Tendons

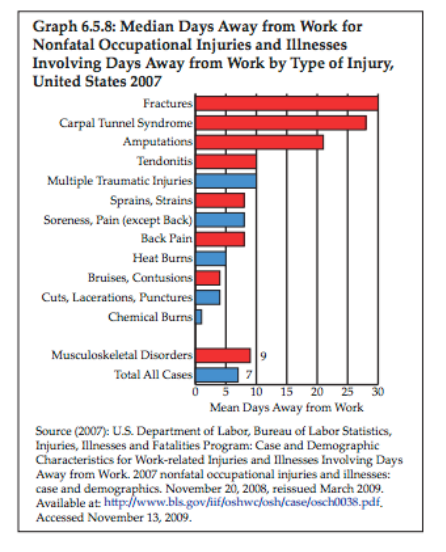
and the Art of

MSK Intervention

MSK Ultrasound Intervention: Tendons

30 to 50% of all sports related injuries are tendon disorders equating to 100 million office visits annually.

Former distance runners have 50% lifetime risk of Achilles tendon injury.



Learning objectives

- Principles of MSK tendon ultrasound
  - Technical considerations
  - Artifact pitfalls
  - Basic tendon anatomy
  - Normal characteristics
  - Abnormal characteristics

- Describe U/S guided interventions of tendons
  - Percutaneous needle fenestration (dry needling)
  - Platelet Rich Plasma injection
  - Calcific tendinosis lavage
  - Sonoelastography

Advantages - ultrasound

- Accessibility to tendon
- Ability to perform real-time dynamic maneuvers (active and passive) – ie “iliopsoas snapping syndrome”

- Low cost
- Multi-planar capability
- Continuous monitoring of needle location and material distribution (aspirate or injection)
- No ionizing radiation
- No metallic artifact as with MRI or CT
- Allows for comparison to asymptomatic contralateral side

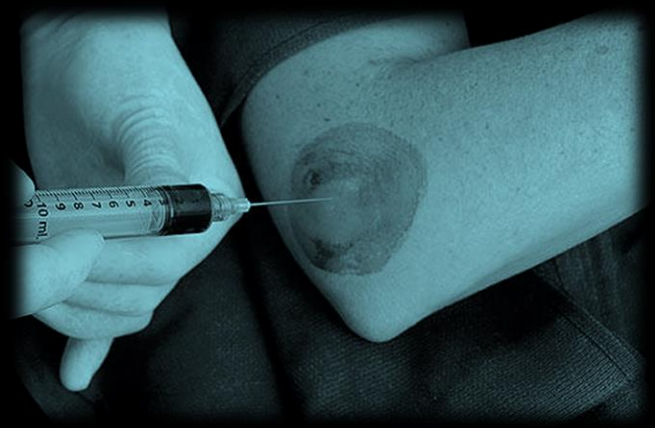
Disadvantages - ultrasound

- Operator dependent
  - Operator expertise
- Learning curve
- Long resident teaching curve
- Physician time intensive

“ Ordering providers are often unaware of potential applications of ultrasound and ultrasound guided procedures. ”

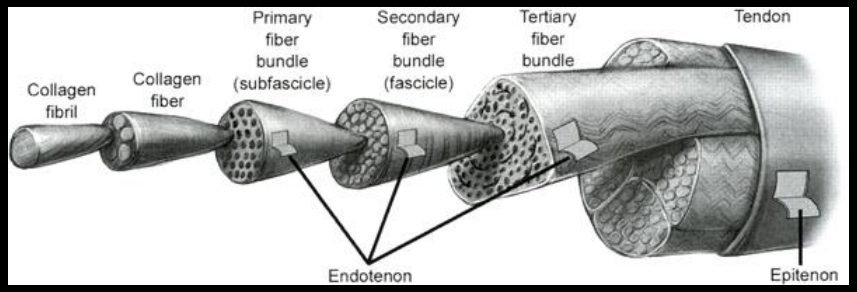
Why? …

Widespread availability of MRI in the US.
U/S widely used in Europe … relatively underused in the US.

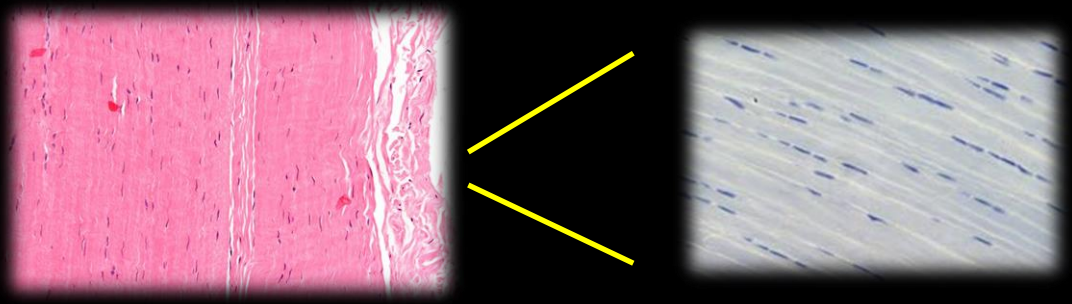


Lin J, Fessell D, Jacobson J, Weadcock, Hayes C. An illustrated tutorial of musculoskeletal sonography: Part 1, Introduction and General Principles. *AJR.* 2000.175; 637-645.

Tendon structure characteristics - normal



- Organized and uniform structure in direction of force.
- Parallel arrays of collagen:
  - 86% collagen (mostly type 1)
  - 2 % elastin
  - 1-5 % proteogylcans

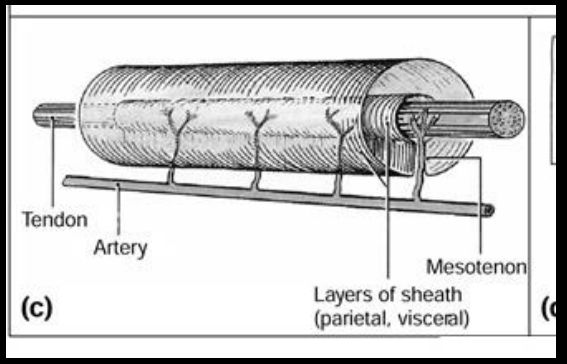


GAGs labeled in supraspinatus tendon by di-2-9-Methyl Methylen Blue

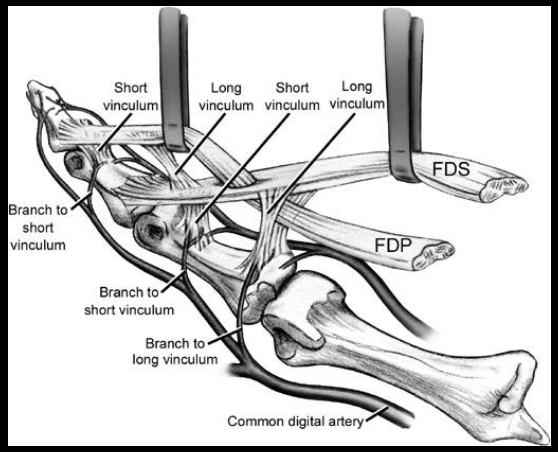
Blood supply –sheathed tendons

Highly cellular and metabolically active during development, thus have a rich capillary network.

Mature tendons are poorly vascularized; tendon nutrition more reliant on synovial fluid diffusion than vascular perfusion.
(do have more blood vessels than commonly accepted).



Sheathed tendons have a better defined, vincular supply – blood vessels enter the tendon at specific points along the tendon.



