



Musculoskeletal Ultrasound Updates

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HOSPITAL
FOR
**SPECIAL
SURGERY**

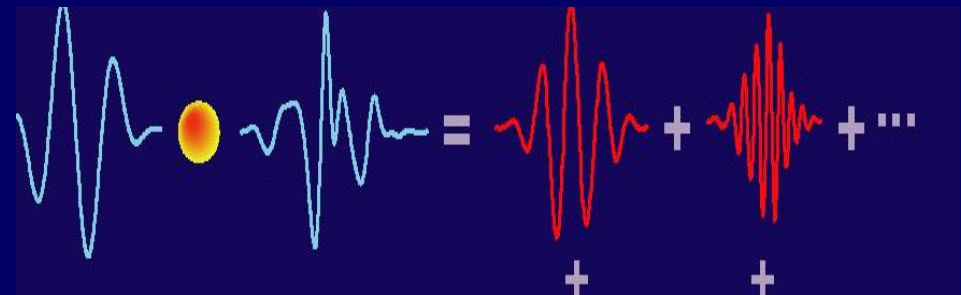


Overview

- Ultrasound
 - Basics
 - Technical considerations
 - Anatomy, pathology and technique
 - Applications
 - Dynamical considerations
 - Blood flow
 - Elastography
 - 3-D imaging

Technical Considerations: Gray-scale Sonography

- Uses a pulse-echo technique
 - short mechanical wave burst from transducer followed by receive mode
 - image formed by ultrasound back-scatter by tissue interfaces
- Highest frequency linear transducer depending on depth (5-20 MHz)
- Specialized features
 - extended field of view (EFOV), tissue harmonics, compound imaging, 3-D, 4-D imaging



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Harmonics

Ultrasound Terminology

- Echogenicity- image brightness
 - Results from density of reflecting surfaces and differences in acoustic impedance
 - Examples
 - Hyperechoic (bone, metal, tendon)
 - Hypoechoic (fluid, muscle)
 - Anechoic (black- simple fluid)
- Specular reflector- large scattering surfaces
 - Strong specular reflectors may produce reverberation (eg., metal, gas)
- Speckle- small scatterers (<acoustic wavelength)
 - Structured noise that produces graininess



Power or Color Doppler Sonography

Power

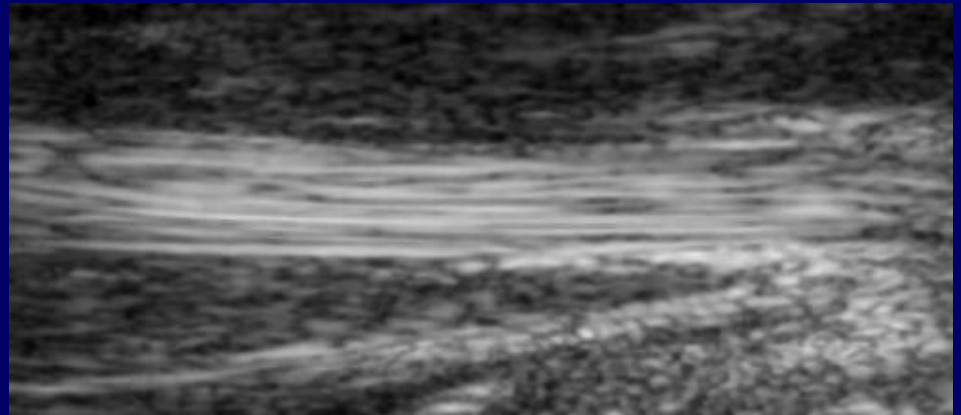
- Encodes integrated Doppler spectrum in color (relates to number of moving scatterers)
- Results in significantly improved flow sensitivity (3-5x)
- Not subject to aliasing
- Angle insensitive

Color

- Encodes estimate of mean frequency shift in color (relate to velocity)
- Random noise affects ability to assess low flow states
- Angle dependent
- Aliasing

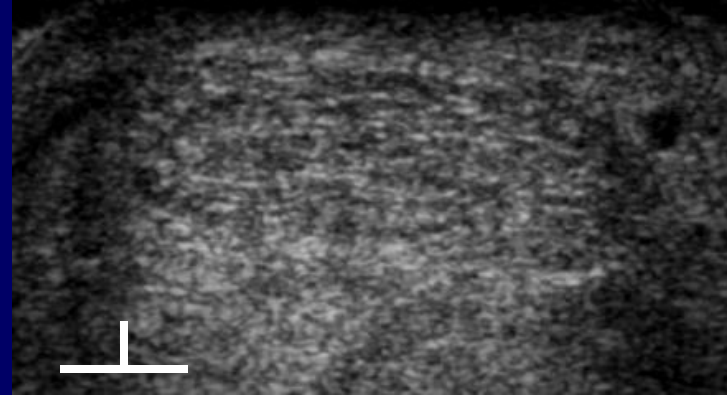
Tendons

- Echogenic
- Fibrillar
- Anisotropy
- May be surrounded by tendon sheath or dense connective tissue (paratenon)

