Insights into Imaging Techniques for Tendonopathy; Tendonosis and Fasciosis

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Indications and Clinical Correlations

Chronic tendonopathy and fasciosis are coincident findings associated with some of the most common complaints of chronic foot and ankle pain. **Flat foot** and **heel pain syndromes** often go hand in hand however they can also occur in isolation. Determining the culprit for the chief complaint, whether that be structural or dynamic in nature, requires the benefit of a thorough clinical evaluation. Typically the clinical assessment with elucidate the diagnosis and conservative management is often effective for symptomatic relief. However when the condition proves recalcitrant and the accuracy of the diagnosis becomes suspect then ancillary imaging is pursued to provide insight into the problem and should either confirm or refute the working diagnosis.

Imaging Techniques in Tendonopathy and Fasciosis

If we take a look at a painful flat foot condition it is common to find localized tenderness about the navicular tuberosity and or along the inner arch of the foot. If this is truly a structural problem then improving the posture of the foot and ankle via an orthotic device should prove definitive in reducing symptomatology. When the chronic flat foot pain is recalcitrant despite aggressive orthotic devices then the diagnoses becomes suspect and in fact there may be a more important dynamic component of the condition that has yet to be uncovered. Commonly tendonopathy and fasciosis develop insidiously over time and often simultaneously. Therefore ancillary imaging becomes helpful in determining the nature and extent of the pathology. This added information will help the physician to devise a thoughtful and protective treatment plan. To begin therapy blindly in the face of a tendonopathy of undetermined severity may well aggravate if not accelerate the problem. This is certainly the case when a partial rupture of the tibialis posterior tendon has developed as a matter of wear and tear over time and has become progressively painful. The patient may have had numerous bouts of tendonitis over the years with reasonable response to elementary conservative treatment such as rest, ice, compression and elevation (RICE). Once tendonitis progresses to structural insufficiency and biomechanical abnormality develops then the condition has likely progressed into a later stage of the tendonopathy spectrum and the potential for tendon rupture increases. To begin an aggressive physical therapy regimen under these circumstances can in fact prompt a more important injury such as complete rupture of the tendon. To best manage the patient and protect them against further injury it is best to pursue ancillary imaging in these cases. There are **three goals** in imaging tendon pathology: **1. Identify the nature of the pathology 2. Determine the location of the pathology** and the zone of transition between normal and abnormal tendon both proximally and distally **3. Prognostication**; Determine the severity of the pathology to best advise the patient regarding treatment options and offer some prediction regarding outcomes. **Fig 1 (Fig 1 caption*: Intra operative assessment of tenosynovitis associated with a painful secondary ossification center of the navicular tuberosity. Notice the neovascularized synovium of the tendon as it approaches it's primary attachment on the navicular tuberosity. At this level the tendon is thickened due to the chronic inflammation and intrasubstance tearing of the tendon. Notice the rent in the sheath of the flexor digitorum longus (FDL) tendon lying inferior to the TPT and the abductor hallucis muscle belly distal and inferior to both tendons.)***

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) has certainly become the first line in imaging for many musculoskeletal complaints and for good reason. The ability to ascertain information about muscle, tendon, ligament, bone and the neurovascular elements in one imaging experience is desirable in many cases if not most. Add to that the fact that the technique is non invasive, can obtain images in multiple orthogonal planes and can provide superior soft tissue contrast and you'll probably consider the MRI for most of your complex cases. This may be particularly important in cases that involve progressive painful collapsing arch with or without associated plantar or posterior heel pain.

In one study MRI was found to be a better prognosticator of post surgical outcome versus intra operative inspection. (Conti S, Michelson J, Jhass M: Clinical significance of magnetic resonance imaging in preoperative planning for reconstruction of posterior tibial tendon ruptures. Foot Ankle 13:208-214,1992.) Interestingly, in this study of 20 patients with torn tibialis posterior tendons MRI actually detected intramural tears and degeneration of the tendon that was not obvious to the surgeons reporting the intra operative findings. Most importantly, at 2.5 yr follow up it was the MRI findings that correlated best with the post operative outcome over the surgical assessment. That underlines the important diagnostic role of MRI as it is able to provide valuable information to prognosticate potential benefits of the proposed treatment. Having a detailed MRI account of the severity and extent of tendon damage is the best proactive measure to help determine whether the condition is likely to do well with conservative management or if surgery should be entertained. **Fig 1 MRI TPTD Sag & TRV** While it is not uncommon for a TP tendon to experience the ill effects of chronic wear and tear within the retromalleolar sulcus there are rare occasions when the tendon will develop an enthesitis about the navicular insertion. Often an enlarged secondary ossification center is found at the navicular tuberosity on x-ray and this can be the source of arch pain. The same cannot be said for the presence of the os tibiale externum i.e. the presence of this ossicle is not typically associated with TP dysfunction rather it may infrequently be associated with localized irritation in cases of tendonitis. And so it becomes important to distinguish whether or not the navicular tuberosity is irritated or inflamed versus the simple local irritation of an ossicle. Ultimately this means differentiating TPT dysfunction versus ossicle irritation. While conservative therapy is the mainstay for both diagnoses when a case proves recalcitrant there is an important functional difference between the two where the painful enthesitis about the navicular calls for a very different surgical treatment than that of the painful ossicle. That is to say the Kidner procedure, geared for recalcitrant enthesitis is a very different from the isolated procedure of excision of an ossicle; the os tibiale externum. The functional ramifications of these two procedures are important as one will alter the functional insertion of the TPT and will not eliminate the pain and tendonitis of an irritated ossicle. Performing the wrong surgery for an inaccurate diagnosis is a category of malpractice that is hard to defend and so ancillary imaging not only aids in arriving at the correct diagnosis but it provides very valuable medical documentation that should be consistent with and support the care plan.