Blood supply – unsheathed tendons

Arise from 3 distinct regions:

A. osseous tendinous junction (via periosteum forming indirect link to osseous circulation)
B. vessels from various surrounding connective tissue (i.e paratenon, mesotenon)
C. myotendonous junction

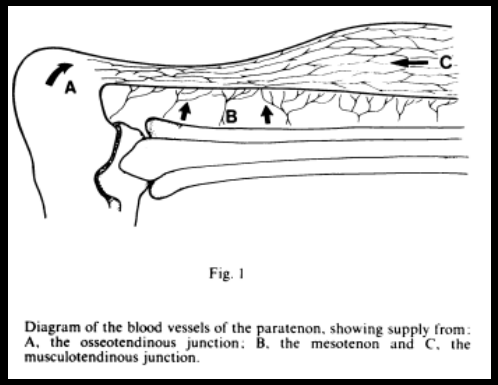


Fig. 1

Diagram of the blood vessels of the paratenon, showing supply from: A, the osseotendinous junction; B, the mesotenon and C, the musculotendinous junction.

Unsheathed tendons, vessels pass through the paratenon at any point along the tendon.

Fig. 2

Radiograph of an injected tendon showing vessels within the paratenon.

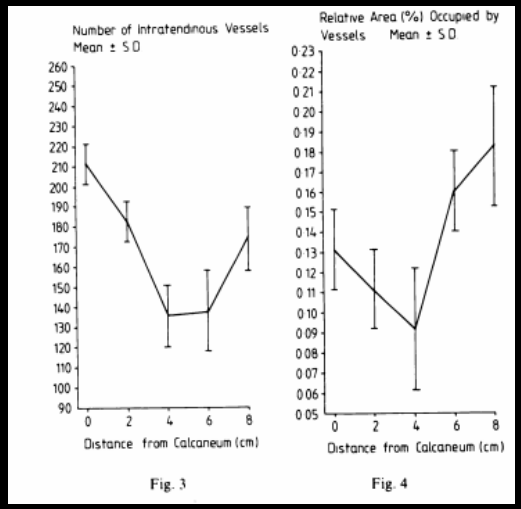
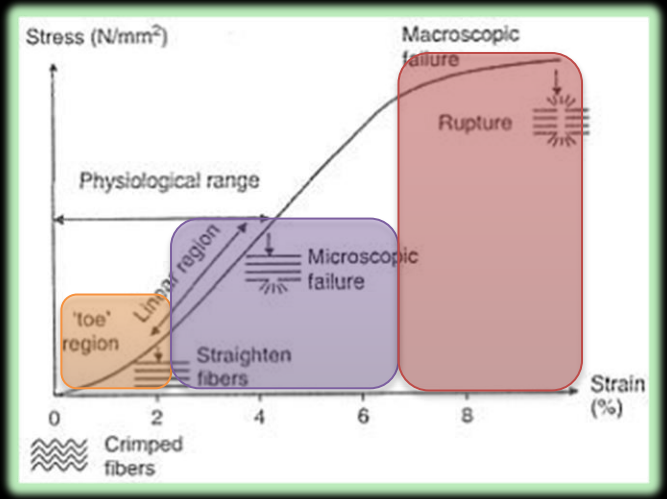


Fig. 3 Fig. 4

Carr and Norris,JBJS: Vol 51-B, No.1 JAN 1

Stress/strain curve – tendon



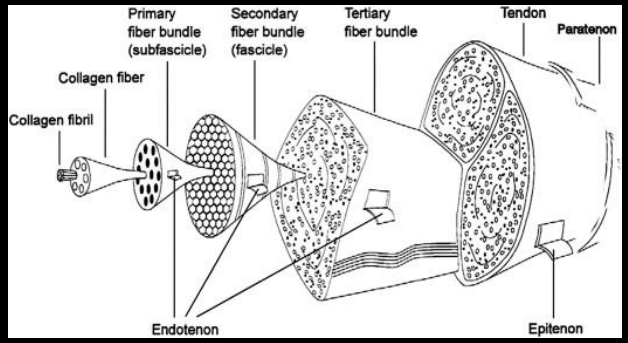
3 regions:

1. Toe region: straightening of zig-zag crimp of collagen fiber bundle (visible with polarized light) disappears under tension, reappears when stress released.

2. Physiologic range – micro trauma occurs here.

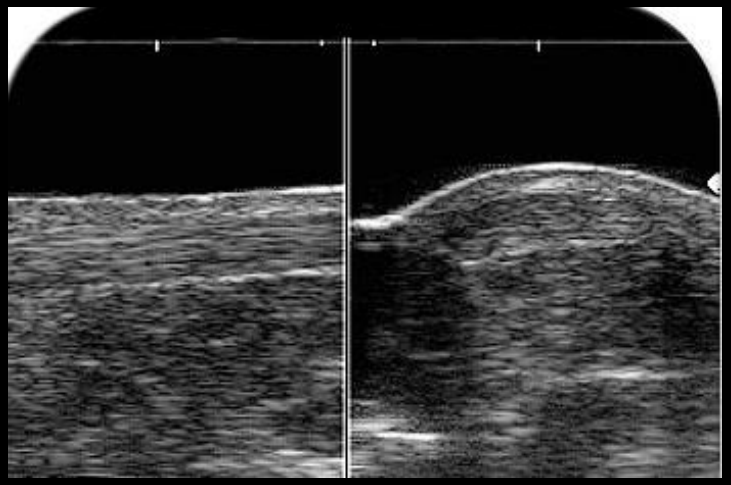
3. Unpredictable failure

Aging lowers the stress/strain curve

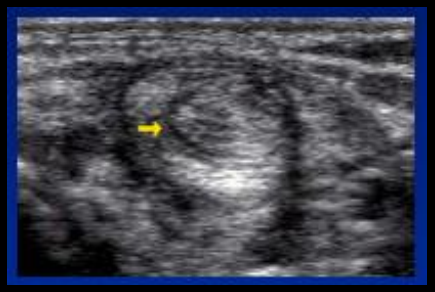


THE JOURNAL OF BONE & JOINT SURGERY · JBJS.ORG
VOLUME 87-A · NUMBER 1 · JANUARY 2005

Tendon – normal appearance



Tendons – abnormal features



Intrasubstance tear

Partial thickness tear

Full thickness tear

- Tendon thickening
- Hypoechogenicity
- Loss of fibrillar pattern

Neovascularity (hyperemia) and pain related?

General Principles and Techniques

- 7 to 12 MHz, linear array
- Free hand technique
- Liberal application of transmission gel in lieu of a stand off pad
- Proper (comfortable) position
  - patient
  - radiologist

- Goal of optimizing visualization of structures
- Coagulation panel not typically drawn

"Creative Visualization"

practice of seeking to affect the outer world by changing one's thoughts and expectations

Anisotropy artifact

Artifact seen in tendon imaging when the transducer is slightly angulated to the target tendon which can mimic hypoechoic tendonopathy

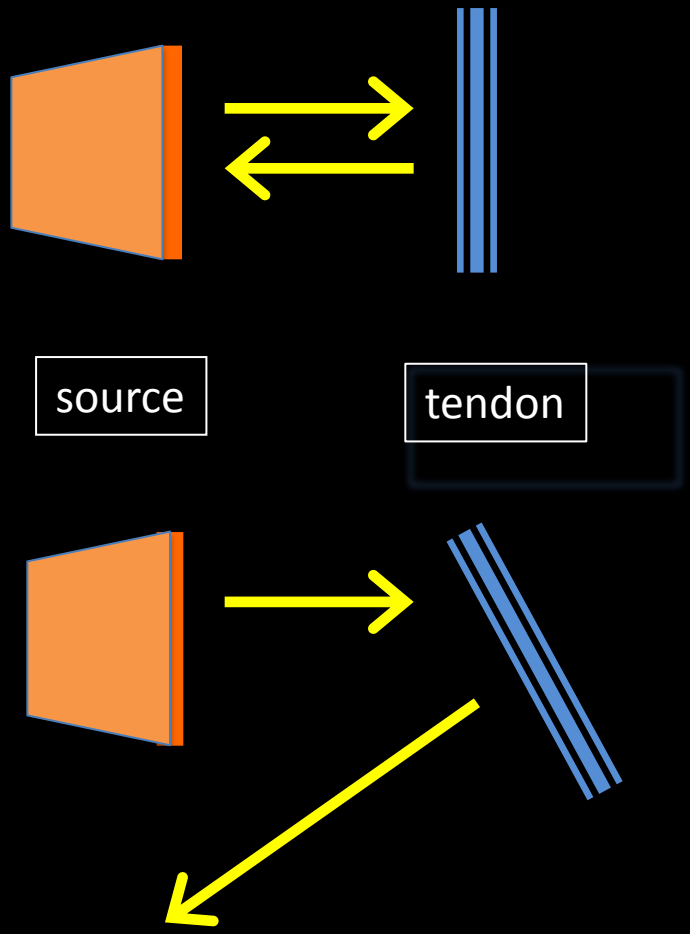
Produced by the highly ordered, parallel configuration of tendon collagen fibers.