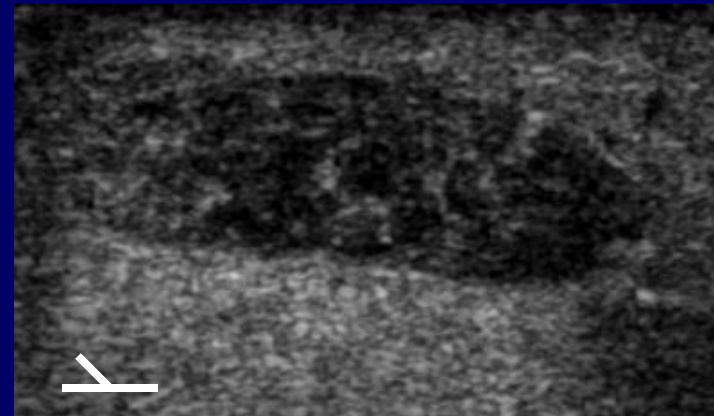


Anisotropy

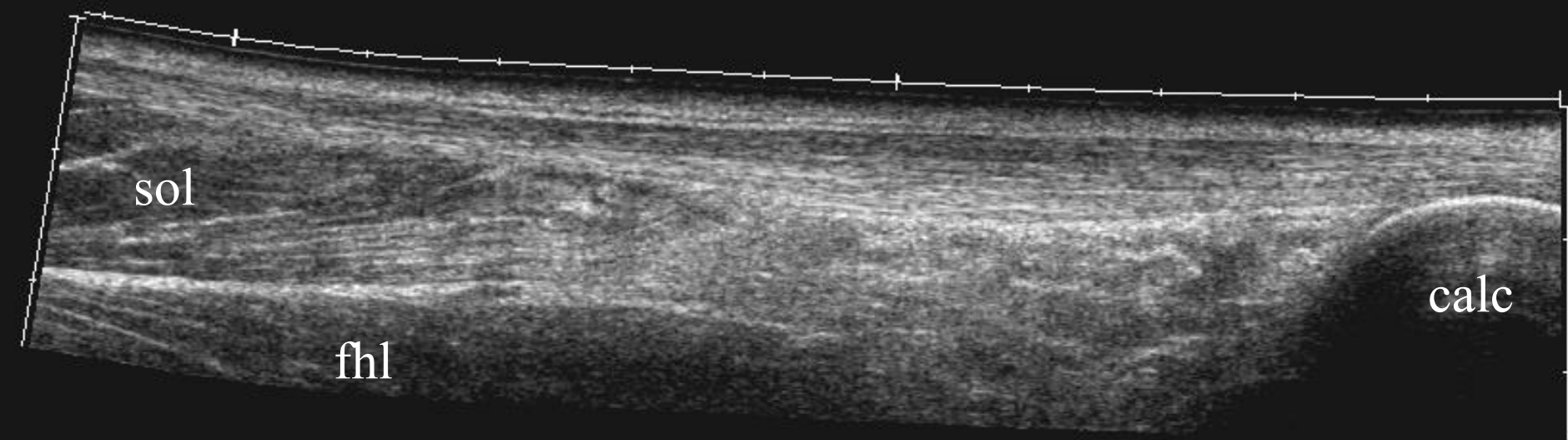
Beam perpendicular
To tendon axis



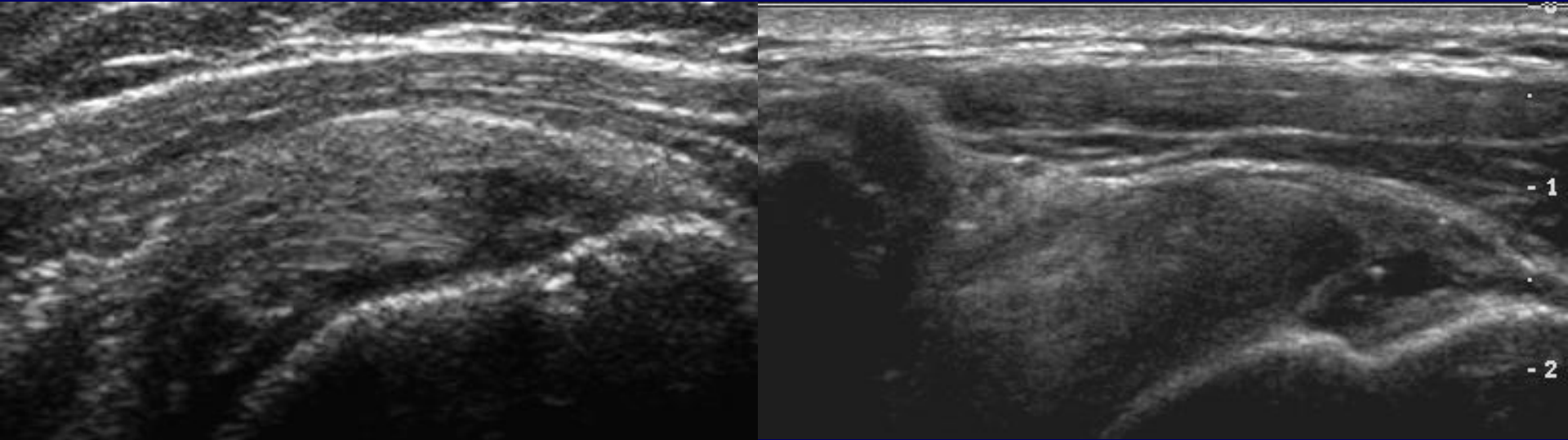
Beam insonates tendon
at an angle other than
90 degrees



Achilles Tendon: EFOV long axis view



Compound imaging



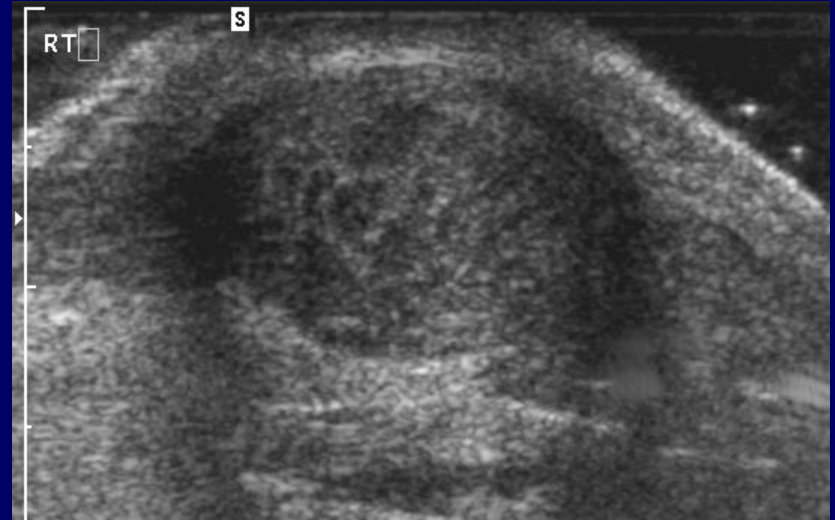
Data from multiple “look” directions effectively reduces speckle

Tendinosis

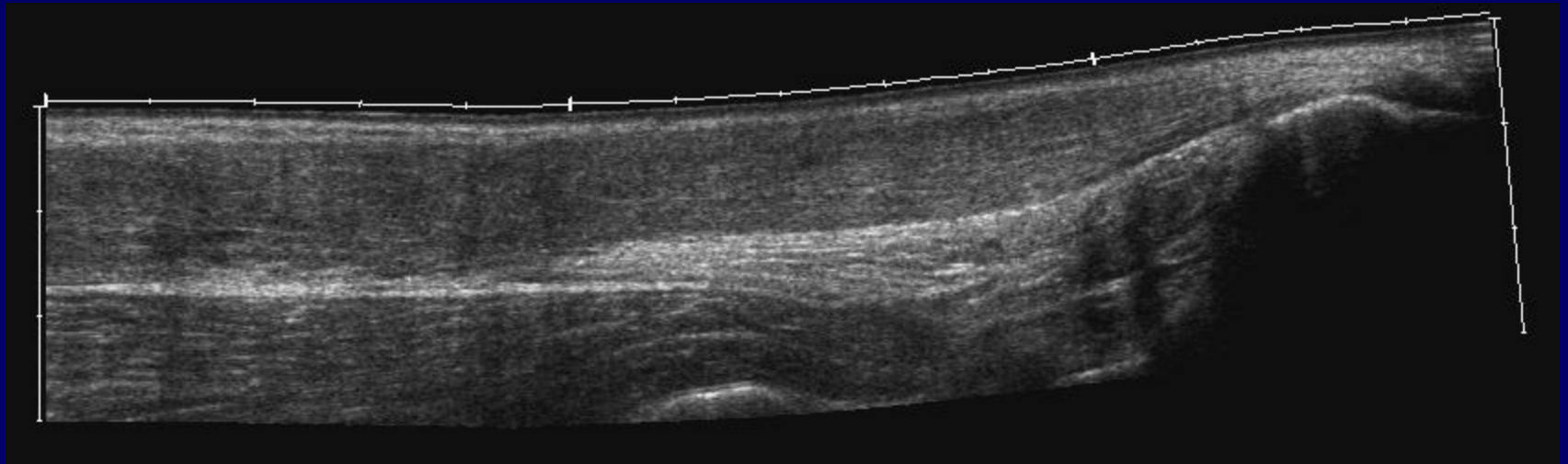
- Hypoechoic or heterogeneous
- Enlarged
- Indistinct margins
- Intrastance tears/ cystic degeneration
- Dystrophic calcification or ossification
- May display increased vascularity

