Anatomy and Pathology of the Achilles Tendon

Achilles

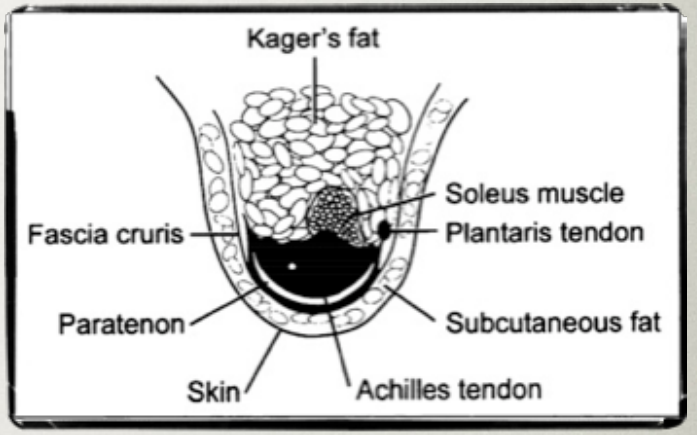
- Achilles was the warrior and hero of Homer's Iliad
- Thetis, Achilles' mother, made him invulnerable to physical harm by immersing him in the river Styx after learning of a prophecy that Achilles would die in battle
- The heel she held him by remained untouched by water and vulnerable
- Achilles led the Greek military forces, which captured and destroyed Troy after killing the Trojan Prince, Hector
- Hector's brother Paris killed Achilles by firing a poisoned arrow into his heel

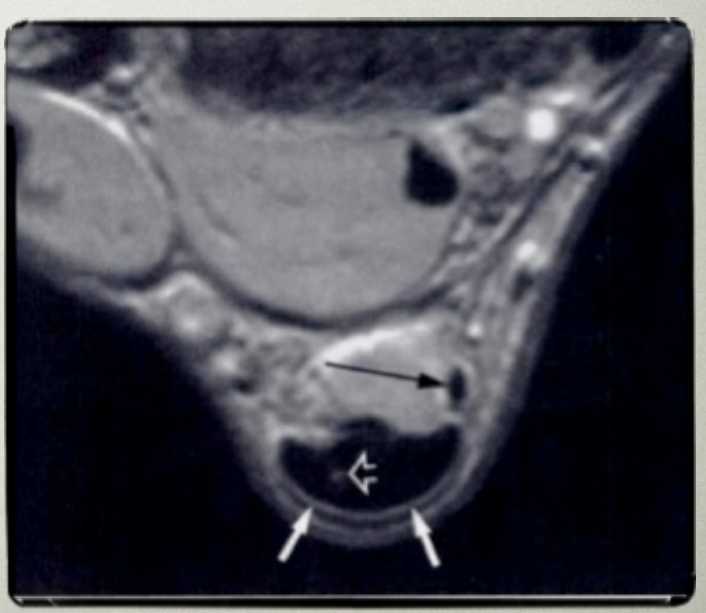
Outline

- Anatomy
  - General anatomy
  - Gastrocnemius muscle
  - Soleus muscle
  - Achilles tendon
  - Calcaneal tuberosity
  - Blood supply
  - Retrocalcaneal bursa
  - Peritenon
  - Plantaris
  - Surrounding soft tissues
- Biomechanics
- Epidemiology
- Pathology
  - Clinical findings
  - Peritendinitis
  - Paratendinitis
  - Partial & Complete tears
  - Muscle atrophy
  - Osseous abnormalities
  - Insertional pathology
  - Myotendinous junction
  - Retrocalcaneal bursitis
  - Haglands deformity
  - Xanthoma
- Post surgical imaging

General Anatomy

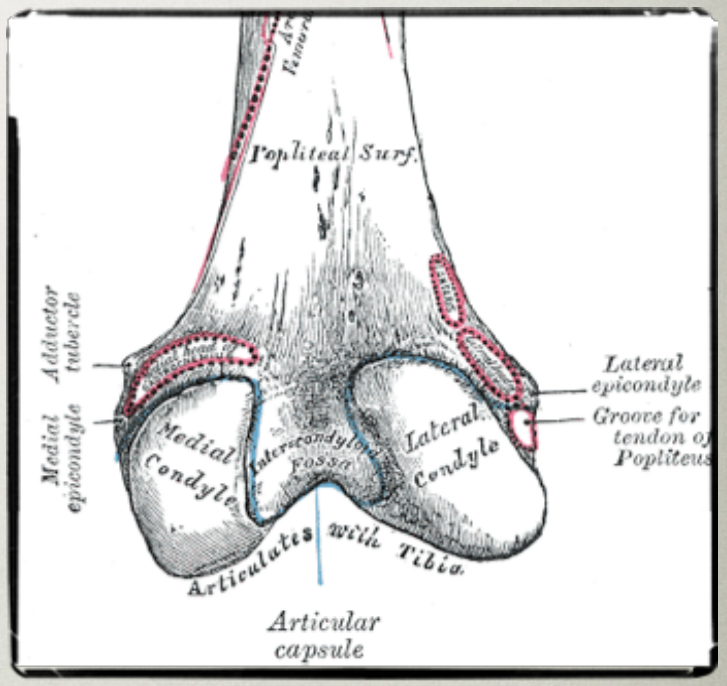
- Achilles tendon is the strongest + largest tendon in the body
- Formed by conjoined tendons of gastrocnemius and soleus muscles (triceps surae)
- Gastrocnemius muscle (GM), soleus muscle (SM), Achilles tendon (AT) and plantaris located in posterior, superficial compartment





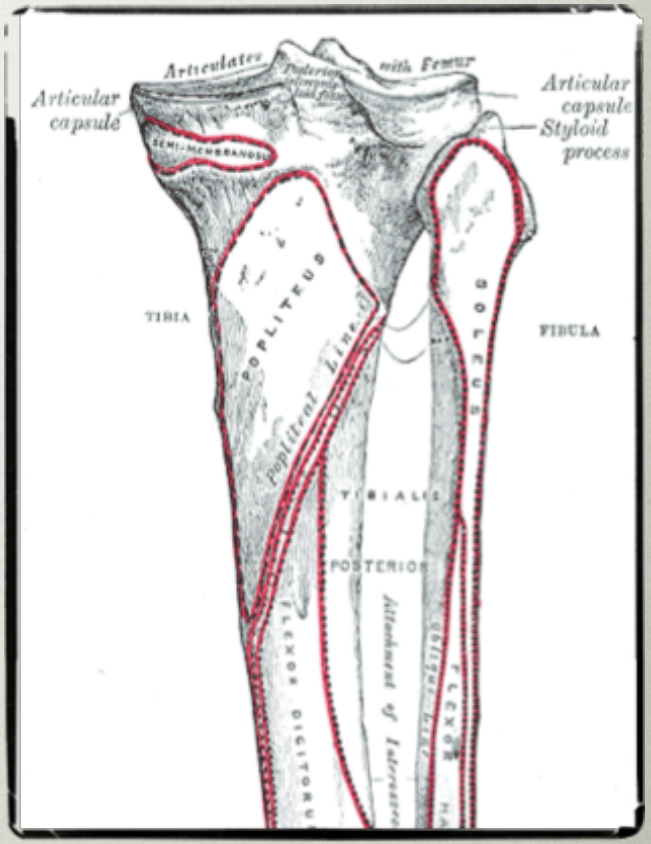
Gastrocnemius Anatomy

- Fusiform, biarticular muscle
- High proportion of fast-twitch type II muscle fibers (rapid movement)
- Medial head (MG) larger; originates from popliteal surface of femur just superior to MFC
- Lateral head (LG) originates from posterolateral surface of LFC and lateral lip of the linea aspera
- Two muscle bellies extend to middle of the calf where they join
- Tendon forms on deep surface
- Tendon 10-15 cm in length