Occurs when the ultrasound beam is not perpendicular to the fibrillar structure of the tendon.

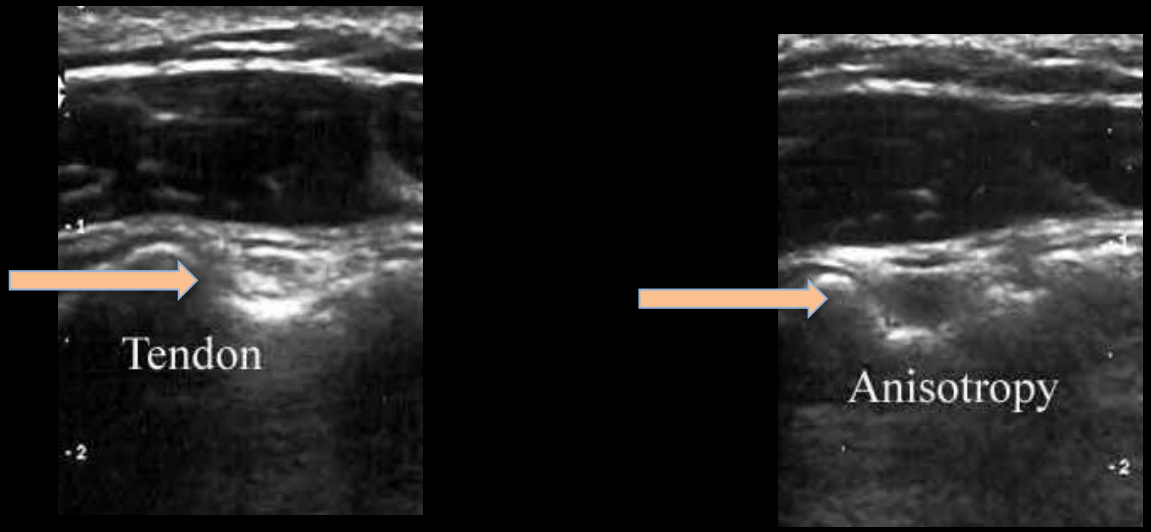
Minor changes to transducer angle make anisotropy disappear, but true pathologic findings do not.

Corrected with “heel-toe” (fore-aft) transducer angulation.