Achilles Tendinosis

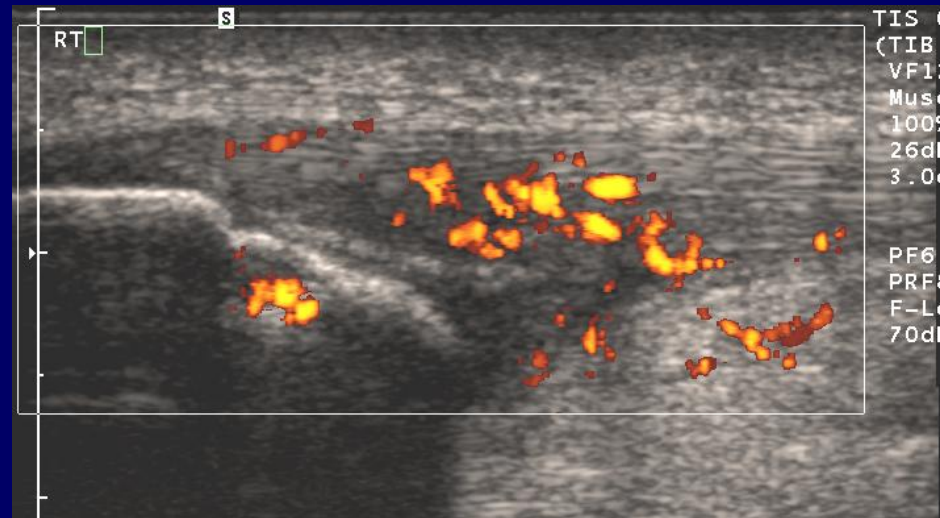
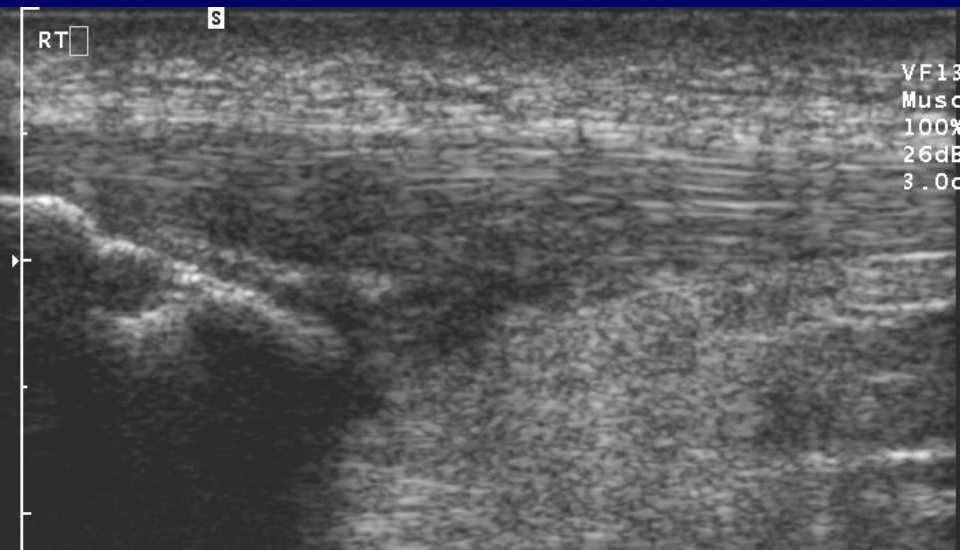
Short axis