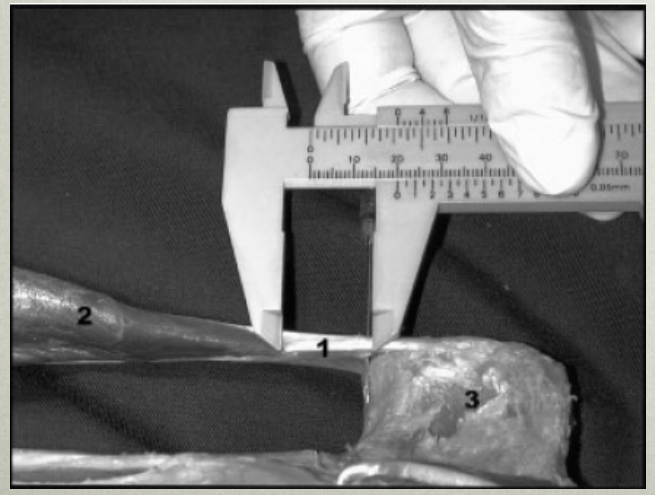
Soleus Anatomy

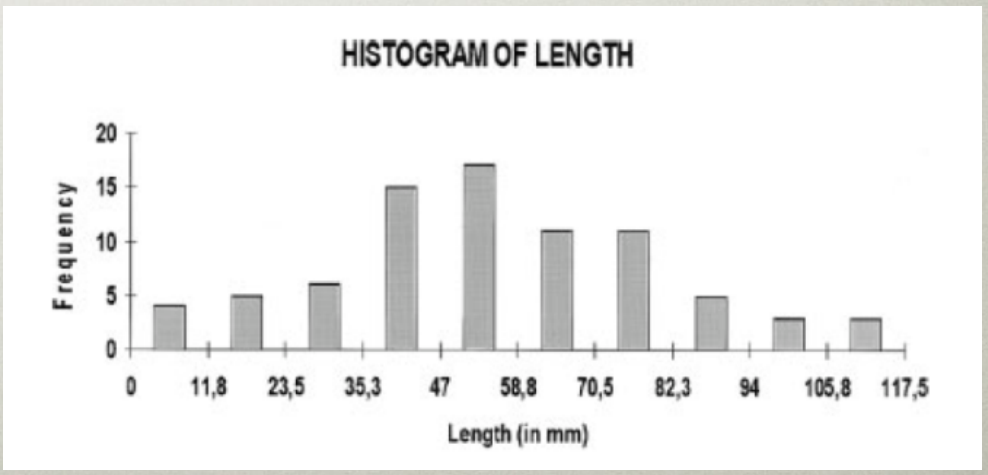
- Multi-pennate monoarticular muscle
- Immediately deep to GM
- Predominantly slow-twitch type I muscle fibers with high fatigue resistance (postural muscle)
- Arises from posterior head and proximal 1/4 of fibular shaft, soleal line and from fibrous band between the tibia and fibula



Soleus Anatomy

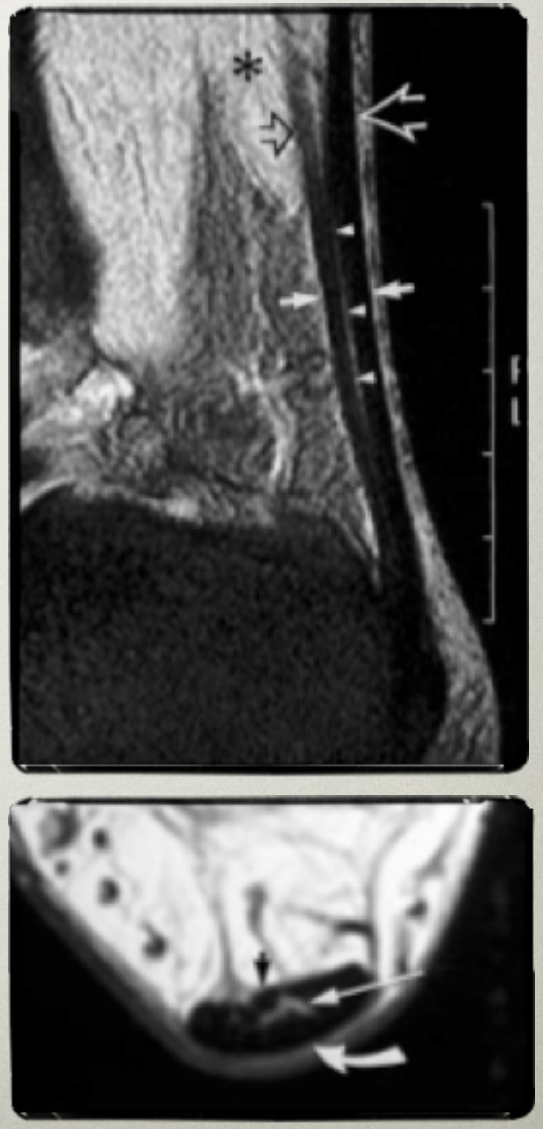
- Muscular fibers terminate in a broad aponeurosis on the posterior surface
- Gastrocnemius and soleus aponeuroses parallel each other for variable distance before uniting
- Large variation in soleus musculotendinous junction
- ? cut off for low lying soleus
  - Pichler et al. Anatomic Variations of the Musculotendinous Junction of the Soleus Muscle and Its Clinical Implications. Clinical Anatomy 2007; 20:444–447.





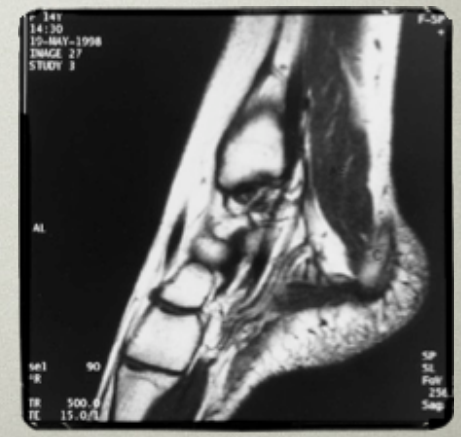
Low Union of Gastrocnemius and Soleus Tendons

- Gastrocnemius and Soleus tendons may remain separate up to their calcaneal insertions
- Can mimic tendinosis on axial images and a longitudinal tear on sagittal images
- Increased SI smooth + linear
- Gradual tapering on sagittal images
  - Rosenberg ZS et al. Low incorporation of soleus tendon: a potential diagnostic pitfall on MR imaging. Skeletal Radiol (1998) 27:222±224



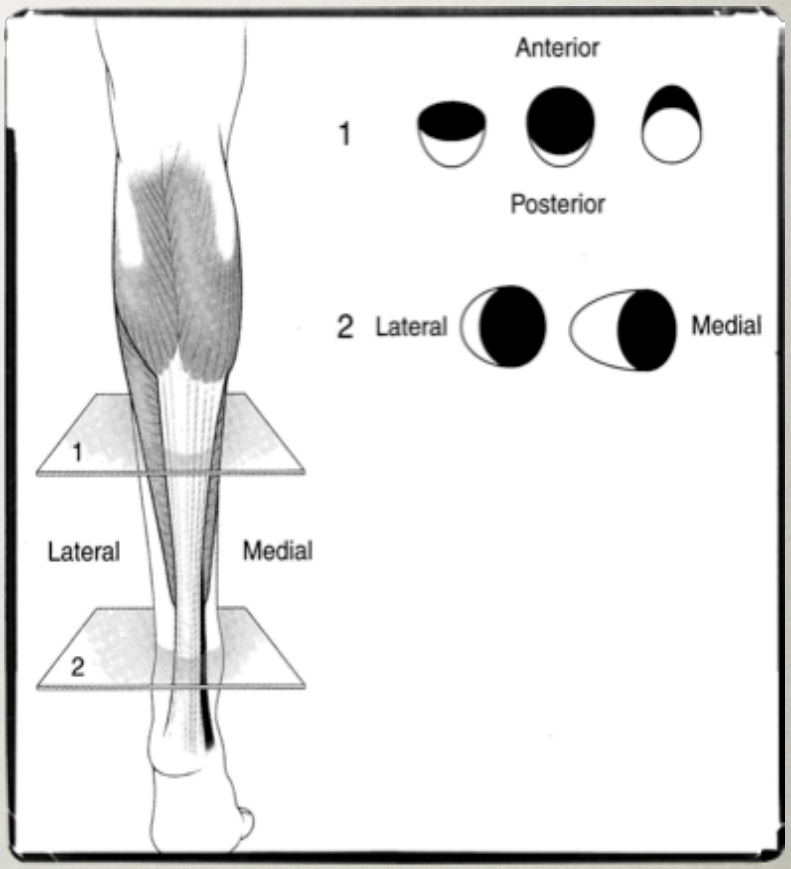
Accessory Soleus

- Rare congenital anatomical variant (0.7%)
- Arises from anterior surface of the soleus, soleal line of the tibia or proximal fibula
- Inserts as muscle or tendon onto medial surface of calcaneus or into Achilles' tendon
- Separate blood supply from posterior tibial artery and separate fascial sleeve
- Manifests in late teens because of muscle hypertrophy due to increased physical activity
- Majority present with a painful swelling caused by muscle ischemia or a compressive neuropathy involving the posterior tibial nerve



