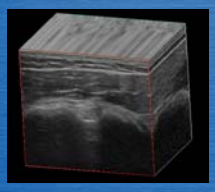
Introduction to Musculoskeletal Ultrasound: Physics, Instrumentation and Image Optimization



Jeffrey A. Strakowski, MD
Clinical Associate Professor, Dept of PM&R
The Ohio State University
Associate Director of Medical Education, PM&R
Riverside Methodist Hospital
Director of Musculoskeletal Research,
The McConnell Spine, Sport & Joint Center

Learning Objectives

- Understand the Fundamental Principles for Imaging Soft Tissue Structures with High Frequency Ultrasound.
- Become Familiar with the Echogenic Appearance of Peripheral Nerves and Other Common Structures Evaluated with MSK Ultrasound.
- Become Familiar with the Basic Terminology and Principles Utilized in Diagnostic Ultrasound Including Image Optimization.

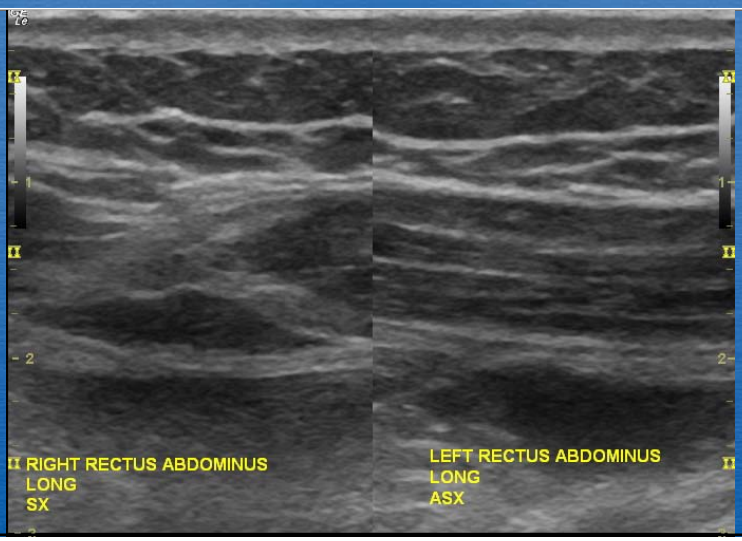
Why Learn MSK Ultrasound?

- Excellent Portable Diagnostic Tool
- Progressive Technology
- Patient Satisfaction
- New Appreciation of Anatomy
- Promote Musculoskeletal Medicine
- Improve Patient Care

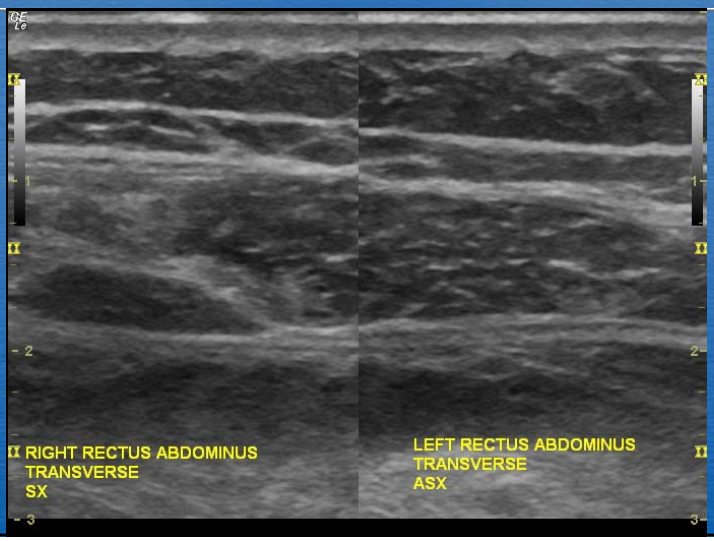
Advantages of MSK Ultrasound

- Relatively inexpensive
- Better soft tissue differentiation than MRI
  - Better spatial resolution (150 microns vs 450)
- Can provide focused evaluation
- Dynamic assessment
- Allows easy side-to-side comparisons
- No issues with “claustrophobia”
- No interference with implants or pacemakers

Rectus Strain - Longitudinal



Rectus Strain



Rectus Stain - Dynamic

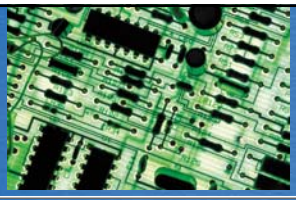
AIUM: American Institute for Ultrasound in Medicine

- Summer 1951, 24 physicians attending the American Congress of PM&R in Denver found a common interest the validity of ultrasonic energy as a medical tool.
- Disraeli Kobak, MD was 1st president
- www.aium.org