Long axis



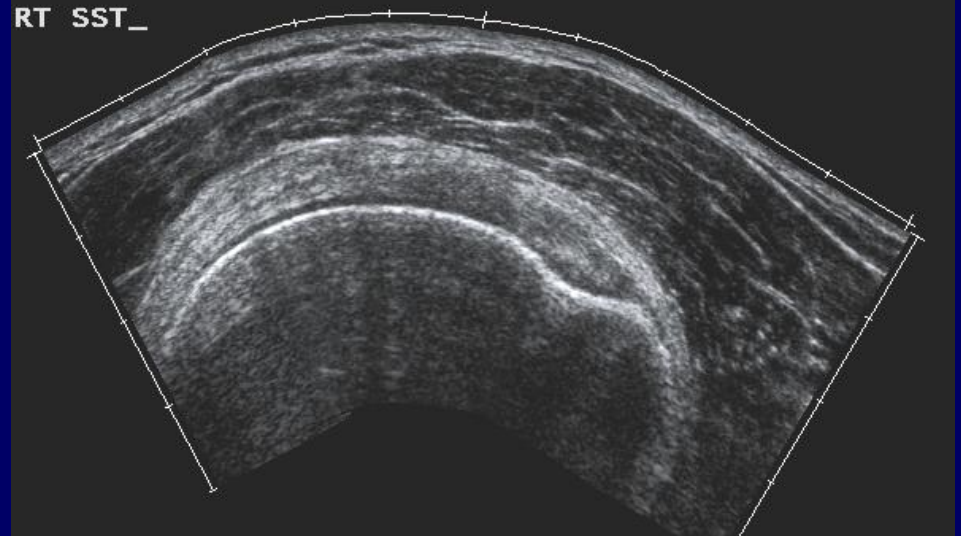
SYMPTOMATIC PATELLAR TENDINOSIS



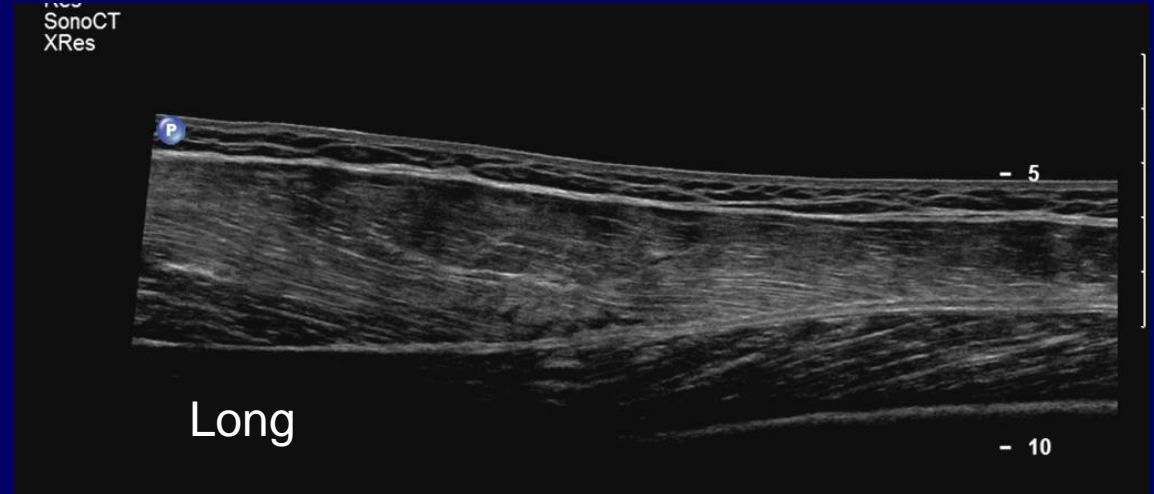
A variety of symptomatic tendinoses develop an angiofibroblastic response (e.g. knee, elbow, ankle)

Muscle

- Hypoechoic
- Contains linear echogenic septations (perimyseum)
- Pathology
 - Traumatic
 - Infectious
 - Inflammatory