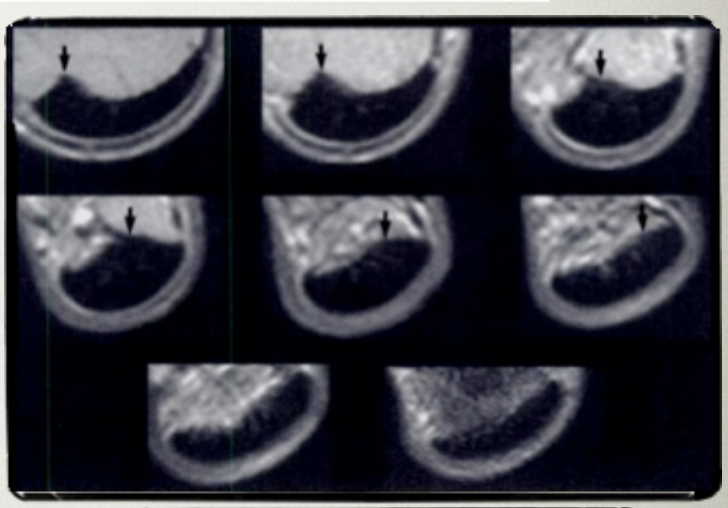
Achilles Anatomy

- Begins at junction of gastrocnemius and soleus tendons in middle of calf
- Contribution of gastrocnemius and soleus tendons varies
- Typically 3 to 11 cm in length
- Rotational twist before inserting on calcaneus
  - gastrocnemius fibers insert laterally
  - soleus fibers insert medially



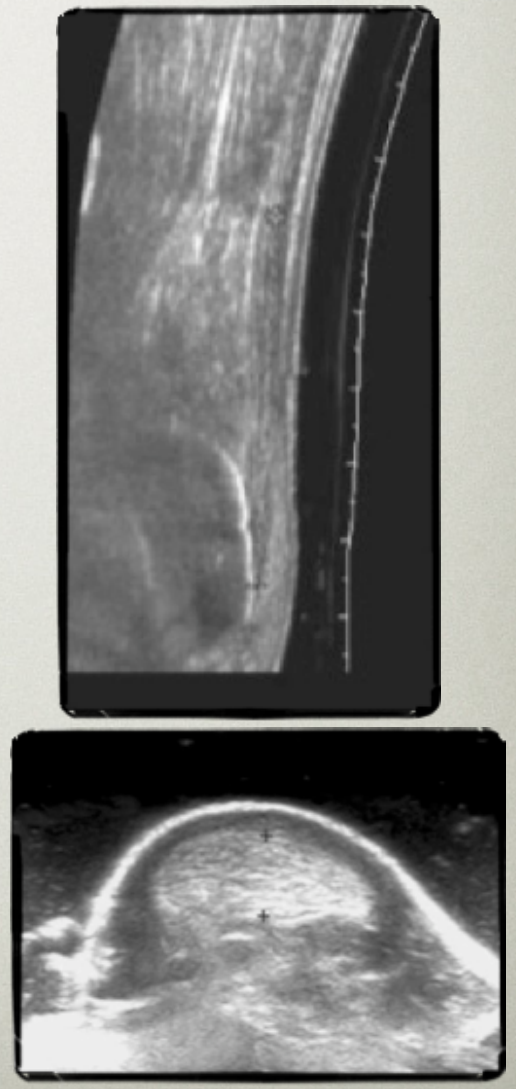
MR Imaging Appearance Achilles Tendon

- 4 - 7 mm thick (average 5.2 mm)
- 12 - 25 mm wide
- Crescent shape
  - Mildly convex 10% asymptomatic pts
  - Wave-like crescent from lateral to medial (may mimic tendinosis on sagittal MRI/US)
- Parallel margins on sagittal images
- Normally dark on all imaging sequences
  - Fascicular anatomy may be visible as punctate areas of increased SI
  - Distal magic angle artifact (internal twisting of fibers)



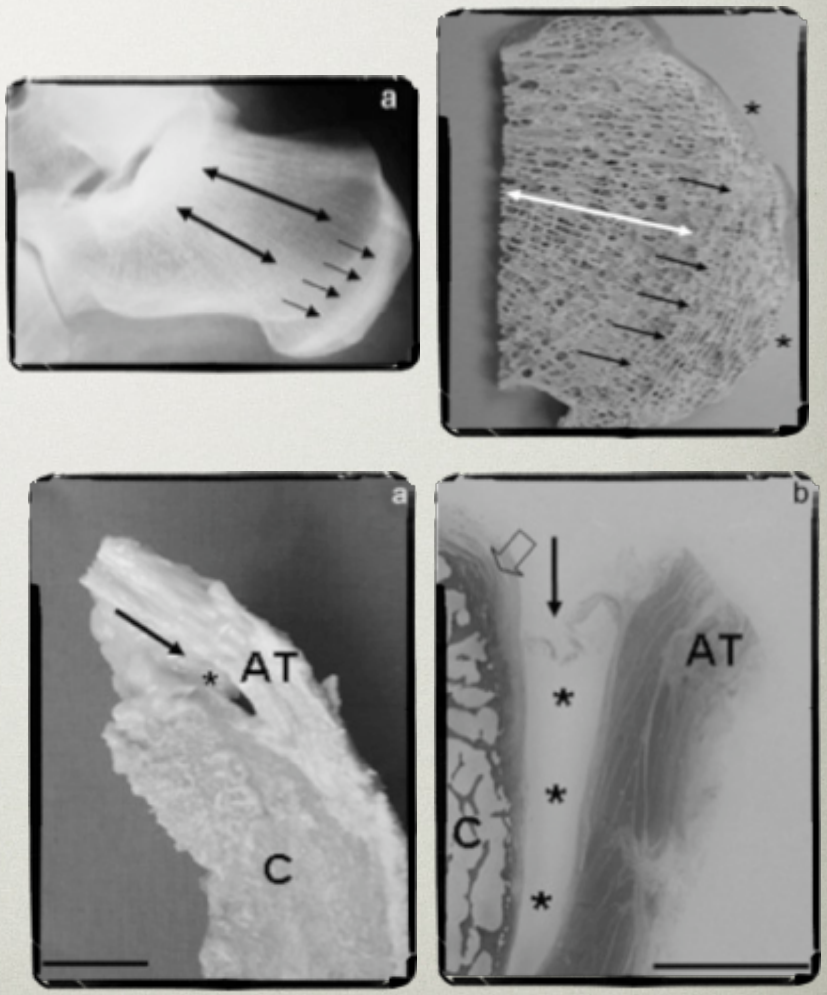
Ultrasound Imaging Appearance Achilles Tendon

- High frequency linear transducer
- Probe should be held at right angles to the tendon
- Normal Achilles tendon:
  - Hypoechogenic, ribbon-like structure contained within two hyperechogenic bands
  - Tendon fascicles appear as alternate hypoechogenic and hyperechogenic bands
  - Bands are separated when the tendon is relaxed and are more compact when the tendon is strained



Posterior Calcaneus/ Achilles Insertion

- Superior 1/3 of posterior calcaneal surface - anterior wall of retrocalcaneal bursa
- Achilles tendon attaches to middle and inferior 2/3
- Cortex extremely thin with sickle-like condensations of cancellous bone just beneath the surface
- Covered by layer of fibrocartilage which merges with periosteum superiorly

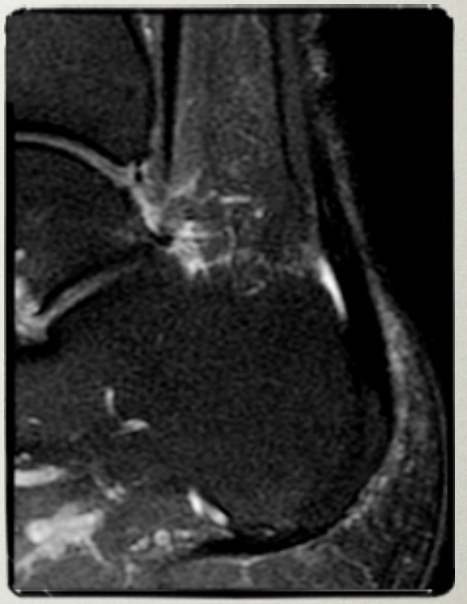


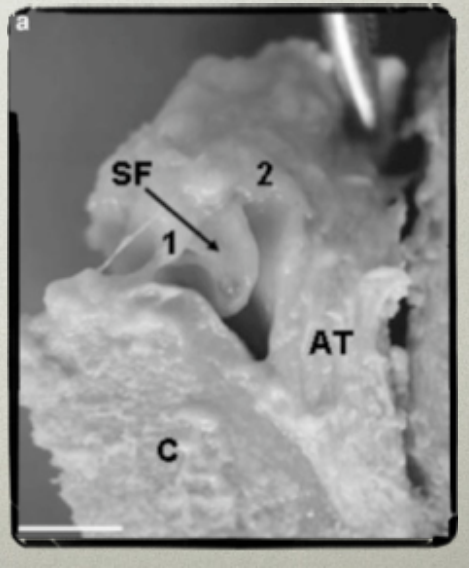
Blood Supply

- Blood supply from musculotendinous junction, peritenon and bone-tendon junction
- AT poorly vascularized (like all tendons)
- Dispute regarding the distribution of blood vessels in the tendon
  - Some investigations have shown the density of blood vessels in the middle of the AT is low compared to proximal tendon
  - Others have shown blood flow is evenly distributed
- Blood flow varies with age and loading conditions