Outline

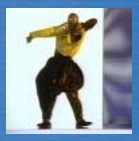
- Basic Physics
- Ultrasound Equipment
- Image Interpretation –Normal Tissue
- Image Optimization
- Scanning Technique

Physics



- Probe: Piezoelectric Crystal
- Electricity is Converted to Vibrations
- Sound Wave at Interfaces
- Bright Echo: High Impedance Differences
- Crystal Receives Echo --> Image

Physics-Breaking it down

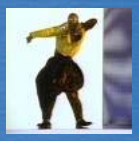


- Sound is a mechanical, longitudinal wave that travels in a straight line.
- Sound requires a medium through which to travel.
- Ultrasound is a mechanical, longitudinal wave with a frequency exceeding the upper limit of human hearing, which is 20,000 Hz or 20 kHz.
- Medical Ultrasound 2MHz to 18MHz

Physics-Frequency

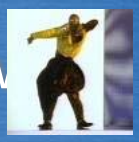
- Cycles per second (Hertz, Hz)
- Function of source (transducer)
- Major factor in determining depth of beam penetration
- increase frequency, decrease penetration
- decrease frequency, increase penetration

Physics-Frequency and Wavelength



- Length for complete cycle (= mm)
- As frequency increases, wavelength decreases and vice versa
- Major determinant of image resolution
- increased frequency, increased resolution
- decreased frequency, decreased resolution

Interactions of Ultrasound w Tissue



- Reflection
- Refraction
- Transmission
- Attenuation

Reflection

- The ultrasound reflects off tissue and returns to the transducer, the amount of reflection depends on differences in acoustic impedance.

Transmission

- Some of the ultrasound waves continue deeper into the body
- These waves will reflect from deeper tissue structures

Attenuation

- Defined - the deeper the wave travels in the body,the weaker it becomes.
- 3 processes: reflection,absorption, refraction

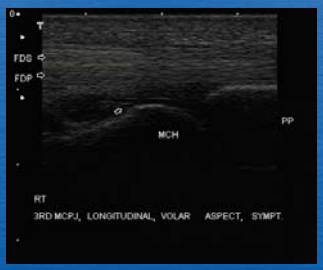
Physics

- Safety: Lower intensity than therapeutic ultrasound.
- Upper limit: 0.72watt/cm^{2*}

*Nyborg. Ultrasound Med Biol 2001; 27:301-33

Equipment: Probe Selection

- Need a LINEAR probe of high resolution (minimal 7.5mHz)



Frequency

- Low frequency transducers provide better penetration.

  -Deep: 5-7MHz linear or curvilinear (eg thigh, hip)

- High frequency transducers provide better resolution with more superficial structures.

  -Superficial: 10-17MHz (extremities, peripheral nerves)

Equipment: Standard Unit

Advantages:

-Powerful, Fast software,

-High Resolution (15-20Hz)

Disadvantages:

-Not portable

-$$

Equipment: Portable Unit

Advantages:

-Small size, Less expensive

Disadvantages

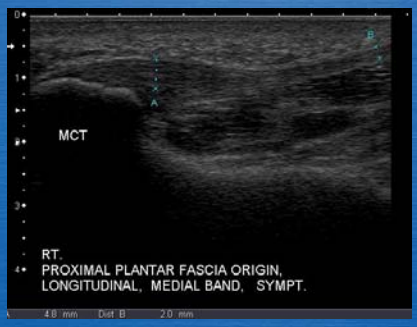
-Often less resolution

-Less “bells and whistles”

*important to have “expandable” software

Terms and Appearance

Echogenicity (hypo, hyper)



Tendon Appearance

- **Longitudinally oriented collagen fibrils**
- **US appearance**
  - **Longitudinal: fine parallel lines, hypoechoic alternating with hyperechoic**
  - **Axial: Speckled pattern**