MRI Sequences for Tendonopathy Images are generally obtained in three orthogonal planes to study pathology. Typical imaging sequences can be best interpreted when the terminology is understood.

T-1 Imaging (Short TR interval and Short TE interval) Fat weighted imaging good for obtaining anatomic detail.

T-2 Imaging (Long TR interval and Long TE interval) Water weighted imaging good for examining pathology.

STIR (Split tau inversion recovery) Fluid sensitive and enhances inflammation or fluid collections.

Intra venous Gadolinium. Good for determination of the presence of masses and synovial disease. Able to differentiate between solid and cystic lesions.

The MRI classification for tears of the tibialis posterior tendon is based soley upon imaging characteristics. **(Rosenberg ZS, Cheung Y, Jahss MH, Noto AM, Norma A and Leeds NE: Rupture of the posterior tibial tendon: CT and MR imaging with surgical correlation. Radiology, 169:229-235, 1988)**

 Where **Type I TPT, partial rupture with micro tears and longitudinal splits** within the tendon. Here the tendon appears to be thickened and takes on a **fusiform shape** due to intra substance edema, hemorrhage and scar formations. What was normally **ovoid in shape becomes more rounded** with an increased signal intensity on T-1 or proton weighted image sequences. In this stage of the tendonopathy spectrum the tendon takes on a **hypertrophic appearance** due to the nature of the histologic changes taking place. This type of damage yields a PTT that may appear **5 – 10 times larger than the FDL** tendon on axial images. **Fig 2 a & b** Normally the PTT is only 2-3 times larger than the adjacent FDL tendon and so this represents a significant degenerative change within the tendon substance. Regarding **secondary changes** noted on MR the fluid of **tenosynovitis** is most notable although thickening of the lacineate ligament and adjacent soft tissue edema may be noted. Over time we have been able to cross correlate this classification of disease with **clinical symptoms** and generally for a type I tendonopathy symptoms may have only been present for **6 to 12 months** duration with little or no evidence of structural insufficiency. (**Funk DA, CASS JR and Johnson KA: Acquired adult flatfoot secondary to posterior tibial tendon pathology. J Bone Joint Surg 68A: 95-102, 1986.)**

Type II PTT is a more **severe partial rupture** with **attenuation** at the region of maximum tendon degeneration. This atrophic change is due to progressive stretching, elongation and splitting as the degenerative process is left unchecked. The portions of tendon just proximal and distal to the zone of attenuation appear hypertrophied in comparison to this atrophic centroid. This pathology is best appreciated just **behind the medial malleolous**. The **diameter** of the tendon now is reduced to **equal to or smaller than the FDL** tendon. **Secondary changes** may include **retro malleolar fluid accumulation within the PT tendon sheath** and **medial migration** of the **FDL** tendon as it begins to fill the void left by the asthenic TPT. **Clinically** type II TPT injury is associated with **hind foot valgus** and **symptoms** may have been present for **1.5 to 2 years duration**.

In **Type III a complete rupture** of the tendon is present and this discontinuity is associated with retraction of the frayed tendon ends. The **tendon gap** between these ends is filled with **fluid, fat** and **mucoid degeneration**. The increased signal intensity of normal sinus tarsi fat is often blunted and becomes a more intermediate signal intensity on proton density images although this finding can be

present in all stages of PTT dysfunction. The presence of an associated sinus tarsitis is easily confirmed on MRI. The appearance of fluid, inflammation or fibrotic changes within the sinus tarsi is also a sign of biomechanical change and structural insufficiency. **Structural changes** such as **obliteration of the sinus tarsi fat, periostitis or osteophytic degeneration about the medial malleolous** may be present as secondary changes associated with the Type III TPTD. Clinically the symptomatology may have been present for 2-years or more and the associated rear foot deformity in this stage of disease is severe.