Retrocalcaneal Bursa

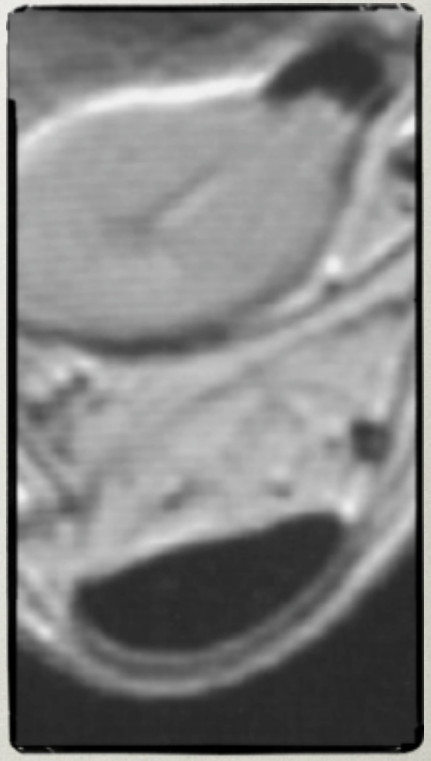
- Visible in 96% of patients on MR
- Normally measures < 7 mm SI, 11 mm ML and 1 mm AP
- Margins: calcaneal tuberosity anterior, AT posterior, Kager's fat pad superior
- Protects the distal AT from frictional wear against calcaneus
- Superior synovial fold with delicate fascicle of skeletal muscle fibers





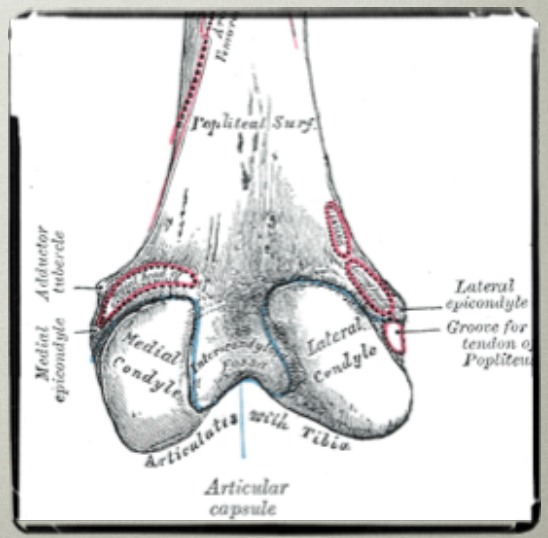
Peritenon

- No true synovial sheath surrounding AT
- Enclosed by a peritenon - thin gliding membrane of loose connective tissue
- Also referred to as paratenon
- Peritenon continuous proximally with the fascial envelope of GM and SM, and blends distally with the periosteum of the calcaneus
- Blood vessels run through the peritenon - provides nutrition for tendon
- Thin, crescent shaped intermediate SI posterior, medial + lateral to Achilles



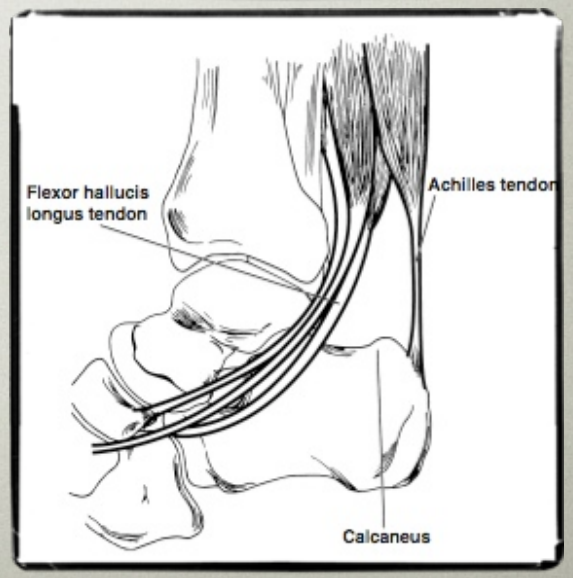
Plantaris

- Variable size
- Absent in 6% to 8%
- Origin from the popliteal surface of the femur above the lateral femoral condyle
- Muscle belly 5 to 10 cm in length, with a long tendon that extends distally between the gastrocnemius and soleus muscles
- Inserts: medial border of the Achilles tendon, calcaneus or flexor retinaculum
- Tendon may rupture
- Tendon may be used as a tendon graft in Achilles reconstruction



Adjacent Soft Tissues

- Kager's fat pad anteriorly
  - Boundaries: flexor hallicus longus muscle/tendon, achilles tendon, calcaneus
  - Normally clean without edema/fibrosis
  - Vessels may mimic edema
- Retro-Achilles bursa
  - Acquired bursa posterior to Achilles tendon



"Achilles' Heel"

- The term "Achilles' heel" was first used by a Dutch anatomist, Verheyden, in 1693 when he dissected his own amputated leg
- Expression used for "area of weakness, vulnerable spot"

Biomechanics

- AT is subjected to the highest loads in the body - up to 10x body weight
- Triceps surae primary plantar flexor of foot
  - Deep muscles of posterior compartment + peroneal muscles contribute 15–35%
- Gastrocnemius and Soleus muscles differ in muscle twitch fibers, muscle length, fascicle length, and pennation angle
- GM and SM capable of acting individually, even though they share a common tendon
- Hyperpronation, pes cavus, genu varum increase tendon stress

Epidemiology

- Achilles tendon pathology rarely reported before 1950s
- Incidence of Achilles tendon tears in industrialized nations is approximately 7/100,000 per year
- Mean age 36; Male predominance (1.7:1 to 12:1)
- Left > Right for unknown reasons
- Etiology of Achilles tendon rupture:
  - Repetitive trauma with collagen degeneration
  - Also: local steroid injection, oral corticosteroids, fluoroquinolones, inflammatory and autoimmune conditions, collagen abnormalities and neurological conditions
  - Violent muscular strain in healthy tendon

Achilles Pathology

- Spectrum of Achilles tendon disorders and overuse injuries ranges from:
  - Inflammation of the peritendinous tissue (peritendinitis, paratendinitis)
  - Degeneration of the tendon (tendinosis)
  - Tendon rupture (partial or complete)
  - Insertional disorders (retrocalcaneal bursitis and insertional tendinopathy)

Clinical Findings

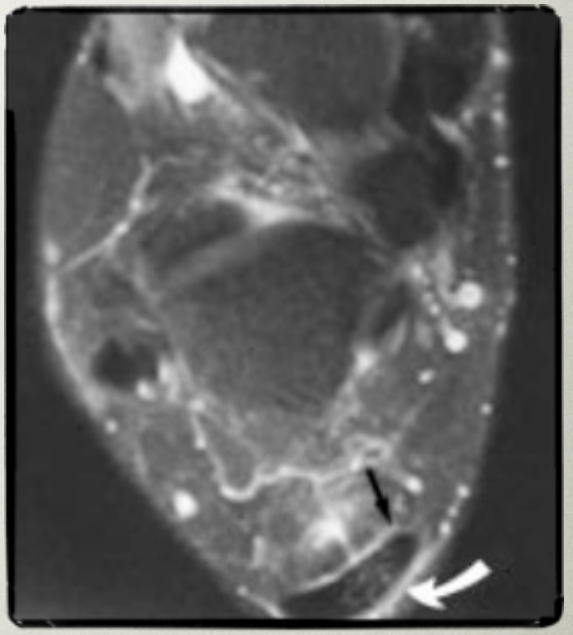
- Clinical terminology variable and distinction between different pathology difficult clinically
- "Achillodynia" general term used for pain in region of Achilles