Tendon Structure

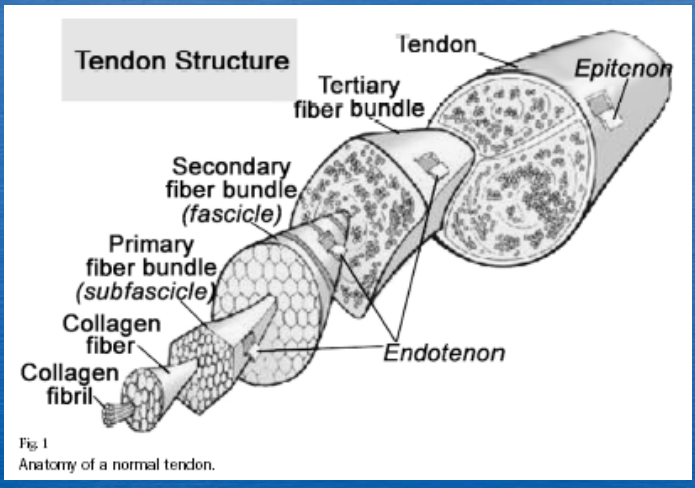
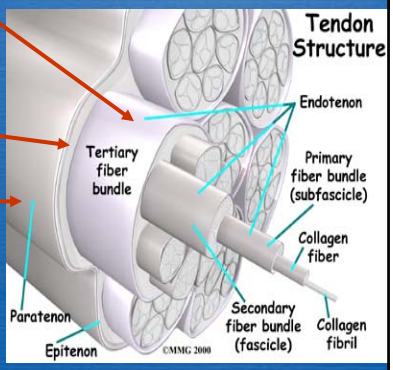


Fig. 1
Anatomy of a normal tendon.

J B J S V 0 I

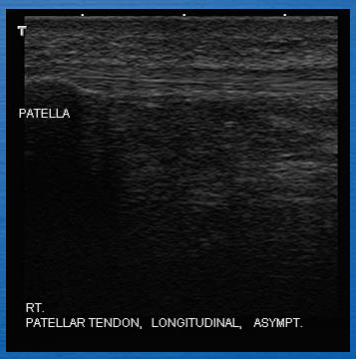
Tendon Histology

- **Endotenon** is loose connective tissue and allows fasciles to slide against each other.
  - Transitions into perimysium and periosteum.
- Sheathed by **epitenon** (neurovascular supply and lymphatics).
  - White shiny part
- Some tendons are surrounded by **paratenon**. (Separate and further decreases friction)
  - Certain tendons have paratenon replaced by TRUE synovial sheath/ bursa lined by two layers of synovial cells referred to as a **tenosynovium**.
  - Within this sheath are blood vessels to tendon.



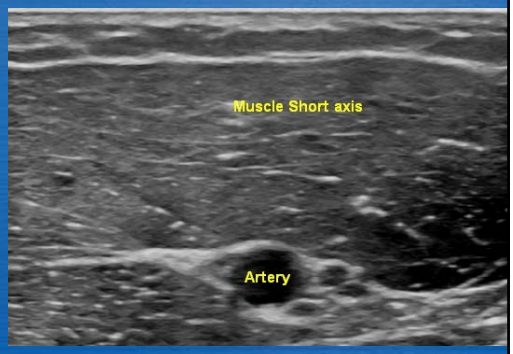
Tendon Appearance

*Normal tendon has a characteristic (“fibrillar”) appearance of low reflective tendon fibrils surrounded by reflective collective tissue matrix.



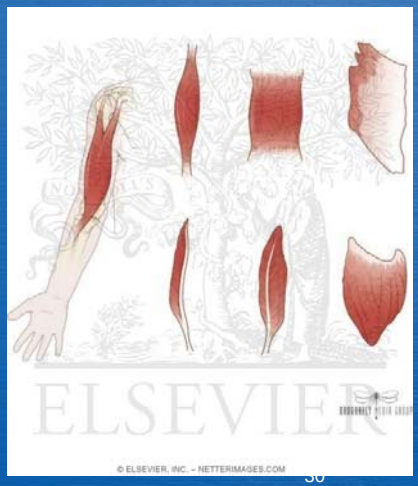
Muscle Appearance

*more hypo-echoic than tendon with intervening hyper-echoic linear perimysium (“starry night”)



