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

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- Consultant: Bioclinica
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Fundamentals of Musculoskeletal Ultrasound are copyrighted by Elsevier Inc.

Sound Wave Frequencies
- Human hearing: 20 Hz to 20 KHz
- 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

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**Supraspinatus**

*Long Axis*
Scanning: basics
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

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 hypoechoic
• Bone cortex: hyperechoic, shadowing
• Fluid: anechoic, posterior enhancement

Long Head of Biceps Brachii Tendon

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

Anisotropy: supraspinatus tendon

Scanning: basics
- Heel-toe maneuver
  - Evaluating long axis of tendon
  - Eliminate anisotropy

Scanning: basics
- Toggle
  - Evaluating short axis of tendon
  - Help identify 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

Achilles ossification
Wood Foreign Body
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
• Tear
• Normal

Muscle: triceps
• Tear
• Normal
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

Median Nerve


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

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

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

Take Home Points

- Scanning technique:
  - Stabilize transducer on patient with hand
  - Move transducer small amount at a time
  - Beware: anisotropy
- Needle visualization:
  - Best when perpendicular to sound beam
  - Be familiar with joint recesses: target

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