Differential diagnosis of Achilles tendon disorders

	Paratendinopathy	Tendinosis	Partial rupture	Insertional disorder	Anomalous soleus	Complete rupture
History						
Pain on exertion	X	X	X	X	X	X
Pain only in tendon insertion				X		
Pain behind Achilles tendon					X	
Gradual onset of symptoms	X	X		X	X	
Sudden onset of symptoms			X			X
Stiffness and pain in the morning	X	X	X	X	X	
Clinical findings						
Tenderness in middle third of tendon	X	X	X		X	X
Tenderness of tendon insertion				X		
Swelling	X	X	X	X	X	X
Palpable nodules that do not move when ankle is dorsiflexed	X					
Palpable nodules move when ankle is dorsiflexed		X	X			
Swelling or bulbous mass at medial or lateral side of Achilles tendon					X	
Crepitation	X					
Palpable gap			X			X
Thompson test positive						X

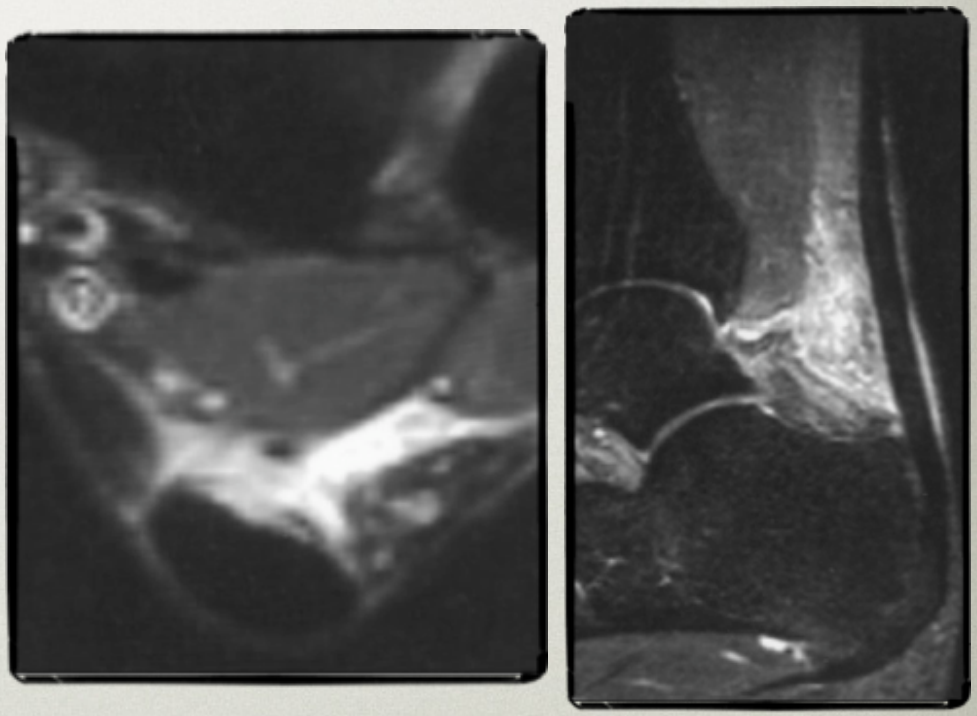
Peritendinitis

- Inflammation of peritenon
- Often represent 1st symptomatic stage of Achilles pathology
- Partially circumferential high SI around Achilles tendon
- Best seen on fat suppressed T2WI
- Margins slightly ill defined
- Isolated peritendinitis - tendon itself is normal
- Adhesion form between peritenon and Achilles



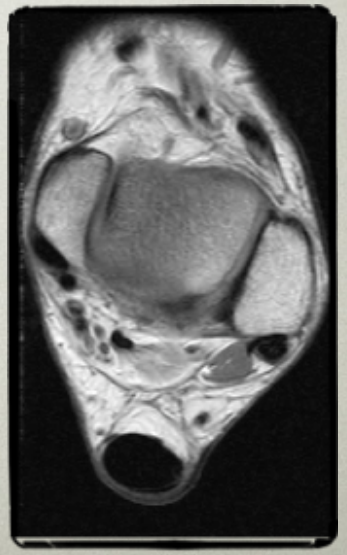
Paratendinitis

- Inflammation about the Achilles tendon
- Edema within Kager's fat pad anterior to Achilles tendon
- Can be seen in asymptomatic patients



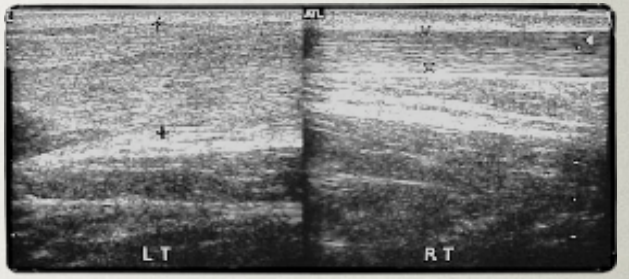
Tendinosis

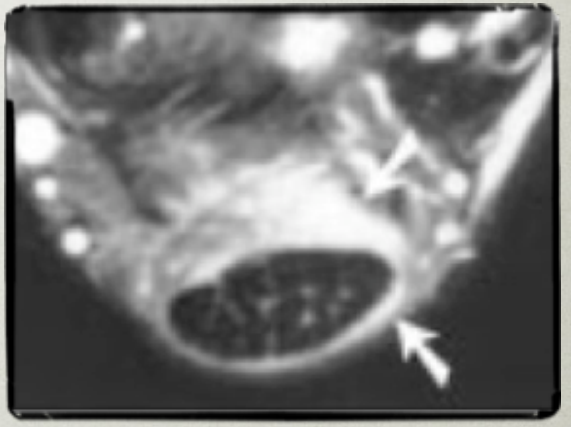
- Degeneration with no significant inflammation:
- Hypoxic or fibromatous:
  - most frequently seen in ruptured tendons
  - leads to thickened tendon with normal SI
- Myxoid
  - 2nd most common
  - May be silent prior to rupture
  - Large mucoid patches and vacuoles between thinned degenerated tendon fibers
  - Interrupted SI on T2WI
- Lipoid: Age dependent fatty deposits that do not affect structural properties
- Calcific: Calcium pyrophosphate



Tendinosis

- Often accompanied by peritendinitis
- Imaging:
  - Diffuse or focal thickening
  - Signal intensity generally low
  - When intratendinous foci of increased T2 SI are present an accompanying partial tear is likely
  - Mucoid degeneration junction entity between tendinosis and partial tears - focal interrupted increased T2 SI (coalesce to form partial tears)





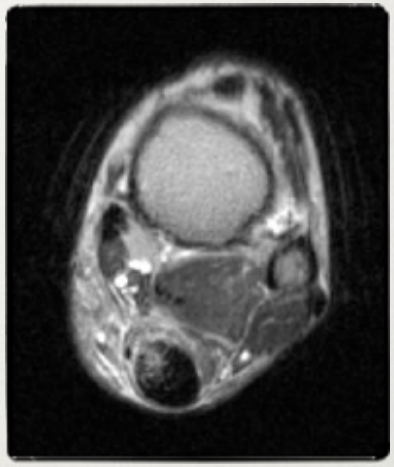
MR Appearance Symptomatic vs Asymptomatic Patients

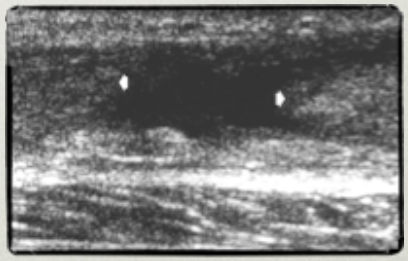
- Increased thickness in asymptomatic and symptomatic patients relative to previous reports (0.747 cm vs. 0.877 cm)
- Similar incidence of peritendinitis (37% vs. 34%)
- Pre-Achilles edema was more common in asymptomatic patients (40% vs. 28%)
- Symptomatic patient had larger retrocalcaneal fluid volume (0.278 mL vs. 0.104 mL)
- Asymptomatic Achilles tendons frequently demonstrated mild increased intratendon signal (70%)
- Symptomatic patients had more frequent tears (36%) although 7% of asymptomatic patients had interstitial tears

Haims , Schweitzer et al. MR imaging of the Achilles tendon: overlap of findings in symptomatic and asymptomatic individuals Skeletal Radiol (2000) 29:640–645