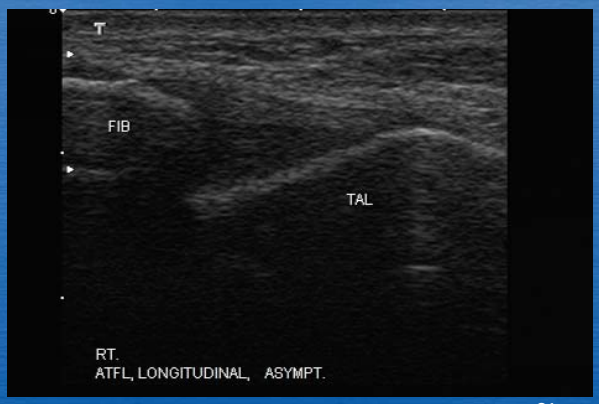
Muscle Shapes

- Circular
- Covergent
- Parallel
- Pennate
- Fusiform



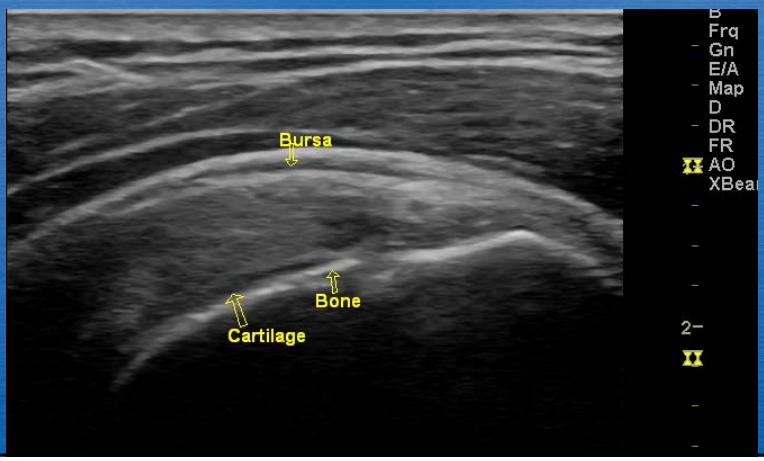
Ligament Appearance

*Generally a thin hypo-echoic structure



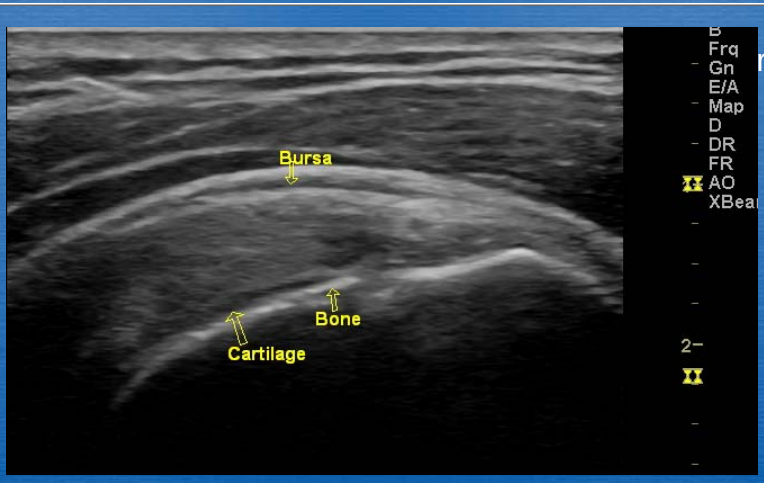
Bone Appearance

*Hyper-echoic interface with deeper hypo-echoic appearance



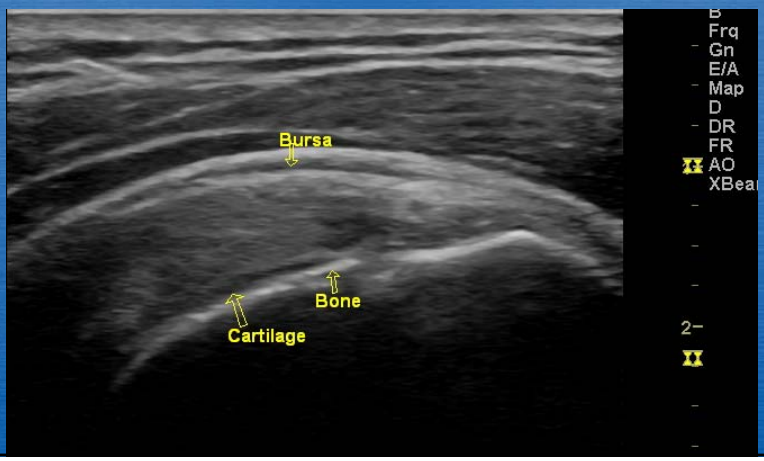
Articular Cartilage

rface



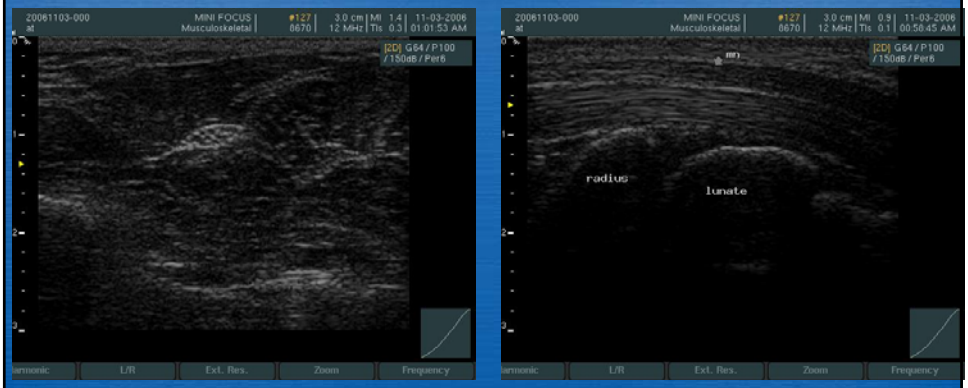
Bursal Appearance

Hypo-echoic- need to know anatomic landmarks

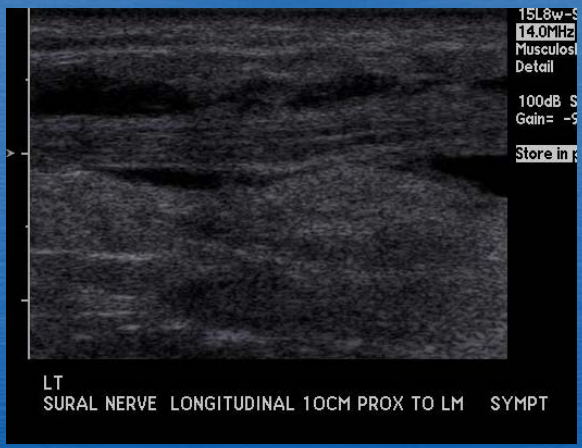


Nerve Appearance

*Displays a fasicular pattern. “Honeycomb” appearance in transverse view

