  - More sensitive than color Doppler

**Optimization: color Doppler**

- Lower velocity scale (or pulse repetition frequency) without creating noise
- Lower filter (which usually automatically happens when scale is reduced)
- Narrow region of interest
  - Which increases frame rate
- Increase color gain until background artifact appears, then reduce until gone
- Float transducer to minimize pressure

**Color Doppler Imaging**

- 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

**Sonoelastography**

- To assess elastic properties of tissue
- Two methods:
  - Manual compression: operator dependent
  - Shear wave: quantifiable
- Compression of tissue
  - Produces strain or displacement within the tissue
  - Displacement is less when tissue is hard
  - Tendon abnormality is soft

  Klauser, Petron. Sem Musculoskel Rad 2011; 14:323

**Elastography:**

- Achilles
  - Accuracy = 97% compared with clinical exam
  - Strong correlation with routine ultrasound
- Common extensor tendon (elbow)
  - Accuracy = 94% compared with clinical exam
  - Strong correlation with routine ultrasound
  - Identified abnormalities of radial collateral lig

  Klauser, Petron. Sem Musculoskel Rad 2011; 14:323
Shear Wave Elastography

- Preliminary studies: limited
- Patellar, Achilles, common extensor tendons
  - 94% sensitive, 85% accurate
  - Gray scale/Doppler: 67%/72%
  - Limited: compared to symptoms
- If better than gray scale, any difference in patient treatment?

Dirricks T et al. Acad Radiol 2016; 23:1204

Take Home Points

- Scanning technique:
  - Use the highest frequency transducer that will allow visualization
  - Stabilize transducer on patient with hand
  - Move transducer small amount at a time
  - Beware: anisotropy
  - Shoulder: protocol

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other educational material

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