Muscle



Strain/contusion

Edema pattern

Tears

Myofascial

Intramuscular

Atrophy

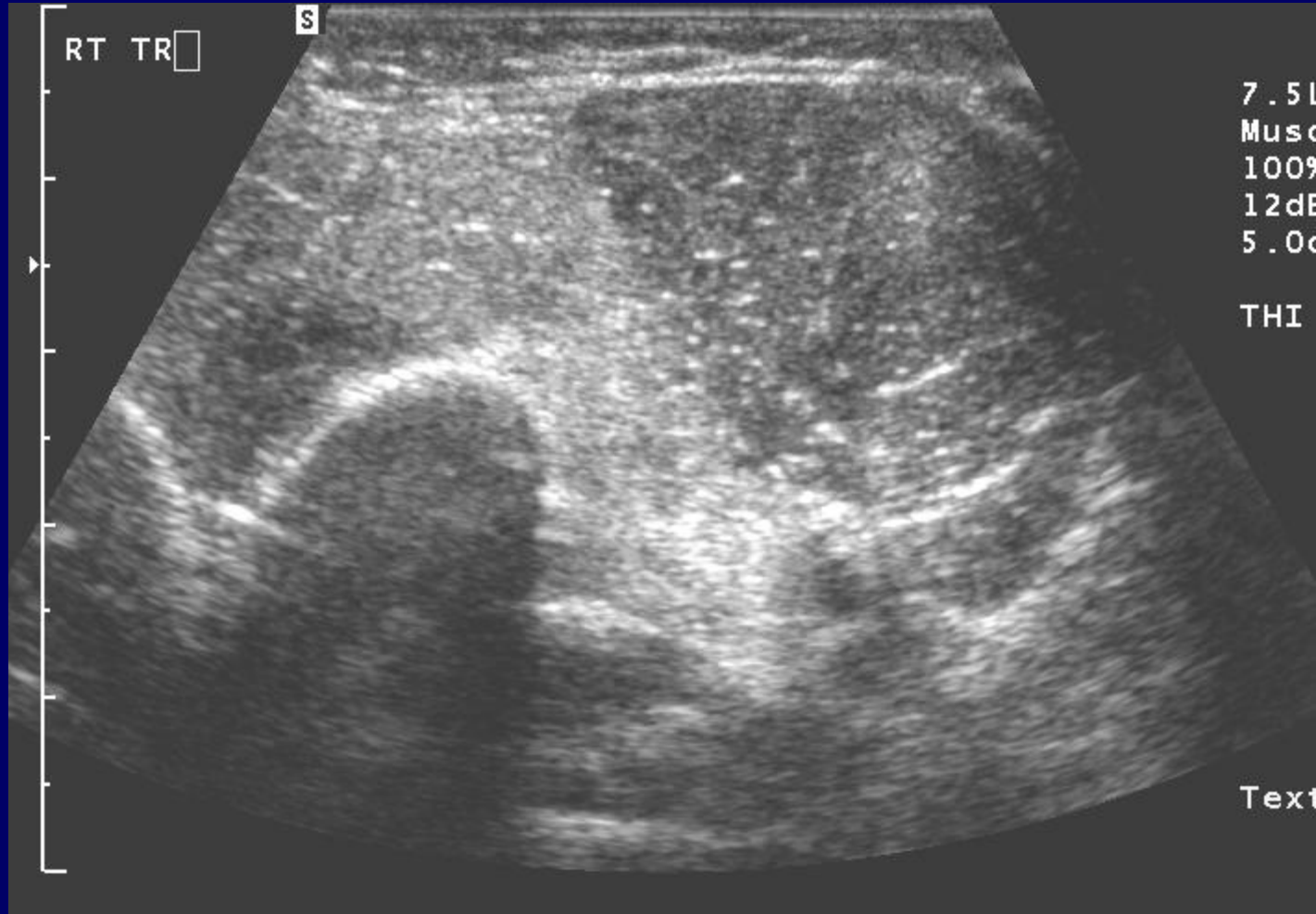
Increased echogenicity

Loss of muscle volume
and morphology



Quadriceps

Viral Myositis of the Brachialis Muscle

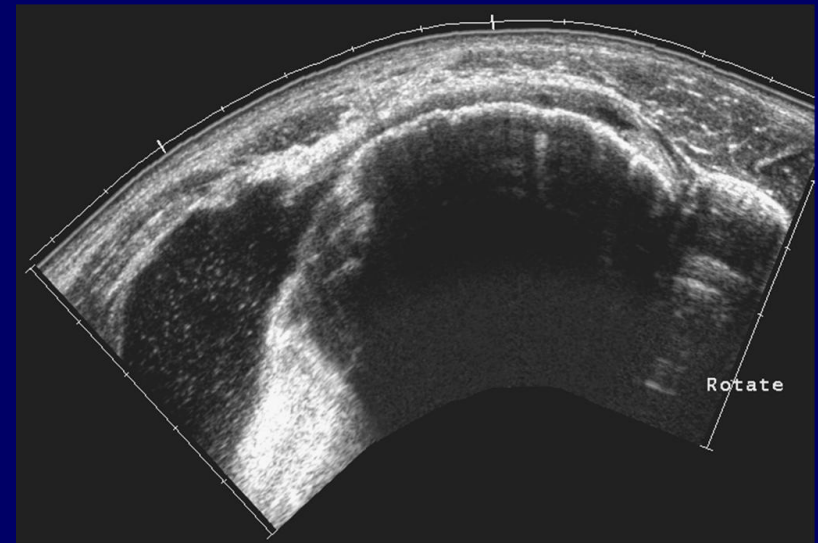


Rhabdomyolysis



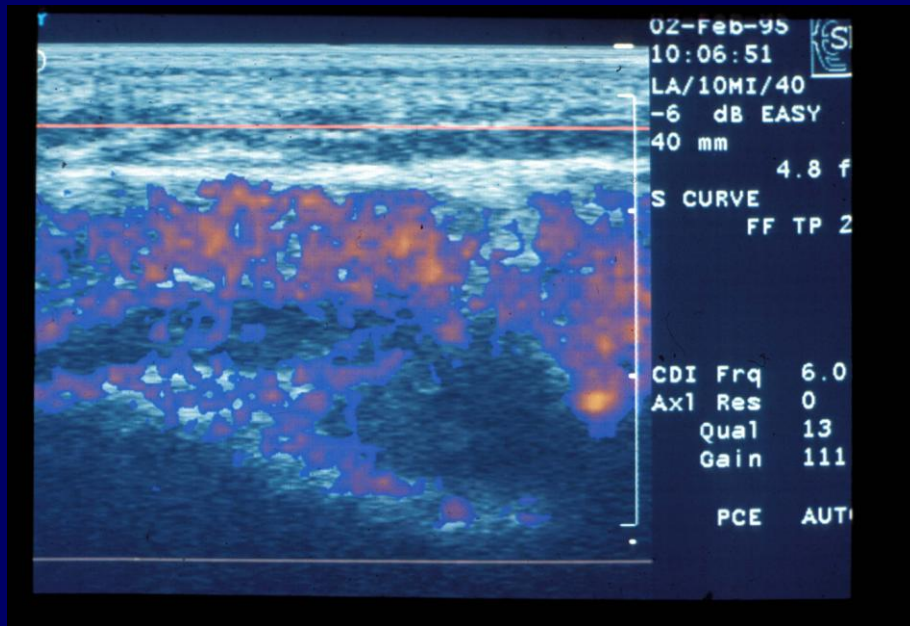
Bursitis

- Distension by fluid and/or synovial debris
- Power Doppler may help distinguish inflammatory from reactive collections
- Ultrasound provides guidance for aspiration and therapeutic injection

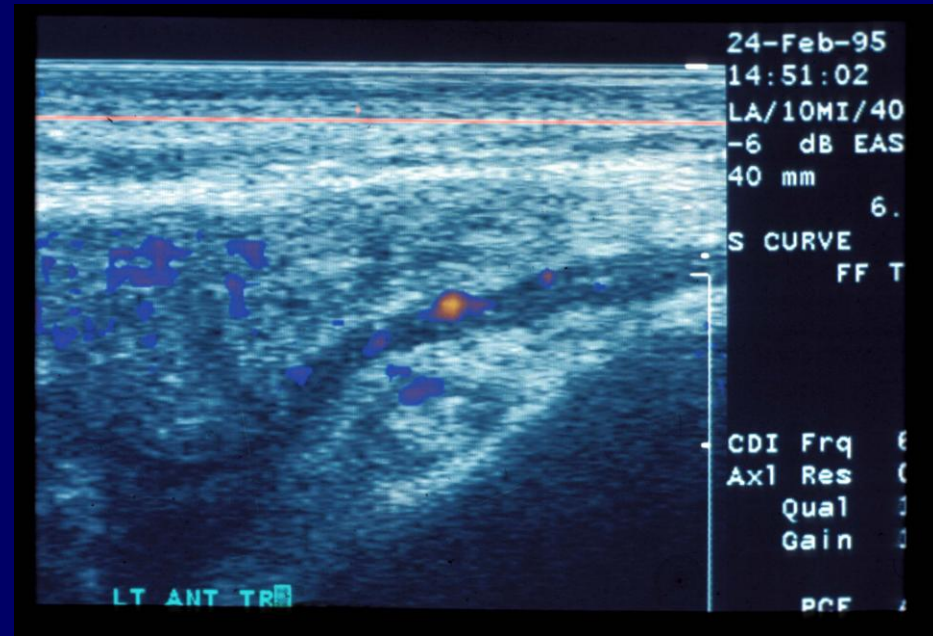


RA with rotator cuff tear
and subdeltoid bursitis

BURSITIS: THERAPEUTIC RESPONSE



PT WITH SHOULDER PAIN
wbc > 100,000



2 WKS S/P I&D
wbc < 10,000

Part 2: Dynamical considerations

- Real-time (30f/s grayscale, 15-20 f/s pds)
 - performance of provocative maneuvers
 - direct visualization during needle placement
 - monitor injected/aspirated material
 - Assess vascularity



Tendon motion



Normal



Adhesions

Some new ultrasound applications

- Monitoring vascularity
 - Inflammatory arthritis
 - PD quantification
 - Ultrasound contrast agents
- Elastography
- 3-D

Joints: arthritis

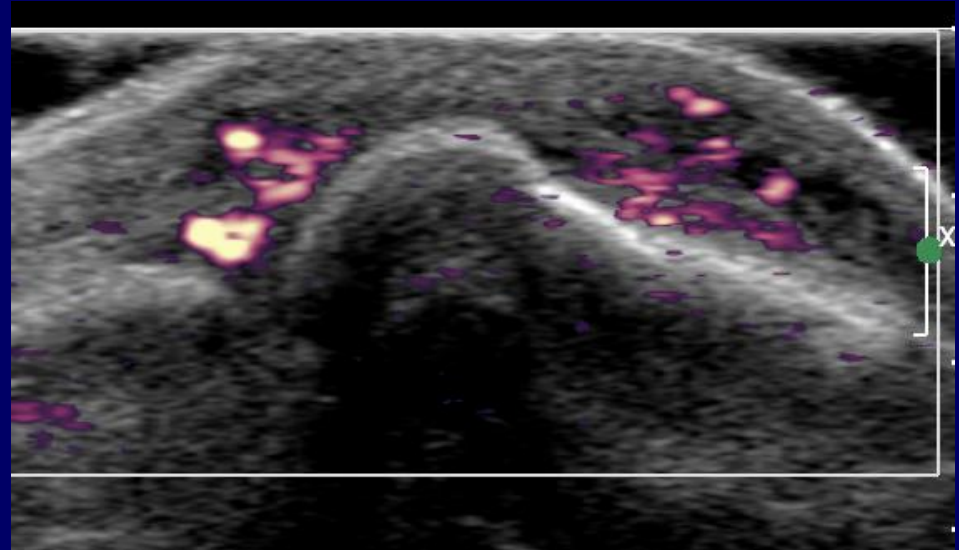
- Clinical exam
 - Document painful/swollen joints
 - Can underestimate the extent and severity of disease
- Radiography of hands and feet
 - Erosions may be apparent late
 - Does not assess joint synovitis or adjacent soft tissues
 - Both US and MRI have been documented to be more sensitive in the detection of erosions as well as assessing the soft tissues (Backhaus, et al., 1999)