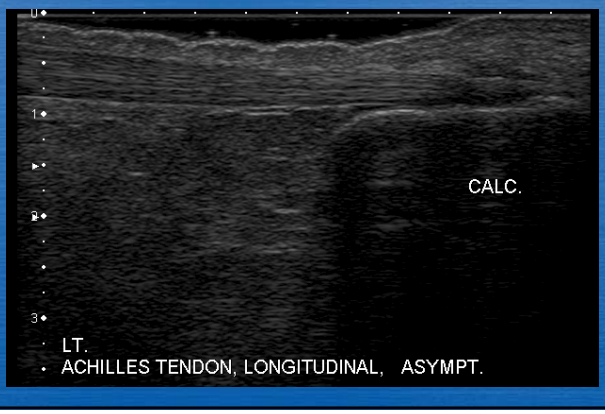


Nerve Appearance - Longitudinal



Anisotropy

Ultrasound signal must be perpendicular to the orientation of the tendon



Anisotropy

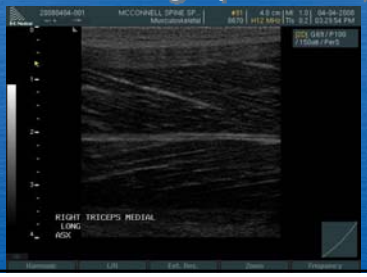
Scanning Basics

- Select Appropriate Transducer
- Adjust Depth
- Optimize Focal Zone Localization
- Adjust Frequency
- Adjust Gray Scale Gain
- Doppler when Needed

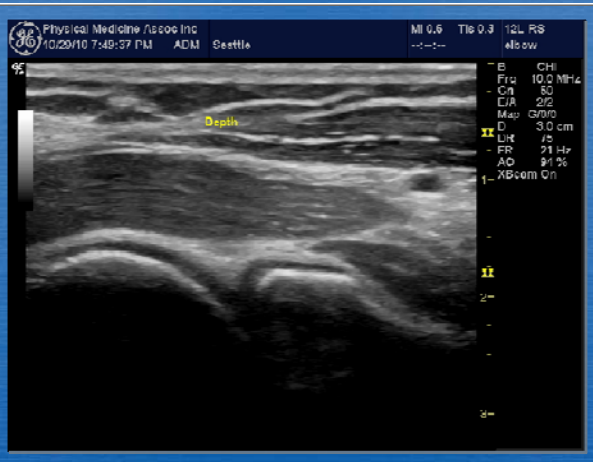
Image Appearance

- Top: Skin Surface
- Bottom: deep away from transducer
- When imaging in long axis:

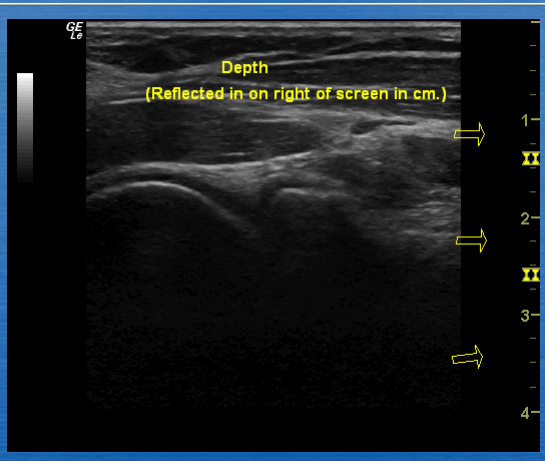
  -Left side of image proximal, right distal