Partial and Complete Tendon Tears

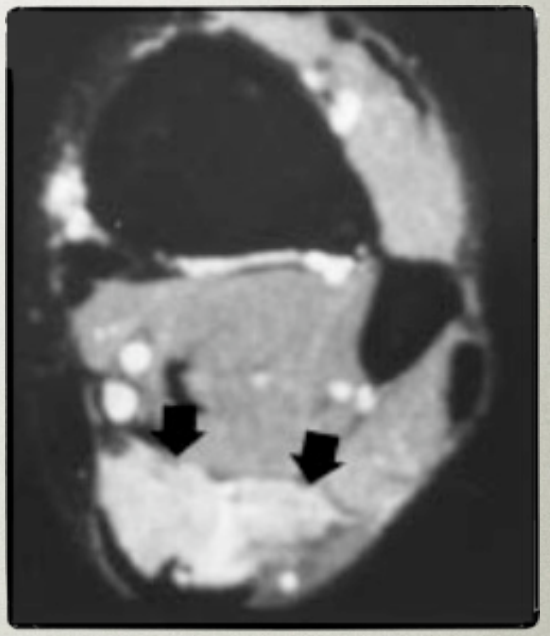
- Spectrum: Microtears - Interstitial tears - Partial tears - Complete tears
- Most common site 3-4 cm proximal to insertion
- Partial tears often lateral
- Discontinuity of fibers
- Intratendinous increased SI on T2/STIR; heterogeneous echotexture
- Intratendinous gap





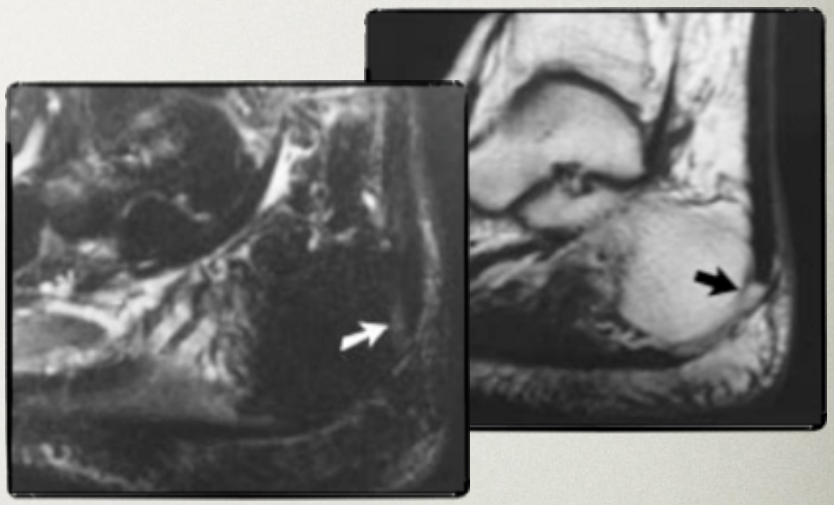
Muscle Atrophy

- Acute atrophy - diffuse edema throughout muscle belly; best prognosis after surgery
- Irreversible atrophy - fatty infiltration
- Atrophy occurs first in the soleus - predominance of slow twitch fibers
- Sagittal images should include at least 3 cm of distal soleus belly
- Atrophy of gastrocnemius rare even in remote Achilles tendon tears



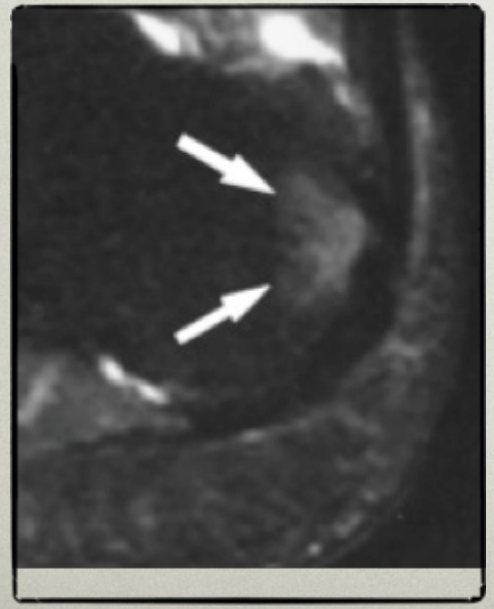
Associated Osseous Abnormalities

- Most common associated osseous abnormality is enthesopathy
  - Usually normal marrow SI
  - Occasionally marrow edema is present - may be acutely symptomatic; respond best to focal surgical resection
- Distal ossification from previous partial tear may mimic a fractured enthesophyte



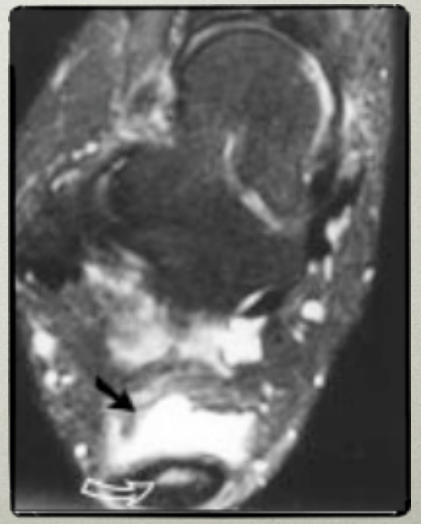
Associated Osseous Abnormalities

- Reactive marrow edema from retrocalcaneal bursitis
- Reactive edema at Achilles insertion
- Degenerative cystic change at inferior Achilles insertion
- Calcaneal avulsion rare
- Calcaneal erosion



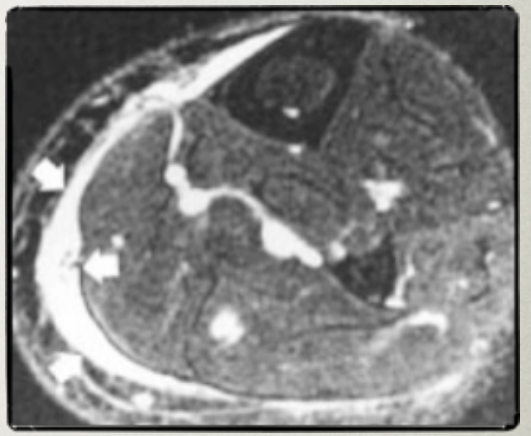
Insertional Pathology

- Degenerative phenomenon
- Frequently leads to enthesophyte
- Achilles thickened distally with vague +/- ill defined longitudinal high signal
- older, less athletic, overweight individuals, older athletes
- If insertional tendonitis inappropriately treated or severe may progress to partial or complete tear



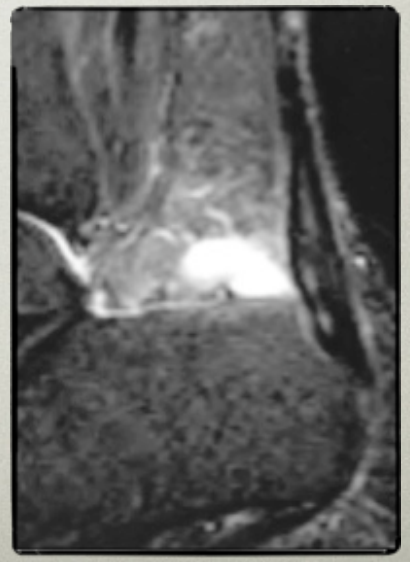
Myotendinous Junction Injuries

- Most commonly medial head of gastrocnemius of dominant leg
- Focal fluid at musculotendinous junction which follows distal muscle belly
- U shaped on coronal images
- More commonly partial
- Adjacent muscle edema due to strain or acute atrophy
- Adjacent hematoma should be noted - may be surgically evacuated
- Complete tears treated surgically; partial tears treated conservatively



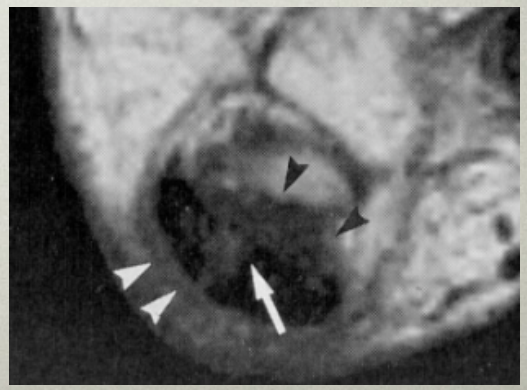
Retrocalcaneal Bursitis

- Hypertrophy and inflammation of synovial lining
- Associated with Achilles pathology and inflammatory arthropathies
- Radiographic findings: absence of normal radiolucency in posteroinferior corner of Kager's fat pad +/- erosion of calcaneus
- SI and ultrasound characteristics of uncomplicated retrocalcaneal bursitis are similar to the those of joint fluid



Rheumatoid Arthritis

- MRI Findings: Normal anteroposterior diameter with marked intratendinous signal alterations and retrocalcaneal bursitis
- No patients had tendinopathy without retrocalcaneal bursitis
  - Stiskel et al. Magnetic resonance imaging of Achilles tendon in patients with rheumatoid arthritis. Invest Radiol. 1997;32(10):602-8.