Synovitis with erosion MCP

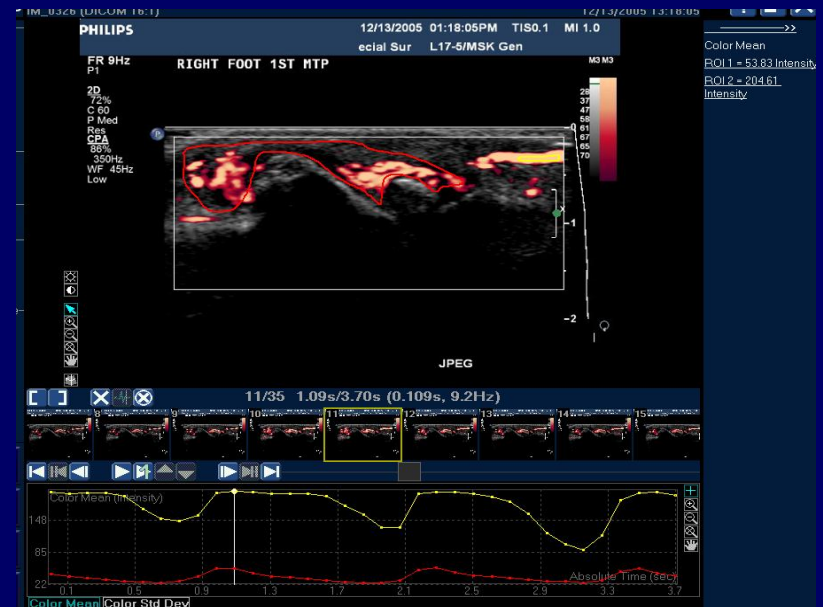
Inflammatory arthritis

- Treatment of the synovitis by new classes of disease modifying agents (eg., antiTNF) requires early detection
- Both US and MRI are capable of assessing disease activity by quantifying levels of angiogenic activity in inflamed synovium (McGonagle, et al., 2001, Klauser, et al., 2002, Szkudlarek, et al., 2002, Taylor, et al., 2004).
 - MRI: gadolinium chelates
 - US: power Doppler
 - contrast agents further increases sensitivity and allows quantification



Blood flow quantification

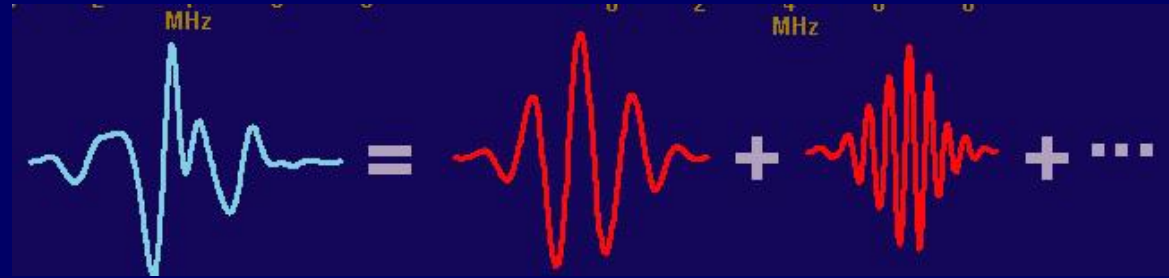
- Measurement of normalized PDS signal intensity per pixel (fractional moving blood volume) relates to specific blood flow
 - Number of moving scatterers/unit volume
 - Dymling, UMB 1991
 - Ratio of mean intensity in ROI to that of a vessel (100% blood volume) yields fractional moving blood volume (FMBV)
 - Rubin JM, et al., Radiology 1995