Curved tendons require segmental evaluation

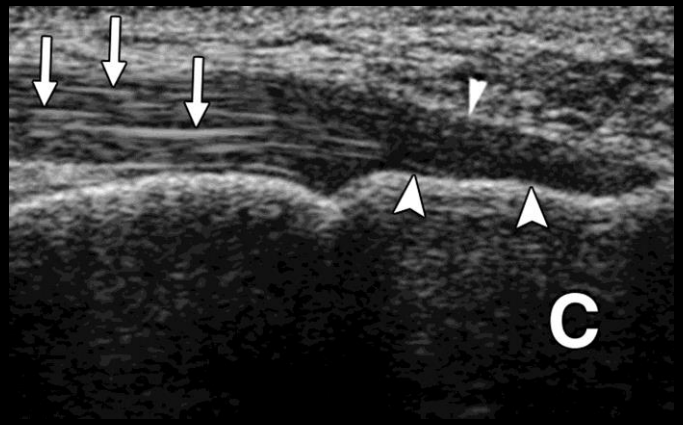


Anisotropy



Proximal biceps tendon in bicipital groove

http://www.dynamicultrasound.org/dugphysics.html



Achilles tendon - anisotropy

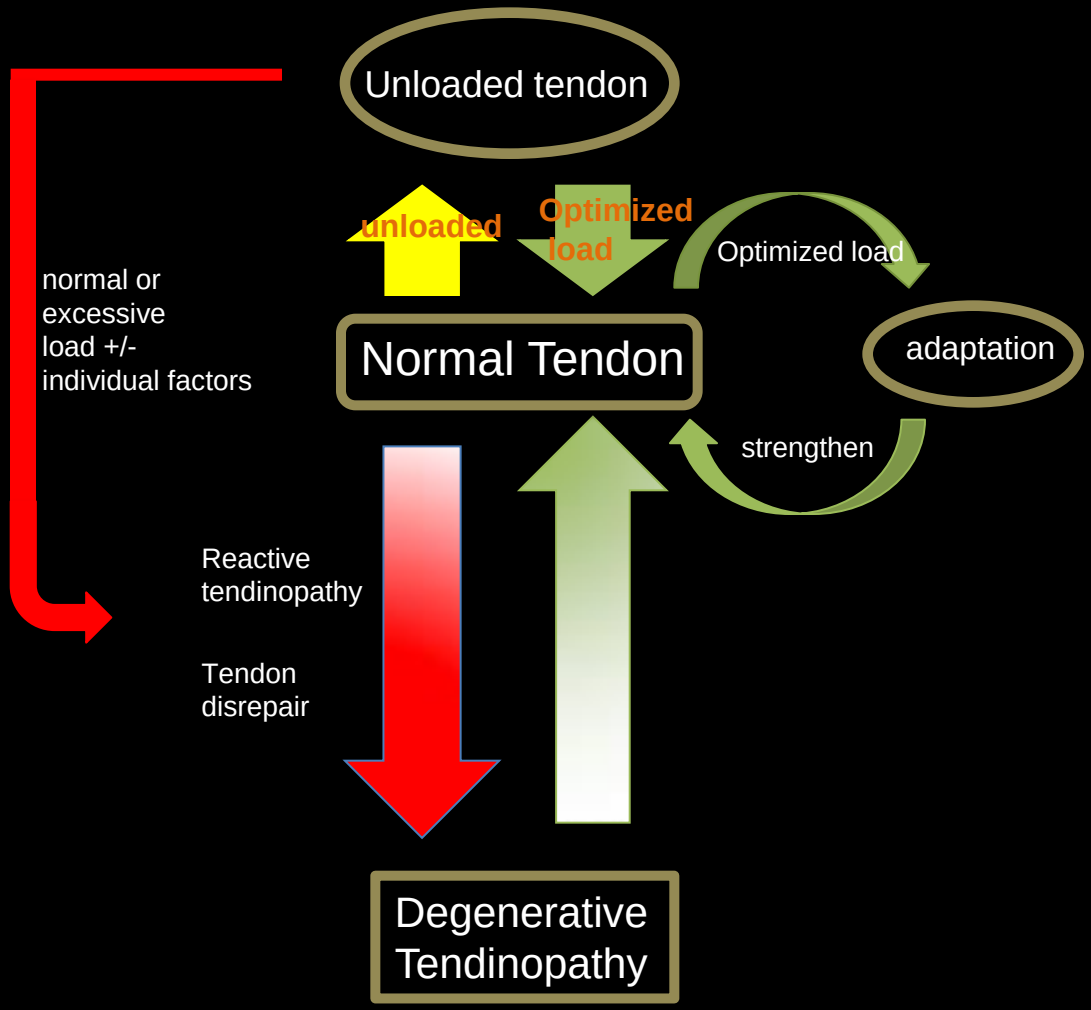
Robinson P AJR 2009;193:607-618

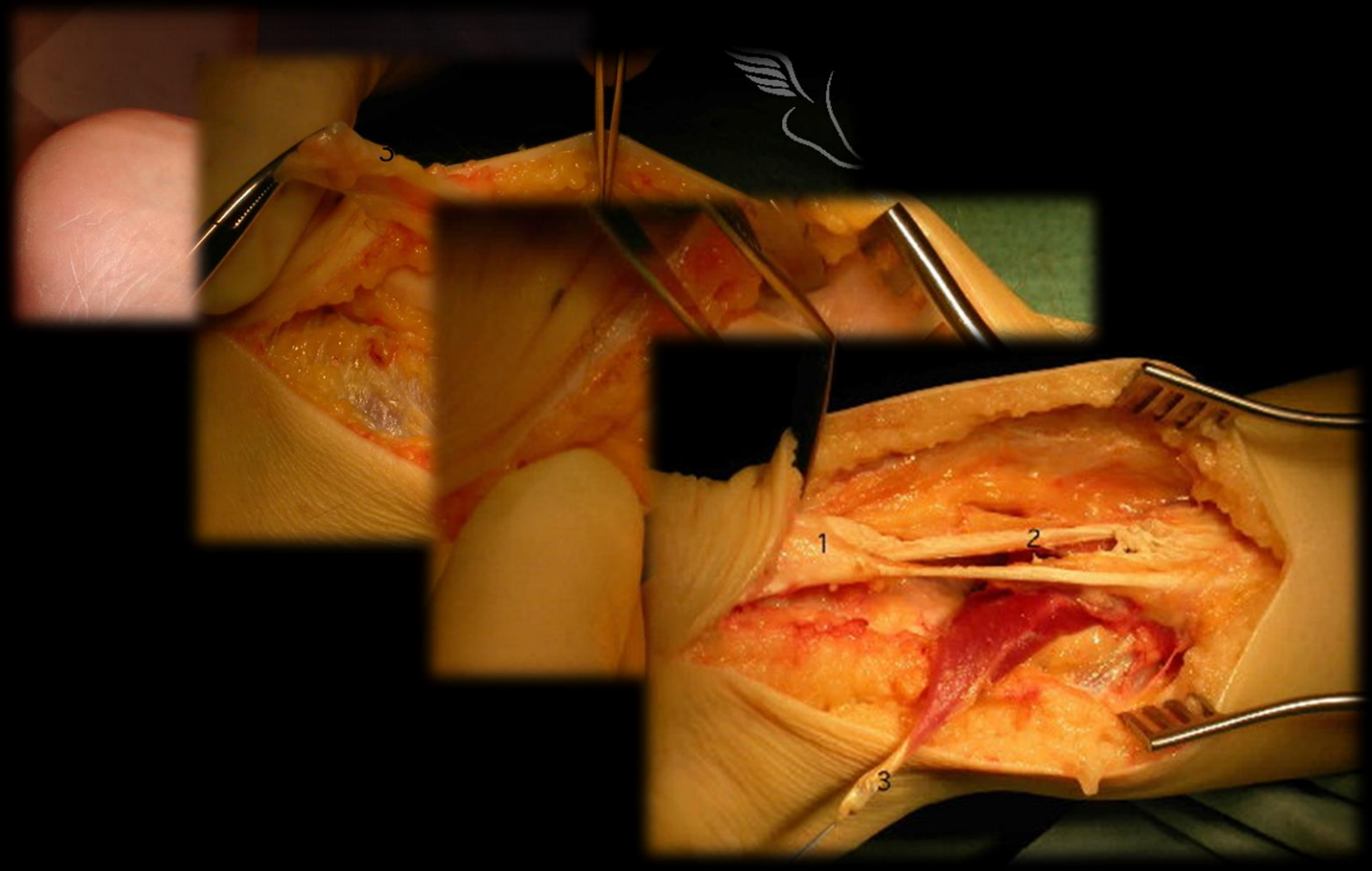
Tendinopathy: Definition and current therapies

Cycle of chronic repetitive micro- trauma , mucoid degeneration, and interstitial tearing.

Pain, swelling, loss of function

- Rest
- Anti-inflammatories
- Physical therapy
- - stretching
- - eccentric strengthening
- - iontophoresis
- Surgical tenotomy





The Foot Surgery Atlas
http://www.footsurgeryatlas.com/foot-surgery-atlas.htm

Interventions

- Needle fenestration, dry needling
- Calcific tendinopathy lavage
- Platelet rich plasma (PRP) injection

Candidate patients:

- Carefully selected (SEALs, USMC Combat Diver,)
  - motivated to improve
- Ortho, sports medicine, and PT collaboration
- Recalcitrant cases

Tendon Fenestration (dry needling)

Tendon Fenestration (dry needling)

Various substances have been injected into tendons:

Steroids -- effective, but short lived.
-- Disadvantage – underlying tendon pathology is not directly treated

Dextrose – irritant

Whole blood - increases the concentration of growth factors to the region.

Ultrasound Guided Tendon Fenestration
Semin Musculoskelt Radiology 2013:17:85-90
Chiavara and Jacobson

Tendon fenestration, dry needling

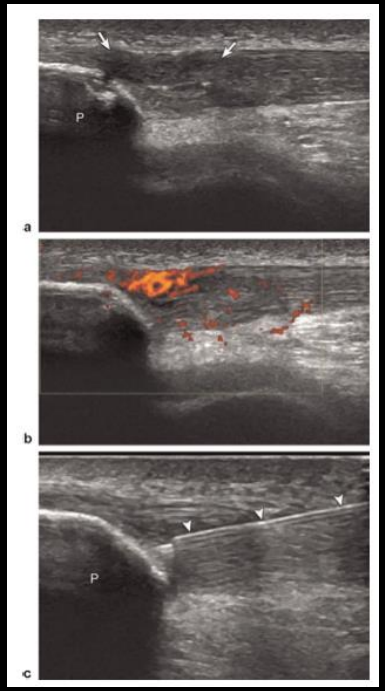
Contraindications:

Bleeding disorders
Patients who are anticoagulated
Local infection

Presence of tendon tear ???

High grade tears may not benefit from fenestration

Avoid fenestration if a tear > 50% of the tendon thickness.



Ultrasound-guided Tendon Festration
Semin Musculoskelt Radiology 2013:17:85-90
Chiavara and Jacobson

Tendon fenestration (dry needling)

Skin surface anesthesia

20 or 22-gauge needle for fenestration

Least possible amount of anesthetic into the target tendon.

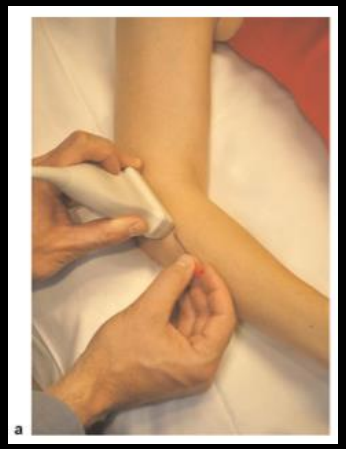
15 to 30 passes through abnormal region with real time observation to include bone/tendon junction.

