Use of Ultrasound Imaging (USI) in Physical Therapy

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Two areas of application

• Diagnostic Imaging:
  • examining the effects of injury or disease on ligament, tendon, and muscle tissues

• Rehabilitative USI (RUSI):
  • evaluation of muscle structure (morphology) and behavior, as well as the use of USI as a biofeedback mechanism.
From: Whittaker et al. Rehabilitative Ultrasound Imaging: Understanding the Technology and its applications. JOSPT 2007; 37;434-449
• the measurement of morphological features (morphometry), such as muscle length, depth, diameter, cross-sectional area, volume, and pennation angles;
• changes in these features and the impact on associated structures (fascia and organs such as the bladder) with contraction;
• tissue movement and deformation (eg, high-frame-rate USI and elastography);
• and qualitative evaluation of muscle tissue density.
“RUSI is a procedure used by physical therapists to evaluate muscle and related soft tissue morphology and function during exercise and physical tasks. RUSI is used to assist in the application of therapeutic interventions aimed at improving neuromuscular function. This includes providing feedback to the patient and physical therapist to improve clinical outcomes. Additionally, RUSI is used in basic, applied, and clinical rehabilitative research to inform clinical practice. Currently, the international community is developing education and safety guidelines in accordance with World Federation for Ultrasound in Medicine and Biology (WFUMB). Dated: 10 May, 2006.”

From: Whittaker et al. Rehabilitative Ultrasound Imaging: Understanding the Technology and its applications. JOSPT 2007; 37;434-449
USI

- 3.5 to 15 MHz
- Transducers:
  - Linear
  - Curved
  - Can be dual or multifrequency
- Modes:
  - B-Mode
  - M-Mode
FIGURE 2. A parasagittal ultrasound image of the multifidus (MF) muscle in the plane of the zygapophyseal joints (Zyg). Note the increased echogenicity at the muscle-bone interface. Reproduced with permission Whittaker 2007.142
FIGURE 7. (A) A linear array ultrasound transducer. (B) A sagittal ultrasound image of the thoracic spine generated using a 7.5- to 10.0-MHz linear array transducer. Abbreviations: PV, paravertebral musculature; TP, transverse process. Note the linear footprint and the rectangular nature of the image.
Curvilinear Probe

**FIGURE 8.** (A) A curved or convex array transducer. (B) A sagittal ultrasound image generated from the same location as in Figure 7B, using a 3.5- to 5.0-MHz curved or convex array transducer. Abbreviations: PV, paravertebral musculature; TP, transverse process. Note the curved footprint and the pie or sector nature of the image.
Image Adjustment

- A: unadjusted image
- B: Increased Depth
- C: Focal Zone adjustment
- D: Gain Adjustment

Sonographic Appearance of Musculoskeletal Tissue

- Bone Surface
- Tendons
- Ligaments
- Muscles
- Nerves
- Meniscal/Discoid tissue
- Articular cartilage
- Bursa
Bone

- Bone appears hyperechoic
- Most important landmark when performing sonographic evaluation
- Surface should be smooth and continuous
- No lifting off of the periosteum
- Enthesis (Sharpey’s fibers) is where the tendon attaches to the bone
Tendon

- Normal tendon tissue appear hyperechoic.
- Tendon fibers are visible as parallel bands linearly arranged.

Quadriceps tendon LAX and SAX views

Ligament

- Hyperechoic
- Less organized than tendons
- Image prone to anisotropy due to the angle of the soundwave
- Can appear relatively hypoechoic when surrounded by hyperechoic subcutaneous fat

Medial Collateral Ligament of the knee (Jacobson, 2013)
Muscle fibrils appear hypoechoic (due to high fluid content)
Fibrils are surrounded by hyperechoic connective tissue, giving a striated appearance
Pennate structure of muscles can also be evaluated