$$\text{FMBV} = 0.21$$

Ultrasound contrast agents

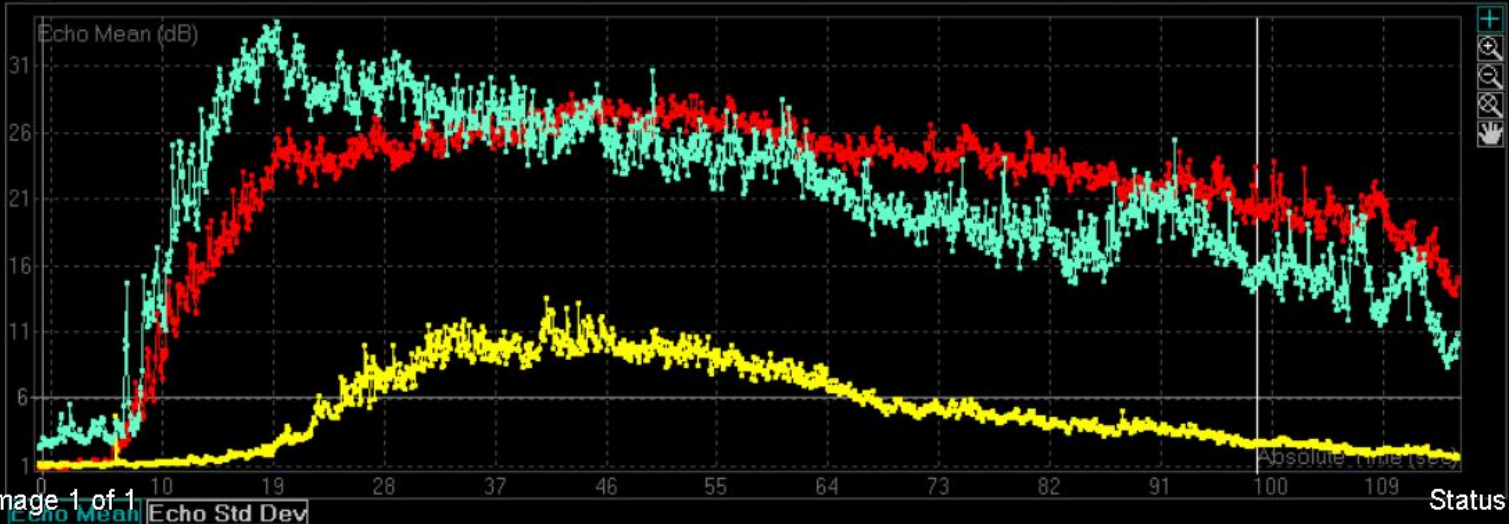
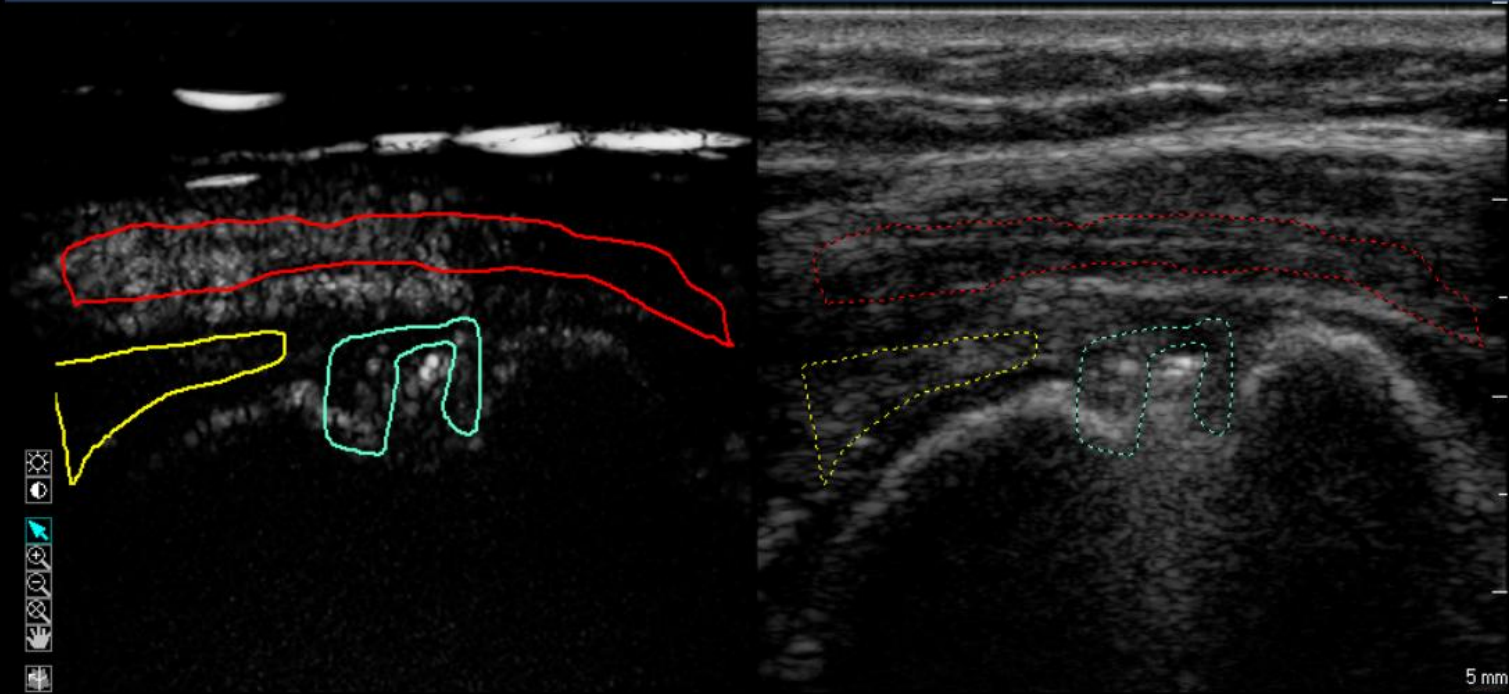
- Greater flow sensitivity than conventional Doppler
 - Encapsulated microbubbles 2-4 microns
 - capillary flow agent
 - Best imaged using gray scale and contrast harmonics (pulse inversion or amplitude modulation techniques)



Fundamental plus higher order harmonics

US contrast: repaired rotator cuff





Ultrasound Elastography

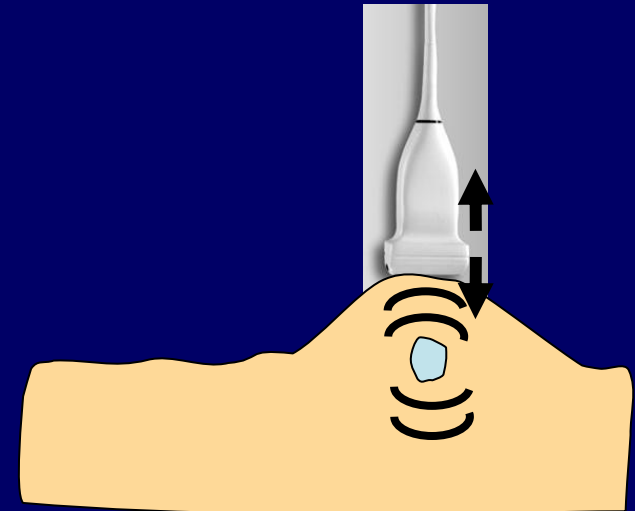
Surface deformation results in a
Detectable strain pattern using speckle tracking
techniques

Source can vary:

External compression-
subjective degree of compression
semiquantitative

Transducer radiation force
High MI- produces local heating
Quantitative

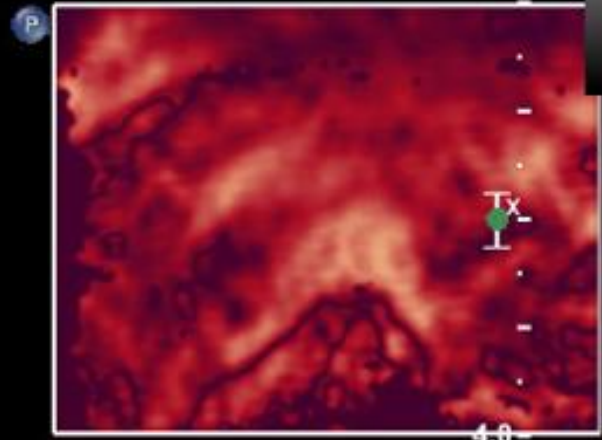
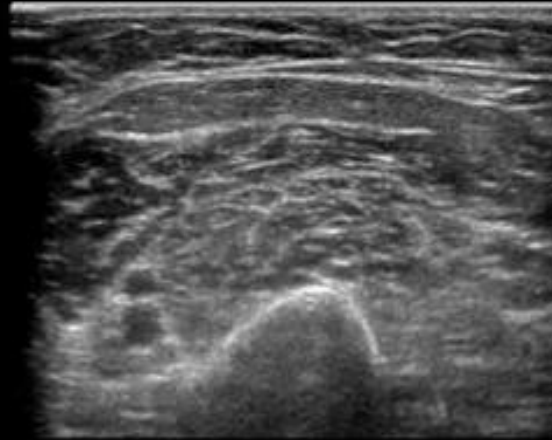
Generation of a shear wave- speed of sound
provides direct measure of shear
modulus
High MI