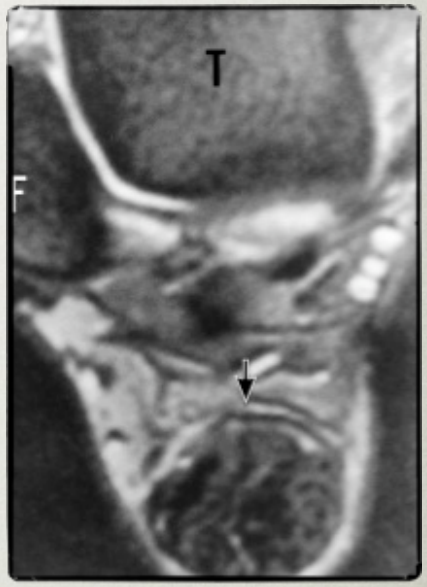


Haglunds Deformity

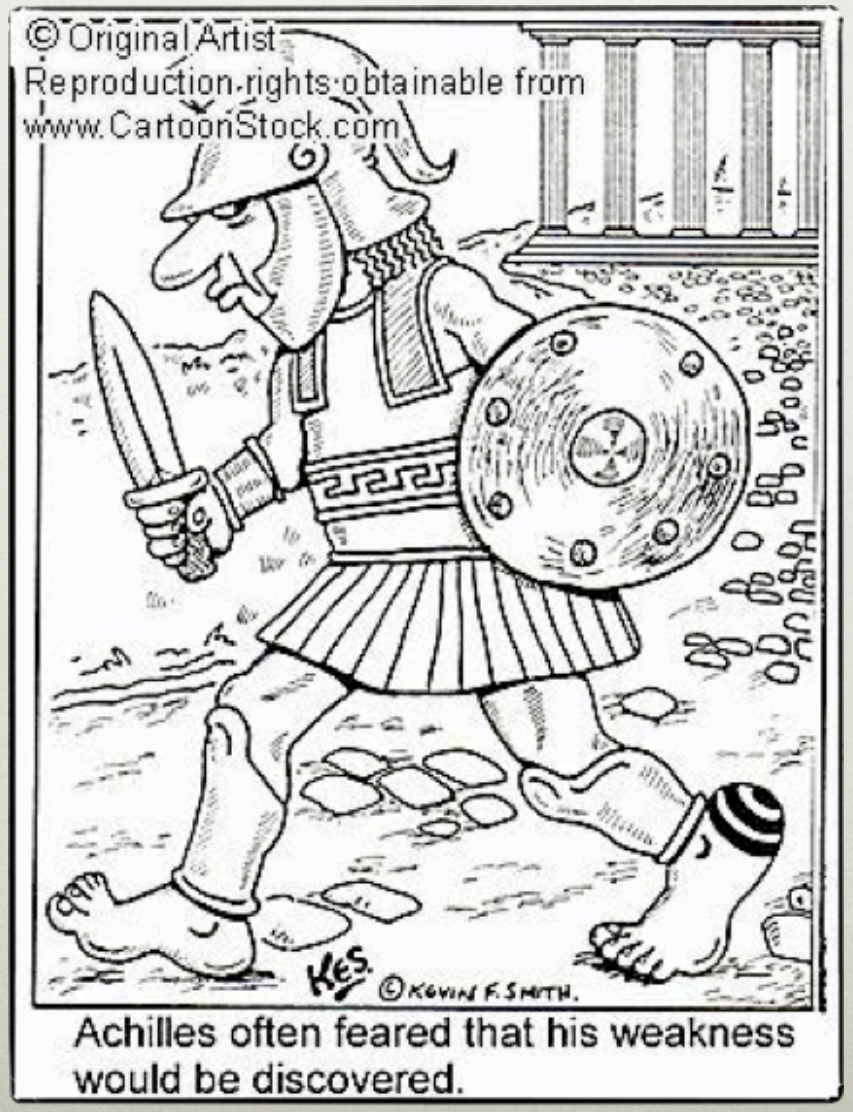
- Triad of thickening of the distal Achilles tendon, retro-Achilles bursitis, and retrocalcaneal bursitis
- "Pump bumps" - stiff heel counter compresses posterior soft tissues against the posterosuperior calcaneus
- Calcaneal tuberosity may focally enlarge in response to chronic irritation
- Leads to cycle of injury, response to injury and re-injury

Xanthomas of the Achilles Tendon

- Achilles tendon is focally or diffusely infiltrated by lipid-laden histiocytes produced by hyperlipidemia
- On all MR sequences diffuse stippled pattern with many low-signal rounded structures of equal size, surrounded by high-signal material
- Achilles tendon normal or enlarged
- Appearance is attributable to hypointense collagen surrounded by hyperintense foamy histiocytes and inflammation
- Can mimic tendinosis and partial tears



Management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KES
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Achilles often feared that his weakness would be discovered.

Management Achilles Tendon Ruptures

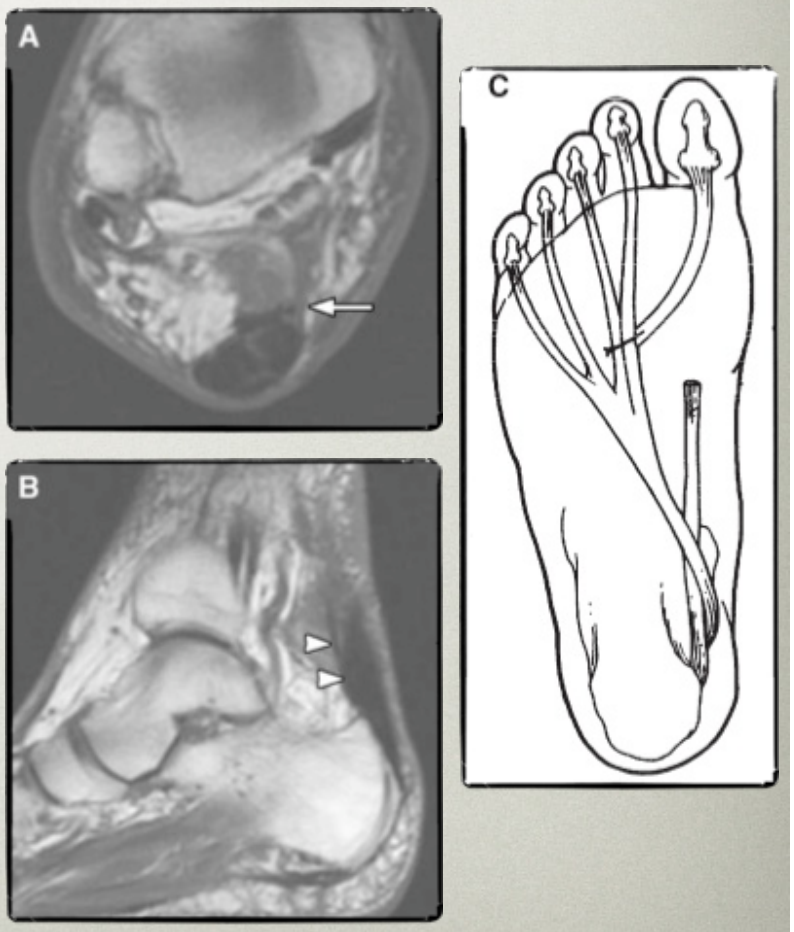
- Management of complete acute ruptures is controversial
  - Operative
    - Open: Better functional outcome, lower rate of recurrent rupture, more post-operative complications
    - Percutaneous: Higher rate of recurrent rupture, fewer post-operative complications, better cosmetic result
  - Nonoperative: High recurrent rupture rate, undesired Achilles lengthening, worse functional outcome
- Treatment for partial ruptures generally conservative
  - Surgical debridement when conservative treatment fails
  - Confluent areas of intrasubstance signal changes on MRI unlikely to respond to nonoperative treatment

Management Achilles Tendon Ruptures

- Management depends on surgeon and patient preference
- Surgery treatment of choice for athletes, young patients and delayed rupture
- Acute rupture in non-athletes can be treated nonoperatively
- Preoperative MRI/US used to assess:
  - Condition of tendon ends
  - Orientation of the torn fibers
  - Width of diastasis
- With conservative management sagittal imaging may be performed after casting to assess for tendon apposition