Ultra Sound Imaging; Tendonopathy

To obtain ultrasound images of the foot and ankle a high frequency (13 MHz) linear transducer is used. Since ultrasound is a dynamic imaging modality it is possible to obtain a variety of anatomic positions that simulate normal and abnormal mechanics. Given this fact it is possible to first image the tendon of interest in a neutral or anatomic position and later image that same part when placed under a stress that represents the extremes of normal motion i.e. for the TPT the extremes of inversion and eversion can be simulated and regions of weakness, tears or rupture can be visualized. Long and short axis views are obtained for each tendon of a given compartment. **Fig 3a &b**. (*3a.* In this longitudinal view the ***black arrows*** indicate the linear orientation of the tibial vessels. Notice that vessels are black as they are devoid of an echo i.e. anechoic zone. The ***black arrow heads*** indicate the tibial nerve which is associated with a hyperechoic nature of the dense fibroadipose tissue of the epinerium. The inner nerve fascicles are hypoechoic which is best appreciated in short axis views. The ***white curved arrows*** indicate the linear arrangement of the fibrillar posterior tibialis tendon. This hyperechoic structure demonstrates a homogeneous pattern of echogenicity in this normal tendon specimen. Notice that the fibrils of tendon are much longer in comparison to the fibrillar arrangement found about the periphery of nerve. **3b.** This short axis view demonstrates the hyper echoic pattern of the normal TPT in an "end on" view. The ovoid to tear drop shape of the normal tendon can be appreciated here with a homogeneous arrangement of dense hyper echoic fibrils indicated by the **white arrow heads**.)

When an abnormality is identified it's presence is confirmed by viewing it in an alternate imaging plane. **Fig 4a** (4a. Here a hypoechoic defect, a partial tear, is found within the anterior border of the TPT as indicated by the ***curved white arrow***. The **asterix** indicates a thick anechoic region that represents tenosynovitis. The large white arrow heads indicate normal homogeneous echogenicity of the TPT fibrils. While the series of ***small white arrows*** indicates a region of periostitis about the medial malleolus in the retromalleolar sulcus.) Therefore 2 planes of imaging are required to confirm pathology at any given level to ensure that there has not been a technical error creating a falsely abnormal appearance. Regarding the TPT specifically the short axis views can reveal the subtle changes associated with tendonosis, split tears, intrasynovial fluid accumulations and cystic degeneration. **Fig 4b** (**Fig 4b** In this short axis view of the TPT the ***arrow*** indicates the region of a partial tear confirming that the defect identified in Fig 4a is not due to the magic angle effect. The arrow heads indicate the normal hyperechoic fibrils of the TPT with the most anterior fibers being slightly more intense or hyperechoic due to the edge effect of the tendon as it lays against the retromallolar surface of the tibia. The ***asterix*** represents the region of tenosynovitis associated with this tendonopathy.) Partial tears and ruptures are distinctly different than longitudinal tears as seen in **Fig 4c** (**Fig 4c** Perhaps best appreciated in the short axis view a longitudinal or split tear is different that a partial tear or rupture given the linear nature of the tendon

defect as seen here as indicated by the small white arrow. This split tear extends beyond the central aspect of the tendon substance and so transects nearly 2/3 of the tendon. The ovoid configuration of the tendon remains intact in this stage I PTTD.) The partial or complete rupture infers a transverse plane defect that involves retraction of the tendon ends. **Fig 4d** (**Fig 4d** In this long axis view the right hand image demonstrates an intact TPT with typical a homogeneous hyperechoic, linear fibrillar arrangement. In the left image there is a black void representative of the anechoic region due to tendon retraction.)

In the longitudinal split tears of tendon the defect runs within the sagittal plane of the tendons fibrillar bundles and affects a variable percentage of the tendons girth depending upon the severity of the pathology. The ultrasound is designed to best produce images when the transducer is oriented at 90 degrees to the target of interest. When there is significant deviation from that orientation a magic angle effect may be produced and this can create an image defect that gives the appearance of a tendon tear or rupture. By imaging in an alternate plane this technical error can be ruled out eliminating the risk of false positive reporting. This is due to a property of tendons referred to as **anisotropy** (Not having properties that are the same in all planes of view).

Perhaps the biggest drawback to musculoskeletal ultrasound imaging is that it operator dependant and so requires a skilled technologist or radiologist to obtain and interpret these studies. Not all technologists are trained in this category of imaging and so musculoskeletal ultrasound is considered a highly technical imaging modality. Not all facilities, hospitals or outpatient clinics, are equipped to perform these studies due to this fact. To date many hospitals do offer such imaging but proficiency in obtaining and interpreting these imaging studies may vary widely from one institution to the next. When ordering any examination that is not performed routinely it is best that the ordering physician have a thorough understanding of what information to expect from these studies. That is to say you will get the most valuable information from these studies when you personally have a firm idea of normal versus pathologic appearance when using this technique. It is always prudent to review these films with the radiologist (in person or over the phone) to maximize your understanding of how these studies are interpreted.