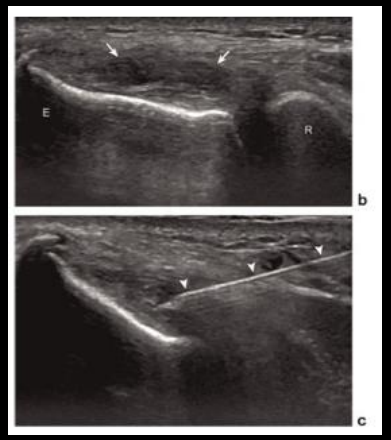
Completed procedure criteria:

- needle passed through all abnormal tendon, calcifications, and enthesis
- the area feels “soft” with needle advancement

Post procedure protocol

- Ice to be avoided
- NSAIDS to be avoided
- Immobilization (patellar tendon, Achilles)
- 4 week specialist f/u
- Gradual return to activities discussed at 2 to 4 week follow-up

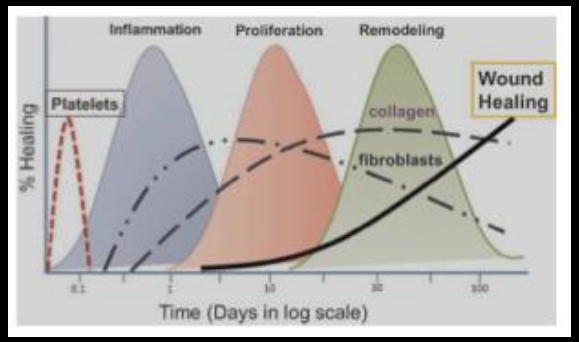




Concept of benefit – needle tenotomy

- Change a chronic tendon injury into an acute inflammatory process
- Disruption of scar tissue
- Release growth factors that stimulate healing response.

Converting a chronic non-healing injury to an acute injury with better healing potential.



Tendon trauma/injury
- laceration
- tear

Clot formation
Inflammatory response
- release of chemotactic agents
Cellular migration
- fibroblasts, macrophages, phagocytes

Further release of growth hormone (tntc IGFs, PDGFs,TGFs)
Continue fibroblast recruitment and proliferation
Deposition of immature/disorganized collagen fibrils and GAG

Reorganization of collagen fibers;
Increased collagen type I
ECM components are synthesized
Decreased cellularity and vascular content
Repetitive microtrauma prevents end stage healing

Effectiveness

- Percutaneous Needling

Numerous studies suggest potential positive effects of
Needle fenestration, however …..

- Inhomogeneous patient populations.
- Lack of standardized treatment protocols.
- No control groups.
- Lack of tendon ultrasound follow up.
- Retrieved data, rather than recorded data.
- Few head to head trials vs surgery.

What factors influence outcome?

- Increased vasculaity?
- Do specific tendons fare better than other?
- Chronicity?
- # of passes?
- Injection vs fenestration alone?

Bottom line:

"Fenestration can be considered a potential treatment for tendonosis."

Ultrasound Guided Tendon Fenstration
Semin Musculoskelt Radiology 2013:17:85-90
Chiavara and Jacobson

Platelet Rich Plasma Injection

Platelet Rich Plasma Injection

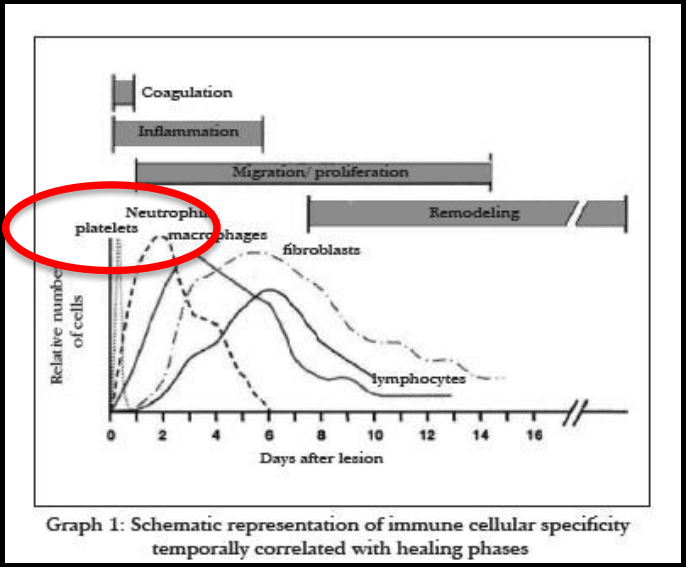
- Emergence as a treatment alternative for chronic, non-healing tendinosis.
- Popularized by professional level sports media reports. (Kobe, Tiger, A Rod, Big Papi, Nadal, Ward)

- Clinical uses:
  - Achilles tendon, patellar tendon, plantar fascia, lateral epicondylitis, intra-articular
  - Very select “high end” operators
  - Close collaboration with orthopedics, sports medicine, physical therapy

Platelet Rich Plasma Injection: Procedure

- Contact a vendor
- Venipuncture – 16 ml of blood withdrawn
- Centrifugation step x2
- Separation step
  - Double syringe
  - Baffled syringe
  - Cork screw tubing
- US guided tendon injection – 3 cc
  - Typically avoid anesthesia
- Follow up instructions as per dry needling

Plasma Rich Protein Injection:
Concept of benefit - accelerate wound healing.



Graph 1: Schematic representation of immune cellular specificity temporally correlated with healing phases

- First step in tissue healing is clot formation and platelet activation
- Needle induced bleeding provides the clotting factor thrombin to activate platelets.
- Hyper activation of wound healing cascade.

Inflammatory
- release of bioactive and hemostatic GF

Proliferative
- angiogensis, collagen deposition, granulation tissue formation, wound contraction

Remodeling
- collagen maturation

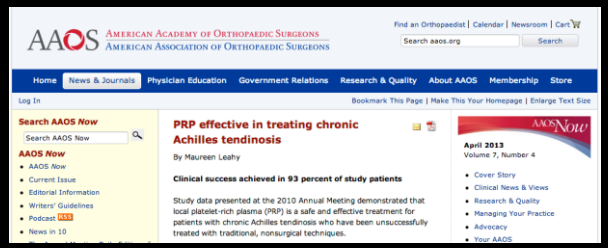
Plasma Rich Protein Injection: Effectiveness

- Safe
- Studies have suggested shortened recovery time with pain/function improvement.
- No uniform success.
- Unproven – however, widely performed.
- Considered investigational by many carriers.

- small non-randomized studies or anecdotal case reports.
  - Tol et al, JAMA. 2010 - no change
  - Harwood et al. 2006 – improvement

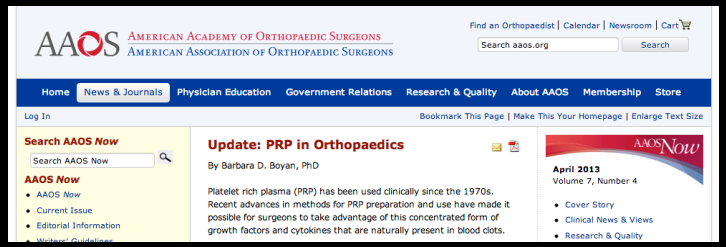
Community use has overshadowed and outpaced evidence based research.

Platelet Rich Plasma - What do the orthopedist think?



At the end of the day, an informal survey of participants found most in agreement that PRP would be an option, particularly if conservative treatments have failed and the next step would be surgery.

“PRP is a simple concept,” …… “but it is surrounded by a complex set of questions that are still unanswered.”



WORLD ANTI-DOPING AGENCY
play true

PRP banned in 2010

SEPT 2012-

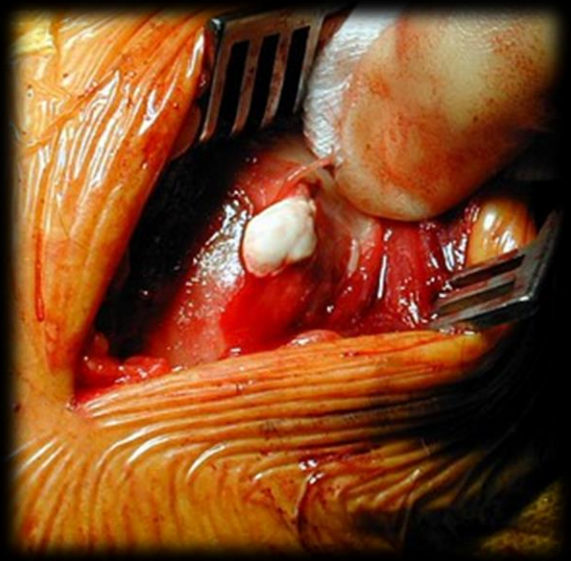
- Removed from “the List” after consideration of any current evidence .. for the purposes of performance enhancement notwithstanding that these preparations contain growth factors.
- “Current studies on PRP do not demonstrate any potential for performance enhancement beyond potential therapeutic effect.”