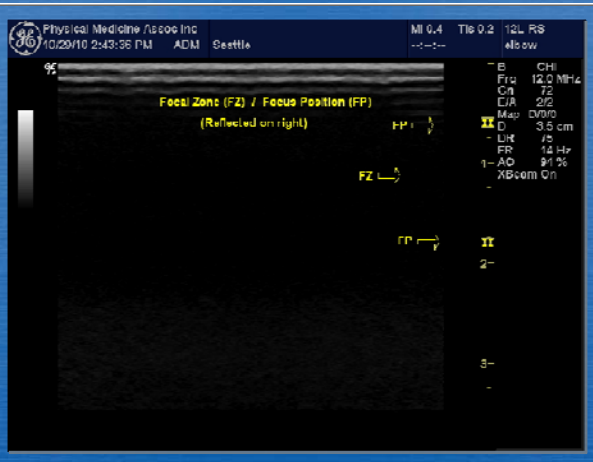
Depth


Physical Medicine Assoc Inc
10/29/10 7:49:37 PM ADM Seattle
MI 0.6 TIs 0.3 12L RS
elbow
Depth
B CHI
Frq 10.0 MHz
Gn 50
D/A 2/2
Map G9/0
D 3.0 cm
Dyn
FR 21 Hz
AO 91 %
XBeam On