Jacobson, (2013)
Nerve

- Nerves have a fascicular appearance
- Nerve fascicles are hypoechoic, with the surrounding connective tissue (epineurium) appearing hyperechoic
- SAX shows honeycomb appearance
- LAX shows “railroad track” appearance

A: SAX view of median nerve with adjacent flexor carpi radialis tendon
B: LAX of median nerve adjacent to flexor digitorum tendon (Jacobson, 2013)
Meniscoid/Discoid structures

- Fibrocartilagious
- Have medium brightness and echogenicity
- Difficult to make definitive diagnosis with US

Medial meniscus of the knee (Jacobson, 2013)
Articular Cartilage

- Articular (hyaline) cartilage appears hypoechoic
- Adjacent to hyperechoic subchondral bone
Bursa

- Thin, hypoechoic layer between potential friction areas

Image source: ESSR
Key terms

- **Penetration** Depth of sound wave
- **Attenuation** Reaction of sound wave with tissues encountered:
  - Reflection
  - Scattering
  - Refraction
  - Absorption
- **Artifact:**
  - Anisotropy
  - Enhancement
  - Shadowing
  - Reverberation
Enhancement

**FIGURE 3.** (A) Depiction of the enhancement of a region deep to a fluid-filled structure. Enhancement occurs as there is less attenuation of the propagating sound wave as it travels through a fluid-filled structure. (B) A transverse ultrasound image demonstrating enhancement of the midline pelvic floor structures deep to the bladder.

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Anisotropy

- Fibrillar tissues (tendons, ligaments, muscles) will display as hyperechoic when the angle of the sound beam increases.

Shadowing

**FIGURE 4.** (A) Depiction of how an acoustic shadow forms behind a strongly attenuating (hyperechoic) structure such as bone. (B) A transverse ultrasound image demonstrating acoustic shadowing (AS) caused by the posterior elements of a lumbar vertebra. Abbreviations: L, lamina; MF, multifidus; SP, spinous process. Reproduced with permission Whittaker 2007.142
Refraction

**FIGURE 5.** (A) Depiction of an edge shadow produced when a sound wave is refracted (bent) around the edges of a fluid filled structure. (B) A transverse ultrasound image demonstrating edge shadowing (ES) caused by the bladder.

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Reverberation

Depiction of reverberation which is caused when a portion of the ultrasound echo from a highly reflective surface, lying parallel to the transducer, is reflected back into the tissue to meet the same interface where it again is reflected back to the transducer. The time delay falsely portrays that interface at 1 or more levels deeper in the tissue structure. (B) An ultrasound image demonstrating reverberation (lines on the left side of the image) produced by the interface between the transducer and air at the skin surface (inadequate use of gel).

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**Imaging Modes**

**FIGURE 9.** (A) A brightness mode (b-mode) image of the lateral abdominal wall. Abbreviations: EO, external oblique; IO, internal oblique; TrA, transversus abdominis. (B) A split-screen image with b-mode on the left and motion mode (m-mode) on the right. The m-mode image represents the information from the dotted line on the b-mode image displayed over time (x-axis). Static structures produce straight interfaces while structures that change in thickness or depth (in this case the TrA) create curved interfaces. The increase in depth of the TrA correlates to a contraction.

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Some examples of pathology

- **Bone**: Avulsion fracture of talus
Tendon Pathology

- Tenosynovitis of the long head of the biceps

Jacobson 2013
- Tendon tear (Patella Tendon)
• Supraspinatus tear

Jacobson 2013
Ligament pathology

- Ulnar Collateral Ligament tear (pre and post)
Muscle Pathology

- Intramuscular hemorrhage

Jacobson 2013
• Partial thickness tear of rectus femoris

Jacobson 2013
Nerve Pathology

- Carpal Tunnel Syndrome:
Bursa and Cysts

- Baker’s cyst:

- Ganglion cyst (LAX):
Resources

• JOSPT Special Issues August/October 2007
• www.essr.org (scan protocols for peripheral joints)