Rotator cuff calcific tendinosis lavage

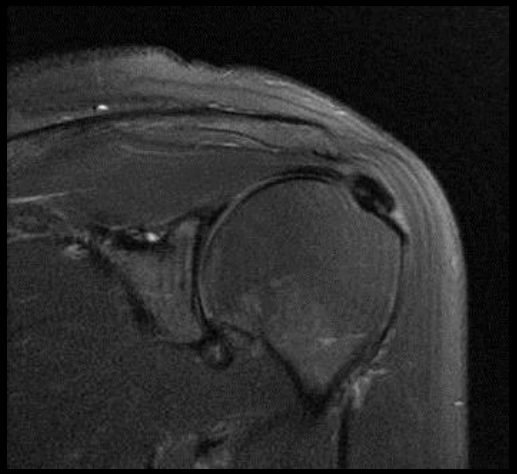
Rotator cuff calcific tendinosis lavage

Calcium hydroxyapatite deposition postulated to initiate from a “hypoxic ”event leading to mild necrosis and subsequent calcium deposition.

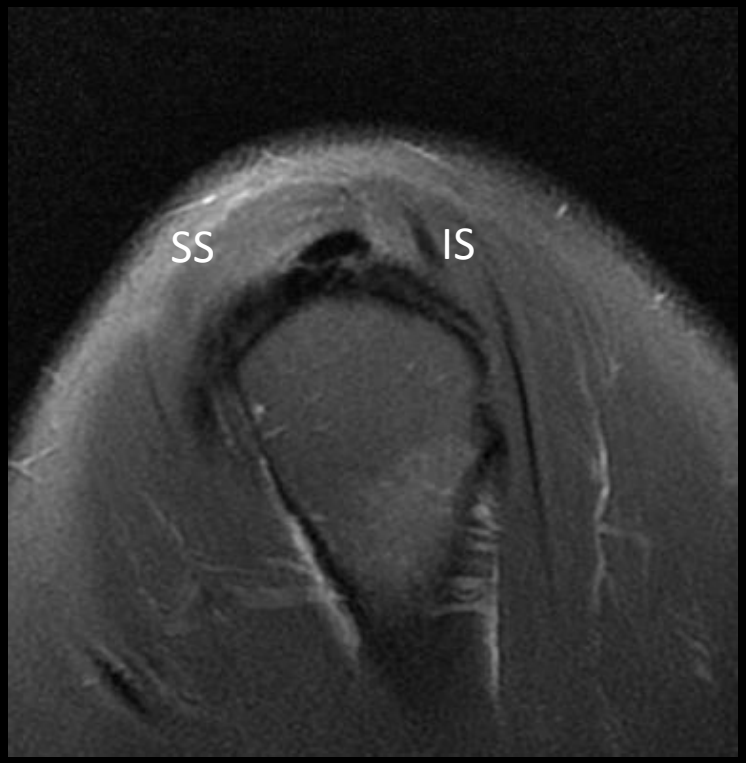
- U/S is an ideal modality to evaluate and treat RC calcific tendinosis – superior access
- Safe and effective
- Single needle technique



RC calcific tendinosis:
case evaluation – 45 yo Special Warfare Combat Craft operator with shoulder pain.



RC calcific tendonosis: case evaluation

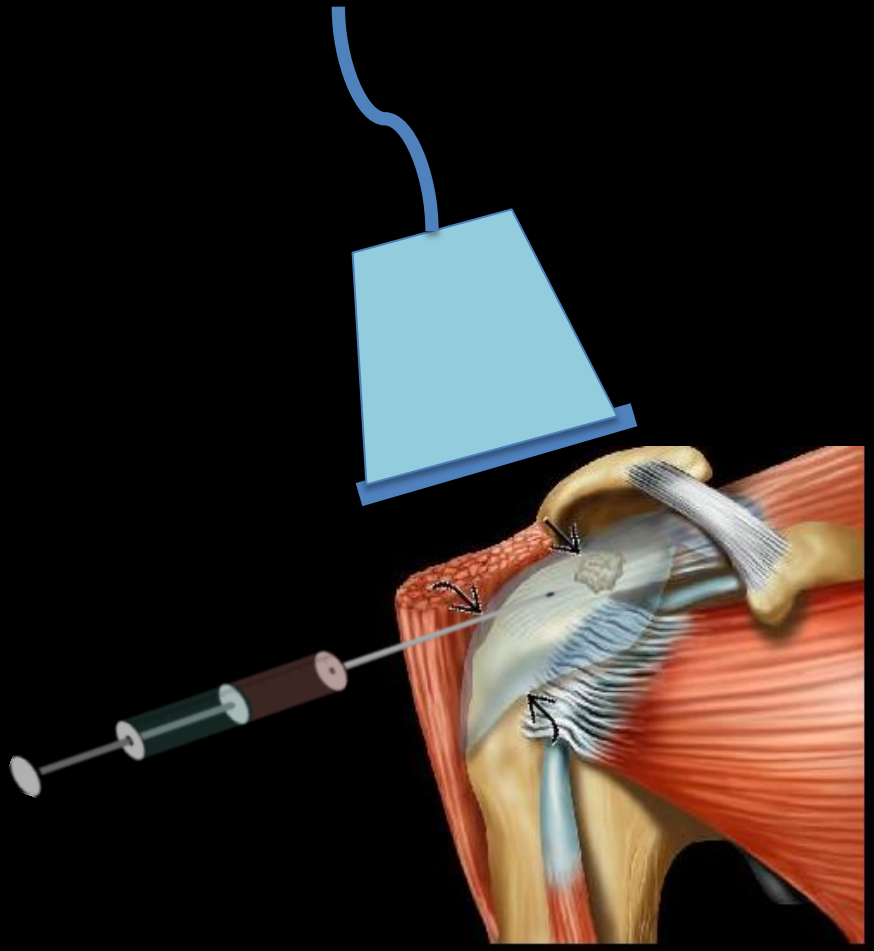


Rotator cuff lavage: single needle technique

Semi-recumbent position on gurney, shoulder bolstered/supported by towel.

Diagnostic US first for additional findings …..RC tear?

Locate the calcifications.



Stat dx

Rotator cuff lavage: single needle technique

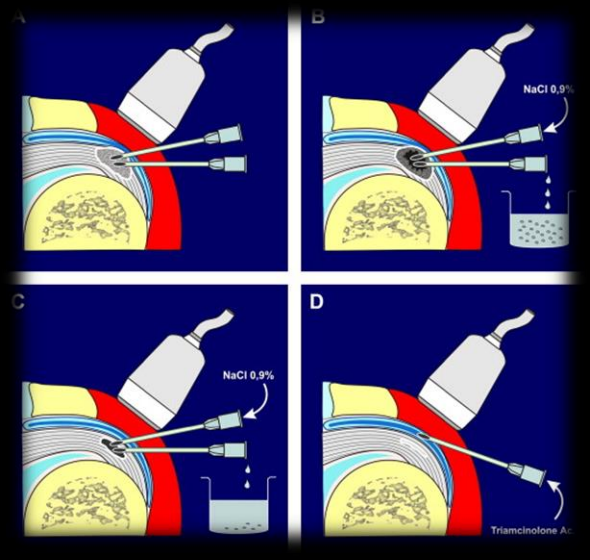
- Skin anesthesia
- Anesthesia tract to calcification
- Anesthesia into SA/SD bursa

- Lavage with 10cc syringe (20 gauge needle) containing equal parts 1% lidocaine/saline

- “pulse” maneuver to disrupt the calcifications
- **Gravity dependent needle orientation**

- 2cc of 1mg steroid/lidocaine into SA/SD bursa to prevent bursitis upon needle retraction

Rotator cuff lavage:
single needle technique



Two needle technique

Musculoskeletal Ultrasound: How to Treat Calcific Tendinitis of the Rotator Cuff by Ultrasound-Guided Single-Needle Lavage Technique
VIDEO; *AJR*. 2010. Sept; 195. No.W213

Tendon Lavage

- Prompt relief of symptoms and improved function up to 1 year followup.
- Safe
- Any benefit over 1 year is uncertain.
- No difference at followup at 5 and 10 years between treat and untreated groups

Sarafini 2009

Sonoelastography

Sonoelastography

“Emerging technology”, but really described in 1991 as non-invasive strain imaging.