Depth

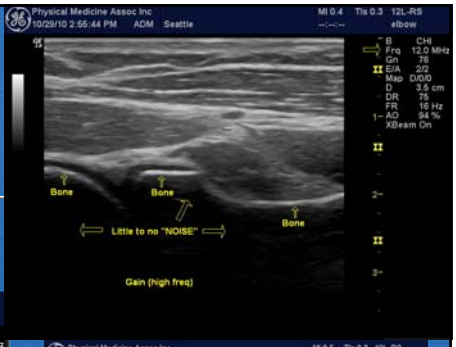

Depth
(Reflected in on right of screen in cm.)
1
2
3
4

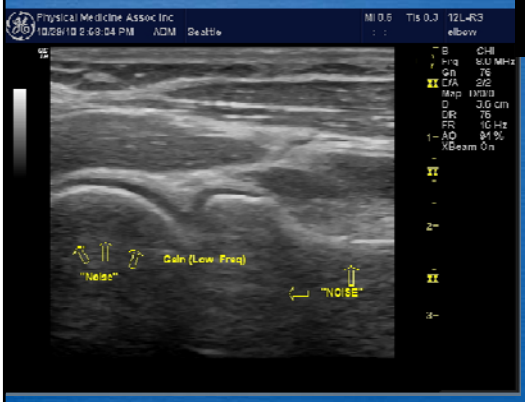
Focal Zone

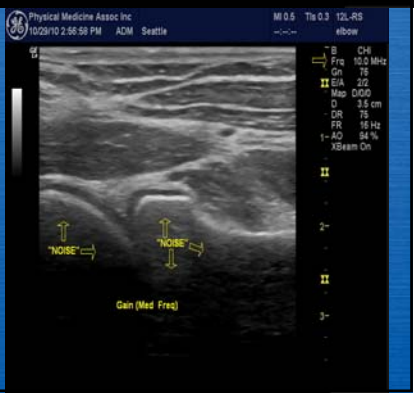


Focal Zone vs Frame Rate

Frequency

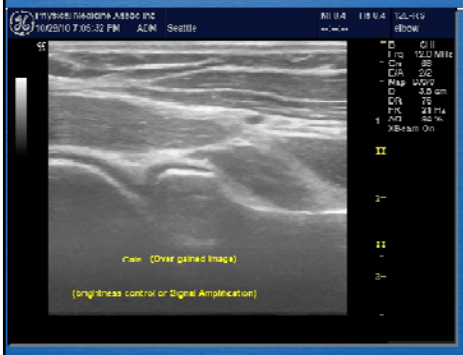


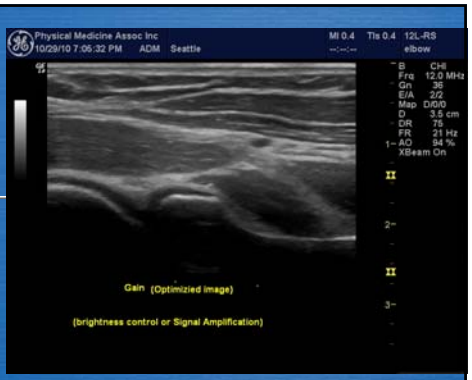




Frequency

Grey Scale Gain



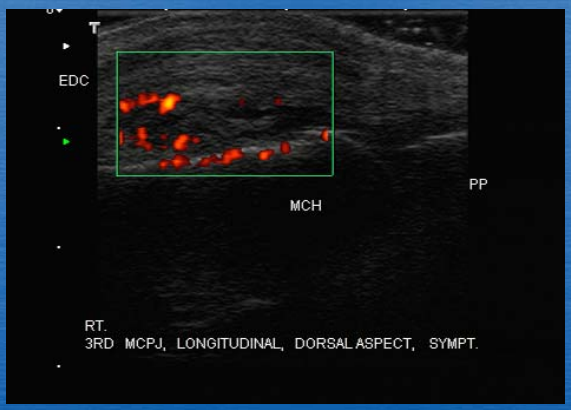


Grey Scale Gain

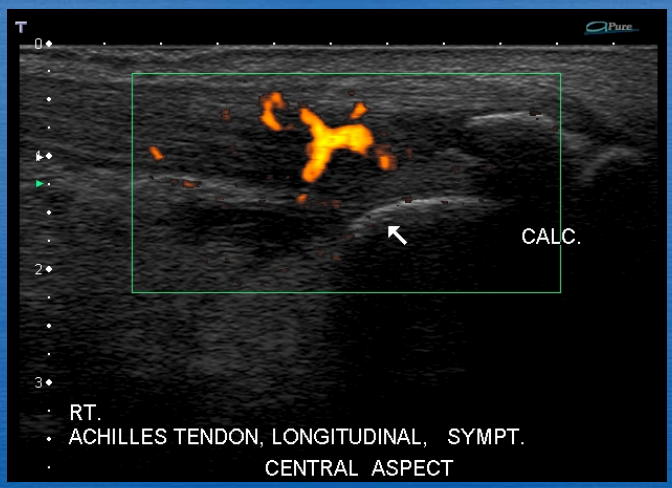
Time Gain Compensation (TGC)

Optimized Image

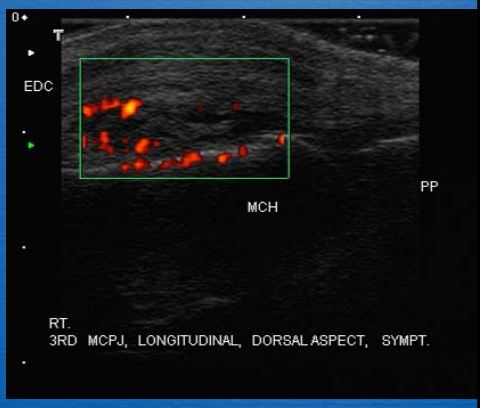
Power Doppler



Achilles Tendonitis: Power Doppler



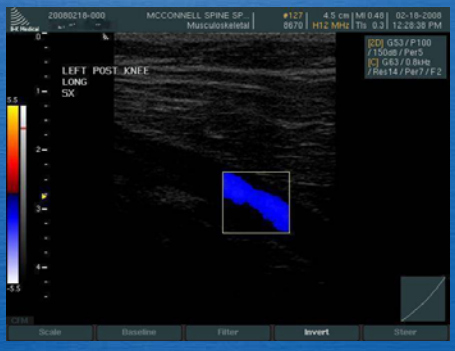
Extensor Tendons



Power Doppler

Power Doppler

Color Doppler



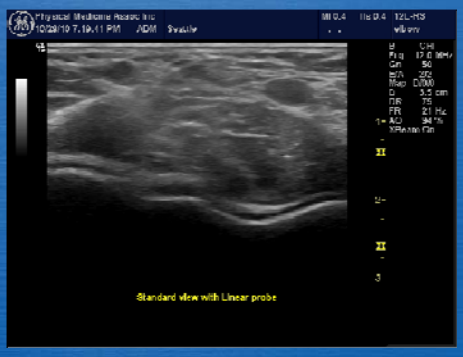
Color Doppler

Advanced Imaging

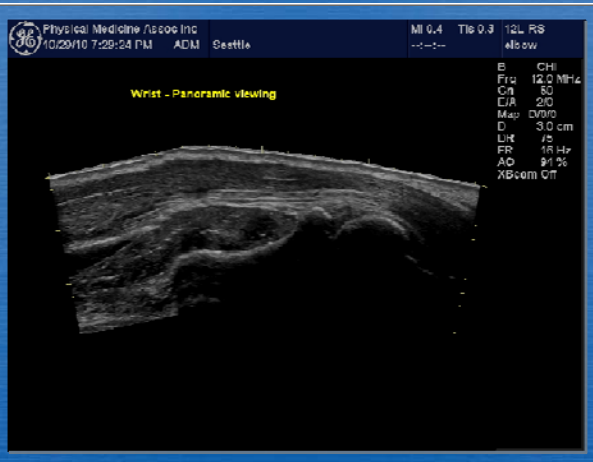
- Needle Visualization Enhancement
- Panoramic Viewing
- Virtual Convex
- 3-Dimensional Ultrasound