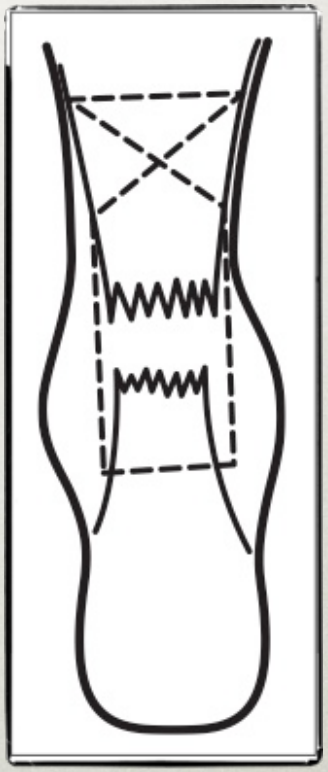
Management Achilles Ruptures-Open Repair

- Tears with < 3 cm tendon gap may be repaired by end-to-end anastomosis using a suture technique
- Gap 3-6 cm: autologous tendon graft
- Gap > 6 cm: free tendon graft or synthetic graft
- Neglected Achilles tendon rupture > 4 weeks' duration require surgical repair
- Tendon grafts: plantaris tendon, peroneus brevis, tibialis posterior, flexor hallicus longus, 1 central or 2 medial and lateral gastrocnemius fascial turndown flaps

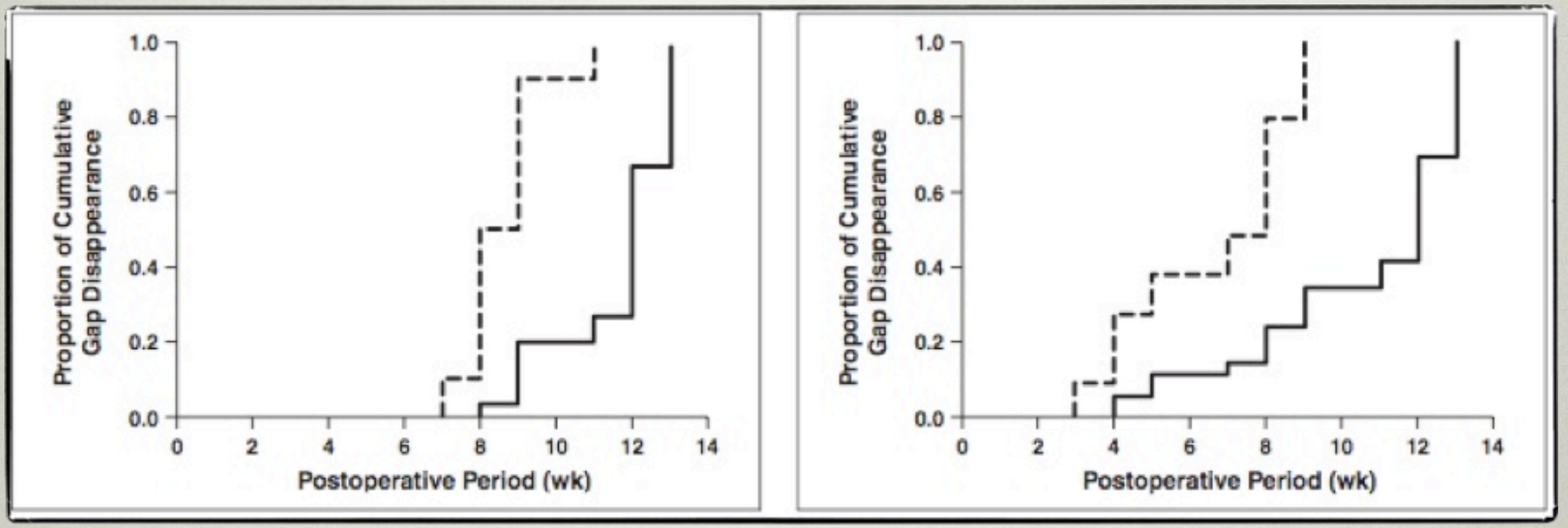


Management Acute Ruptures- Percutaneous Repair

- Suturing the Achilles tendon and pulling ruptured tendon ends toward each other
- Simpler to perform, better cosmetically outcome and less frequent postoperative infection
- Higher risk of postoperative re-rupture
- Risk of sural nerve injury
- Contact between two ends of the ruptured tendon is incomplete

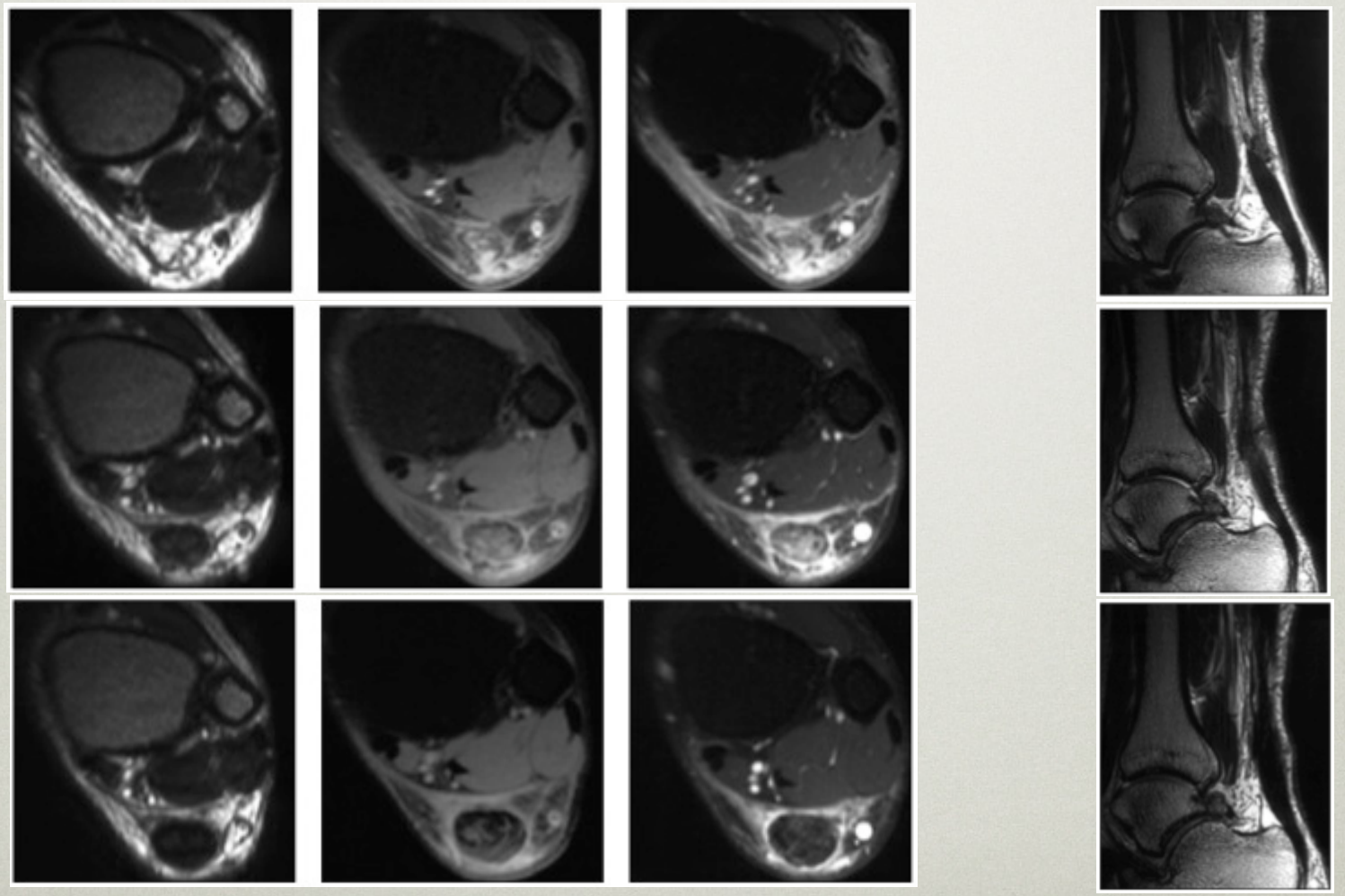


Post-operative MRI Imaging



- Gap expected to disappear approximately by 12 weeks after percutaneous repair (10.4 wks T2/11.6 wks T1)
- Open repair by 9 weeks (6.5 wks T2/ 8.6 wks T1)
- Tendon gap disappeared early on T2 weighted images

Post-operative MRI Imaging



T2 T1 GAD

The End

Thank you for providing original images Tudor!

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