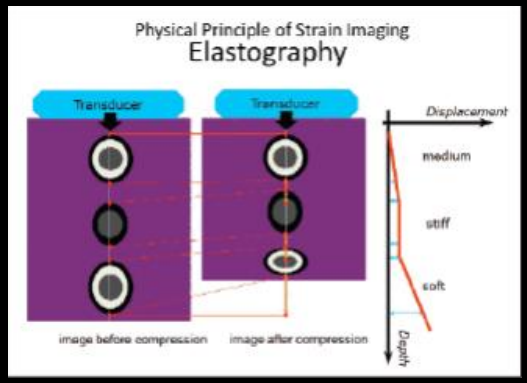
Principle:

Tissue compression produces displacement (strain) within tissue.

Strain is less in hard tissue than soft tissue.

Inflammation can lead to changes in issue elasticity (less stiff).

Real-time sonoelastography can show strain differences (displacement difference) by comparing image pairs before and after compression is applied.



Hitachi Real-Time Elastography, Clinical Abstract 2010

Sonoelastography - Technique

Apply gentle compression with a hand-held transducer (6 to 12 MHz) (typically 4 cycles)

Force applied adjusted to a quality factor visual indicator set on the U/S machine.

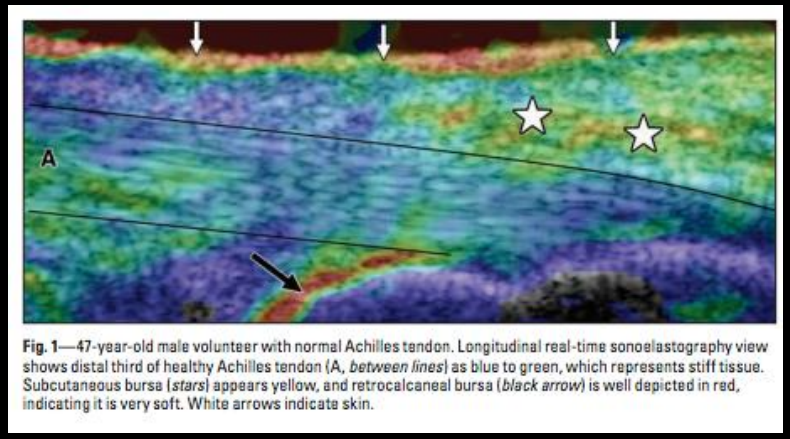
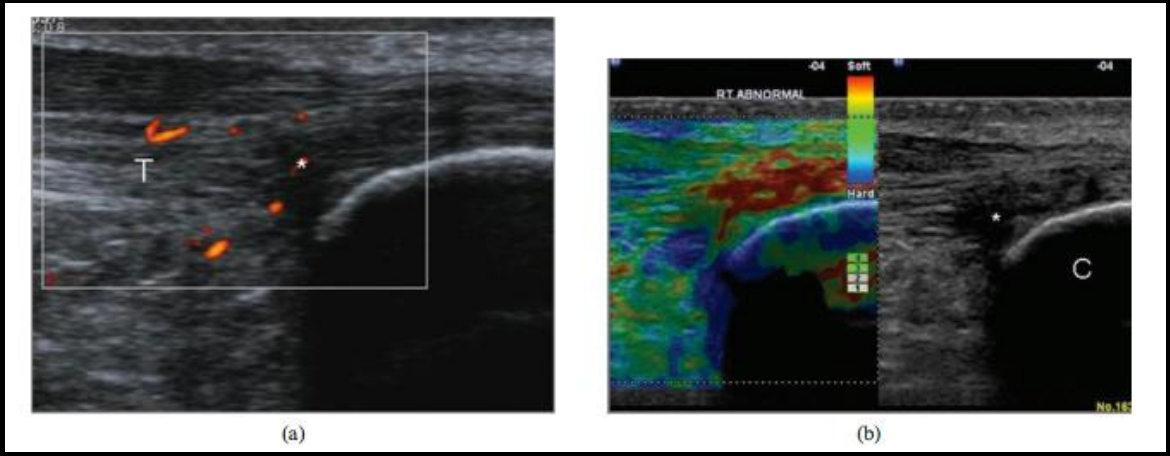


Fig. 1—47-year-old male volunteer with normal Achilles tendon. Longitudinal real-time sonoelastography view shows distal third of healthy Achilles tendon (A, *between lines*) as blue to green, which represents stiff tissue. Subcutaneous bursa (*stars*) appears yellow, and retrocalcaneal bursa (*black arrow*) is well depicted in red, indicating it is very soft. White arrows indicate skin.

White arrows – skin
Black arrows – retrocalcaneal bursa
Stars – subcutaneous bursa

Blue = hard (less elastic)
Yellow = intermediate
Red = soft (more elastic)

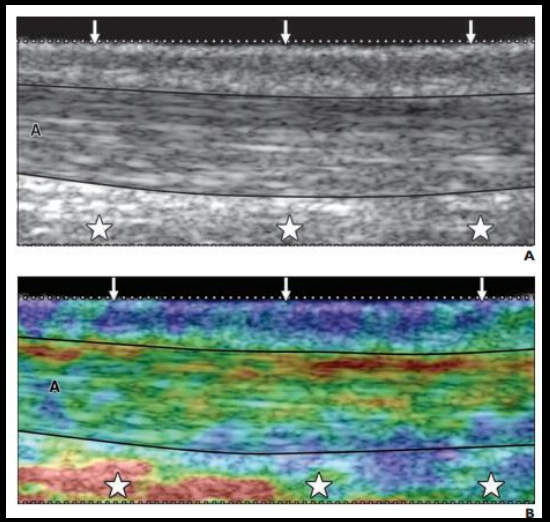
AJR:193, AUG 2009



23 yo recreational runner with insertional Achilles tendoopathy

Blue = hard (less elastic)
Yellow = intermediate
Red = soft (more elastic)

The British Journal of Radiology, November 2012

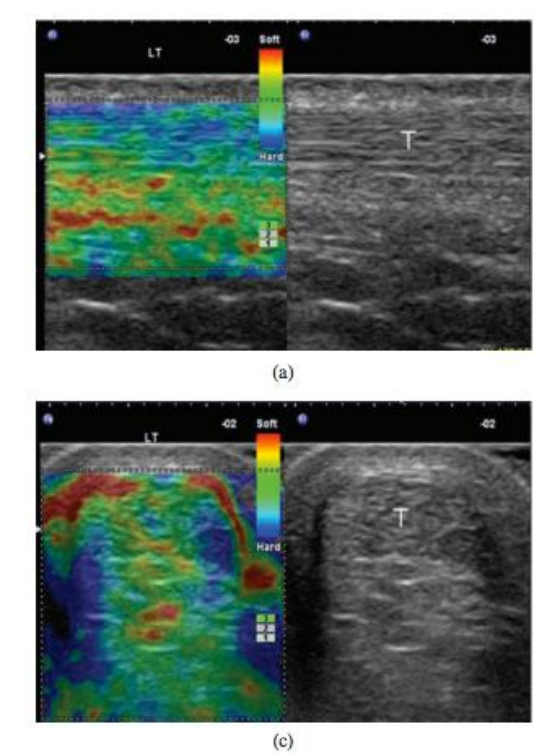


Blue = hard (less elastic)
Yellow = intermediate
Red = soft (more elastic)

