Tendons and the Art of MSK Intervention
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.

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% proteoglycans

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

Unsheathed tendons, vessels pass through the paratenon at any point along the tendon.
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
Tendon – normal appearance
Tendons – abnormal features

- 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
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

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Unloaded tendon

Normal Tendon

Degenerative Tendinopathy

Unloaded

Optimized load

Optimized load

adaptation

strenthen

Reactie tendinopathy

Tendon disrepair
**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.
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 Fenestration
Semin Musculoskelt Radiology 2013:17:85-90
Chiavara and Jacobson
Tendon fenestration (dry needling)

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

Skin surface anesthesia

Completed procedure criteria:
- Needle passed through all abnormal tendon, calcifications, and enthesis
- The area feels "soft" with needle advancement
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.

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

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

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

Tendon trauma/injury
- laceration
- tear
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.”
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.

- 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
- angiogenesis, 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.”
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
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
Musculoskeletal Ultrasound: How to treat calcific tendinitis of the rotator cuff by single needle US-guided lavage technique

Kenneth S. Lee, M.D.
Humberto Rosas, M.D.
University of Wisconsin
School of Medicine & Public Health
Department of Radiology

Two needle technique
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.
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.

![Diagram showing sonoelastography technique](image)

**Fig. 1**—41-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 (star) 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

**Legend**
- Blue = hard (less elastic)
- Yellow = intermediate
- Red = soft (more elastic)
23 yo recreational runner with insertional Achilles tendinopathy

Blue = hard (less elastic)
Yellow = intermediate
Red = soft (more elastic)
26 yo asymptomatic volunteer

Blue = hard (less elastic)
Yellow = intermediate
Red = soft (more elastic)
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)
Sonoelastography – what do we have so far?

Table 1. Summary of EUS applications for tendons

<table>
<thead>
<tr>
<th>Article</th>
<th>Correlation with</th>
<th>Area examined</th>
<th>Number of cases</th>
<th>Results regarding EUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drakonaki et al, 2009 [17]</td>
<td>Clinical exam</td>
<td>Achilles</td>
<td>50 normal tendons (33 volunteers)</td>
<td>Two normal patterns</td>
</tr>
<tr>
<td></td>
<td>Conventional ultrasound</td>
<td></td>
<td></td>
<td>Reproducibility better in longitudinal plane</td>
</tr>
<tr>
<td>De Zordo et al, 2010 [18]</td>
<td>Clinical exam</td>
<td>Achilles</td>
<td>25 tendons (25 patients)</td>
<td>Accuracy 97%</td>
</tr>
<tr>
<td></td>
<td>Conventional ultrasound</td>
<td></td>
<td></td>
<td>Good correlation with ultrasound</td>
</tr>
<tr>
<td>De Zordo et al, 2009 [19]</td>
<td>Clinical exam</td>
<td>Achilles</td>
<td>80 normal tendons (40 volunteers)</td>
<td>Two patterns (grades) in normal tendons</td>
</tr>
<tr>
<td></td>
<td>Conventional ultrasound</td>
<td></td>
<td></td>
<td>Three patterns (grades) in symptomatic tendons</td>
</tr>
<tr>
<td>De Scorfienza et al, 2010 [21]</td>
<td>Clinical exam</td>
<td>Achilles</td>
<td>12 tendons (12 patients)</td>
<td>Good correlation with ultrasound</td>
</tr>
<tr>
<td></td>
<td>Conventional ultrasound</td>
<td></td>
<td></td>
<td>Three patterns (grades) in normal tendons</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
<td></td>
<td></td>
<td>Symptomatic tendons are harder</td>
</tr>
<tr>
<td>De Zordo et al, 2009 [22]</td>
<td>Clinical exam (VAS score)</td>
<td>Common extensor tendons (elbow)</td>
<td>38 tendons (32 patients)</td>
<td>Accuracy 94%</td>
</tr>
<tr>
<td></td>
<td>Conventional ultrasound</td>
<td></td>
<td></td>
<td>Good correlation with ultrasound</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Greater sensitivity and accuracy than ultrasound</td>
</tr>
</tbody>
</table>

Fig. 1. Elastographic color spectrum of healthy Achilles tendons

5 patterns in normal Achilles
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.”

**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?
Achilles Tendon Assessed with Sonoelastography: Histologic Agreement

Andrea S. Klauser, MD, Hideoaki Miyamoto, MD, Mario Tamegger, MD, Ralph Raschingbauer, MD, Bernd Moor, MD, Guenther Klimek, MD, Guido M. Feuchter, MD, PhD, Martin Kaslunger, 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


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

The Journal of Bone and Joint Surgery· Vol 87-A · No 1 · Jan 2005

Carr, Norris. The blood supply of the Calcaneal Tendon, JBJS.1989.vol 51, No.1
Chiavaras and Jacobson, Ultrasound Guided Tendon Fenestration, Semin Musculoskelt Radiology 2013:17:85-90


De Zordo et al, Real-time Sonoelastography Findings in Healthy Achilles Tendons AJR:193, Aug 2009