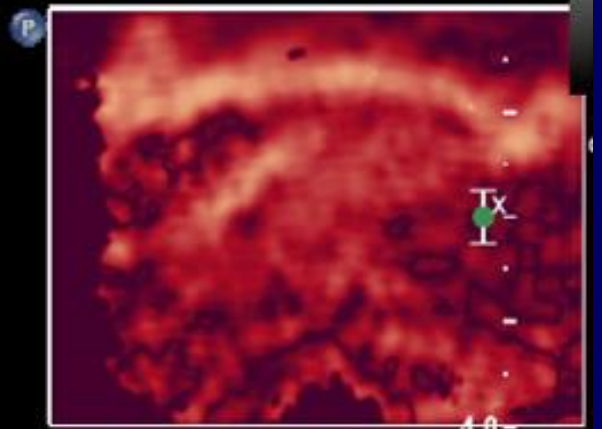
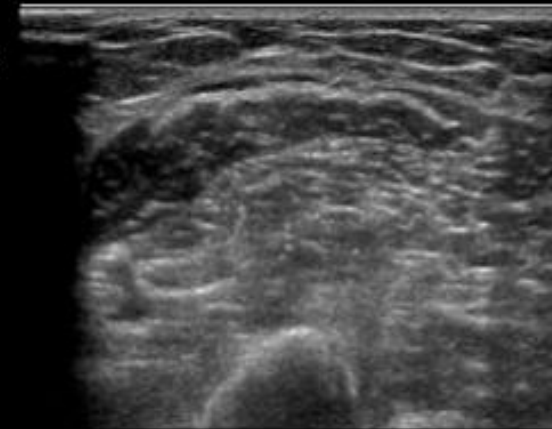
Ultrasound Probe

Muscle elastography

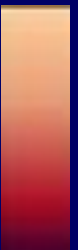
Neutral



Following curls



soft



stiff

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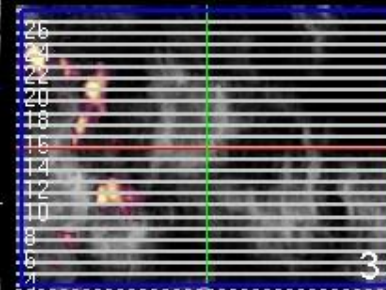
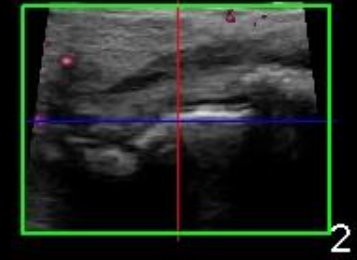
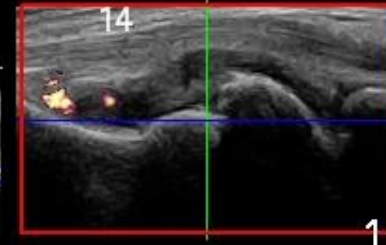
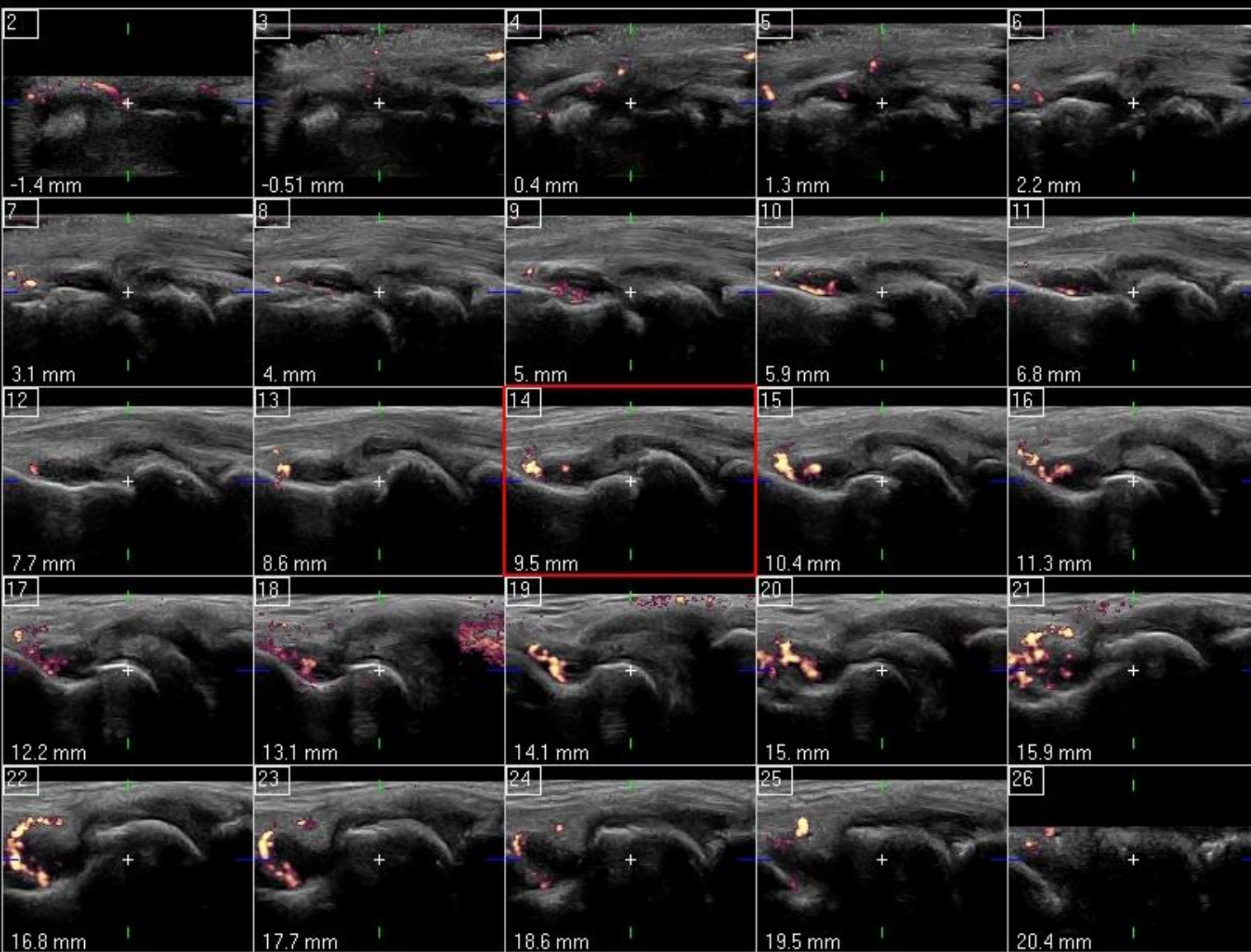
Compression based elastogram

3-D imaging

- External registration
 - Cumbersome
 - Used for registration of different acquisitions
- Elevational plane speckle tracking
 - Not quantitatively accurate
 - Subjectively helpful
- **Transducer-based**
 - Mechanical sweep in elevational plane
 - 2-D matrix array
 - True isovoxel imaging
 - Allows 4-D imaging



Mechanical 3D



Rheumatoid Arthritis

Ultrasound from a radiologists (my) perspective

- Have a good working understanding of ultrasound and what it is capable of
- Know your equipment
 - How to optimize the image for the specific application
- Have a thorough knowledge of the relevant anatomy

Thank you