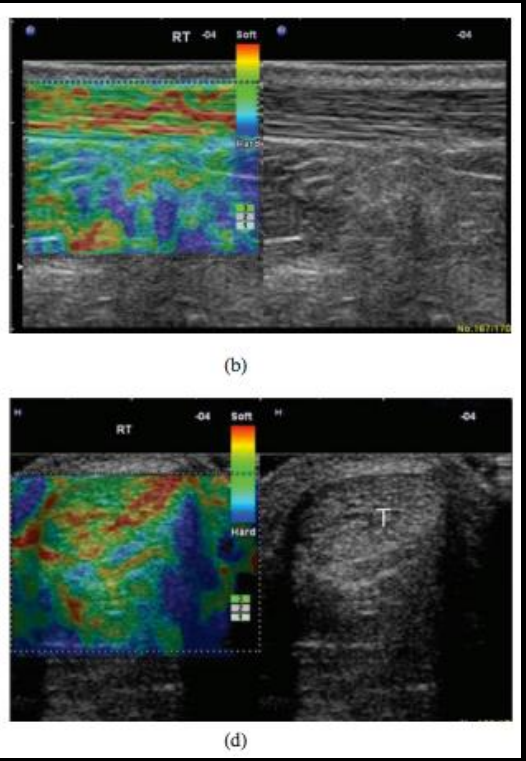
26 yo asymptomatic volunteer

AJR:193, August 2009

Two distinct sonoelastographic patterns of normal tendons



Type 1
Homogenously stiff without softening



Type 2
Inhomogeneous with softening.

Blue = hard (less elastic)
Yellow = intermediate
Red = soft (more elastic)

The British Journal of Radiology, November 2012

Sonoelastography – what do we have so far?

Table 1. Summary of EUS applications for tendons

Article	Correlation with	Area examined	Number of cases	Results regarding EUS
Drakonaki et al, 2009 [17]	Clinical exam	Achilles	50 normal tendons (25 volunteers)	Two normal patterns
	Conventional ultrasound			Reproducibility better in longitudinal plane
De Zordo et al, 2010 [18]	Clinical exam	Achilles	25 tendons (25 patients)	Accuracy 97%
				Good correlation with ultrasound
	Conventional ultrasound		50 normal tendons (25 volunteers)	Two patterns (grades) in normal tendons
				Three patterns (grades) in symptomatic tendons
De Zordo et al, 2009 [19]	Clinical exam	Achilles	80 normal tendons (40 volunteers)	Good correlation with ultrasound
	Conventional ultrasound			Three patterns (grades) in normal tendons
De Sconfienza et al, 2010 [21]	Clinical exam	Achilles	12 tendons (12 patients)	Good correlation with MRI
	Conventional ultrasound		36 normal tendons (18 volunteers)	Symptomatic tendons are harder
	MRI			
De Zordo et al, 2009 [22]	Clinical exam (VAS score)	Common extensor tendons (elbow)	38 tendons (32 patients)	Accuracy 94%
	Conventional ultrasound		44 normal tendons (28 volunteers)	Good correlation with ultrasound
				Greater sensitivity and accuracy than ultrasound

EUS, ultrasound elastography; VAS, visual analogue scale.

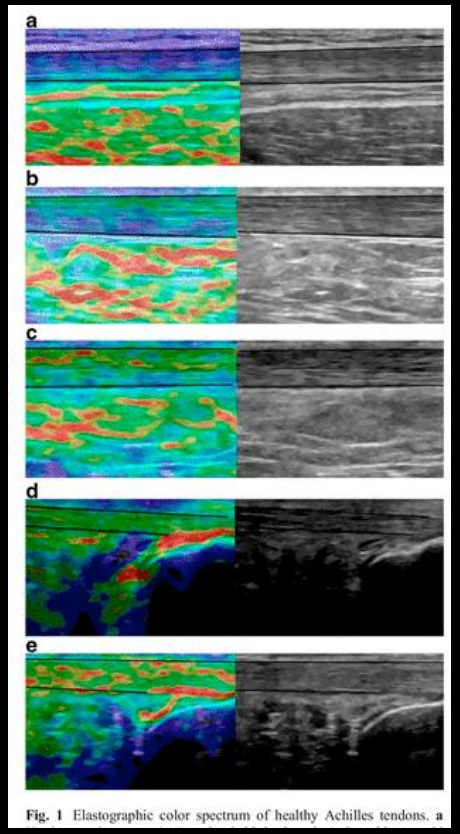


Fig. 1 Elastographic color spectrum of healthy Achilles tendons. a

5 patterns in normal Achilles

Skeletal rad (2012) 41:1067-1072

Sonoelastography - Limitations

Technical

Technically challenging in terms of proper application of technique

- correct mount of pressure
- fluctuant changes at edges of elastograms.

Lack of quantitative measurements.
--- What's normal for a 23 yo?? For a 43 yo?

Clinical

Researchers need to define the diagnostic and prognostic benefit of elastography over gray-scale, color, or power Doppler imaging.

The EUS shows changes already evident on conventional US, whereas EUS changes not evident on conventional US were occult… and therefore not clinically important.

"There are potential applications"…
"What remains to be seen is how much of that can be used clinically."

Drakonaki, Allen, and Wilson 2012; The Brit Journ of Radiol, 85 (2012), 1435-1445

In Review

- Principles of MSK ultrasound
  - Technical considerations
  - Normal characteristics
  - Abnormal characteristics
  - Artifact pitfalls

- Describe U/S guided interventions
  - Percutaneous needle fenestration
  - Calcific tendinosis lavage
  - Platelet Rich Plasma injection
  - Sonoelastography

Clinical Use Application

- Safe

- Viable option in those who fail conservative therapies although limited proven effectiveness.

Do you know what meditation is Daddy?

Radiology

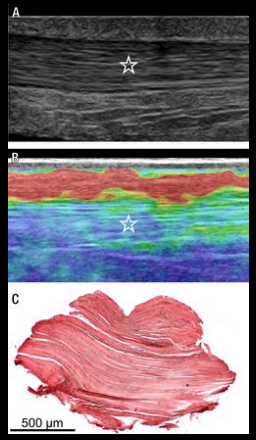
Achilles Tendon Assessed with Sonoelastography: Histologic Agreement

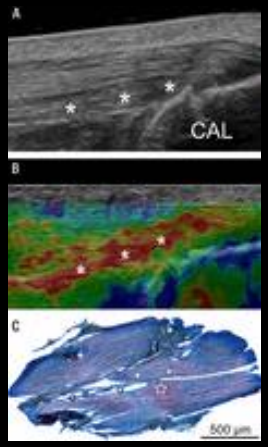
Expand

Andrea S. Klauser, MD, Hideaki Miyamoto, MD, Mario Tamegger, MD, Ralph Faschingbauer, MD, Bernhard Moriggl, MD, PhD, Guenther Klima, MD, Gudrun M. Feuchtner, MD, PhD, Martin Kastlunger, MD and Werner R. Jaschke, MD, PhD

13 Tendons in 10 cadavers
Male- mean age 77
Female – Mean age 81

Grace 1: normal
Grade 2: fusiform or diffuse enlargement
Grade 3: hypoechoic area w/wo enlargement





US and Sonoelastographic Findings	Histologic Findings		Overall
	Pathologic	Normal	
Pathologic (grade 2 or 3)	12/14	0/0	12/14
Normal (grade 1)	2/0	11/11	13/11
Total	14/14	11/11	25/25

US Findings	Sonoelastographic Findings			Overall
	Grade 1	Grade 2	Grade 3	
Grade 1	11	1	1	13
Grade 2	0	3	6	9
Grade 3	0	0	3	3
Total	11	4	10	25

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