Needle Visualization Enhancement

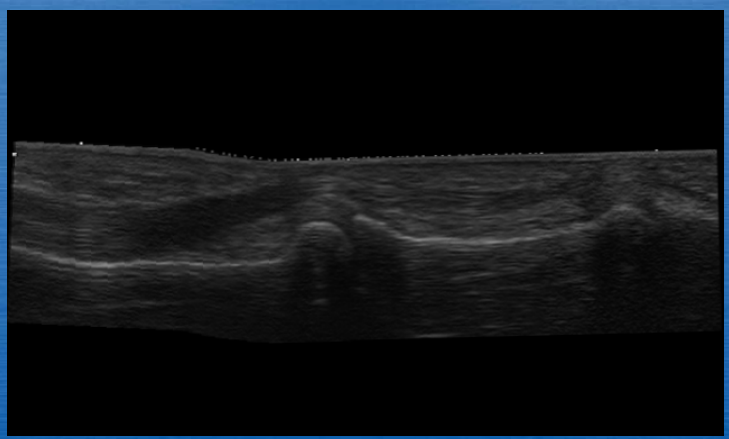
Extended Field of View (aka convex or trapezoid view)



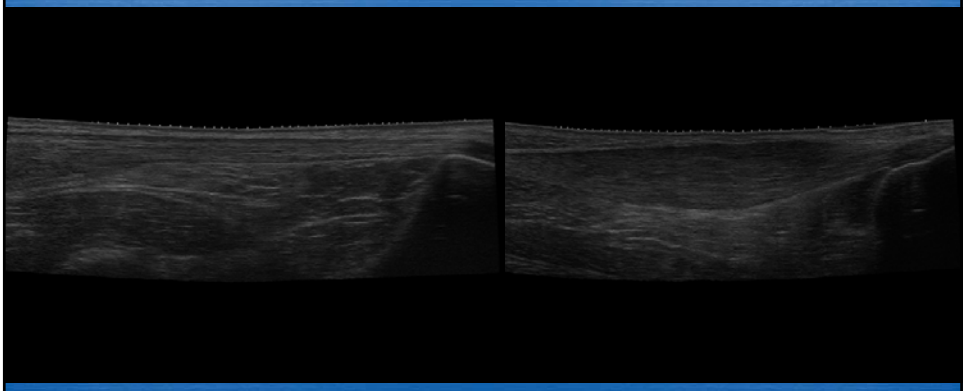
Panoramic



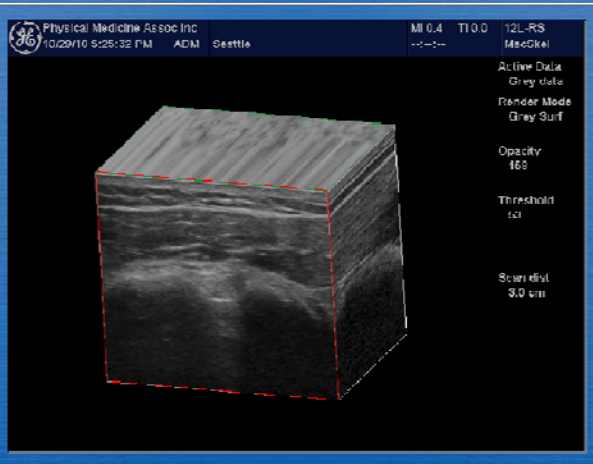
Flexor Tendons -Panoramic



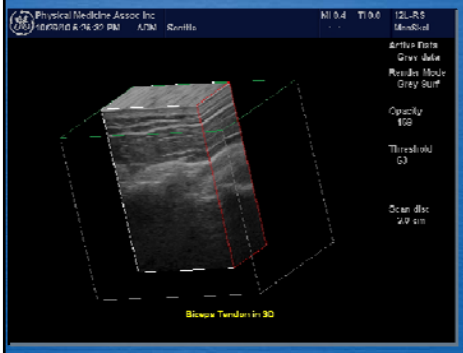
Achilles Panoramic



3D Imaging



3D Imaging



3D Imaging

3D Imaging

Scanning Technique

- Holding Transducer:

  -Anchor hand/transducer

  -5th Finger or hand on patient

- Imaging Plane:

  -Long axis of transducer

  -Orient yourself

Scanning Techniques

- Toggle
- Heel-toe rock
- Up/Down/All Around
- Not too many moving parts!
- Don't forget anatomy that you already know!