Nuclear Medicine Imaging

Triphase Bone Scan (99mTc - Methylene Diphosphonate)

Nuclear medicine imaging (NMI) can be very insightful when the clinical symptoms are out of proportion to the presumptive diagnosis. The three phases of the bone scan will reveal associated perfusion abnormalities in the angiogram (phase I), soft tissue and muscular hyperemia in venous blood pool imaging (phase II) as well as regions of osseous injury that prompts hyper perfusion on the bone image (phase III). **Fig 5 a-c** Ideally this study should be pursued prior to therapy since any invasive technique, surgery or even injection therapy, will disrupt normal anatomy and may yield changes that produce a false positive scan.

 In patients with flat foot and chronic heel or arch pain plantar fasciitis is perhaps the most common diagnosis. When this condition fails to respond to typical conservative therapies such as stretching or

orthotic therapy ancillary imaging is often beneficial. In these instances the underlying culprit may not be fasciitis at all. Although clinical correlations are generally able to rule out alternate diagnoses there are those atypical cases that require additional imaging to sinch the diagnosis. The triphase bone scan is a readily available, inexpensive, and non invasive form of imaging used for many musculoskeletal conditions. *In the authors experience it is rarely, if ever, questioned by insurance company's and we have learned from experience that the same is not true for most other imaging modalities.*

From practical experience we know that **plantar heel pain** may represent a myriad of conditions such as **contusion** of the heel bone which won't show immediate signs of relief with a steroid injection and in fact may progress into a stress fracture given the right circumstances. So too a **stress fracture** will prove recalcitrant to the usual heel pain therapies such as stretching, orthotic therapy and NSAID use. In fact given aggressive weight bearing exercise this condition will only be aggravated by this regimen and may progress into a frank fracture with displacement. **Infra calcaneal bursitis** is another common condition that is often mistakenly labeled as "heel spur syndrome" and often proves recalcitrant to the typical heel pain therapies.

The term **"heel spur syndrome" (HSS)** has become a catch all aka waste basket term for heel pain in general and is grossly overused by specialists and general medicine physicians alike. The usual treatment scheme of stretching, orthosing, NSAIDs and injections are pursued for HSS often without performing a meaningful clinical exam. Given this clinical misbehavior many patients fail at the conservative line of therapy simply due to an inaccurate diagnosis or simple failure to complete the physical exam. For this reason plantar fasciitis aka HSS should probably be treated as a diagnosis of exclusion as this would necessitates a detailed examination to differentiate this from the others in the diagnostic list. An article written on this subject reviewed the study of chronic heel pain using NMI, specifically the triphase bone scan. This prospective study of 24 patients (32 feet) was aimed at predicting the outcome of injection therapy for plantar fasciitis using the NMI bone scan technique. **(Frater, C et al: Bone scintography predicts outcome in Plantar Fasciitis. J. Nuc Med 2006, 47:1577-1580)**

Patients were divided into three groups based upon the duration of their symptoms; acute (6wks or less), subacute (6wk – 3 mos) or chronic (greater than 3 mos). Each patient would have the triphase bone scan complete prior to initiating injection therapy. What they found was that patients responded to injection therapy with complete or near complete relief (62.5%) when hyperemia was well localized to the infra calcaneal region of the rear foot. When the hyperemia or increased intensity of the bone scan was found extending into the plantar fascia i.e. beyond the region of the heel bone then poor response or lack of response was realized. What this infers is that patients that truly have plantar fasciitis do respond well to injection therapy and that diagnosis can be easily elucidated and differentiated from other conditions using the bone scan. In this study those cases that proved recalcitrant to injection therapy had been misdiagnosed as having a localized osteoarthritis or bursitis when the condition actually involved a considerable amount of the plantar fascia. Regarding plantar fasciitis or fasciosis, therapy should be geared at relative rest of the fascia via strapping or orthotic therapy and improving tolerance to stretch via night splinting, aggressive stretching exercises with or without adjunctive physical therapy techniques. Injection therapy is not effective at achieving these goals. Whereas in the case of infra calcaneal bursitis or enthesitis a well placed injection may be exceedingly helpful at eliminating symptoms. In most rear foot and heel pain conditions there is an associated biomechanical component and so formal orthotic devices often play a role in long term management. The use of

orthotic devices should not preclude a thorough clinical evaluation or the determination of a specific and accurate diagnosis and that is where ancillary imaging comes into play.

In considering tendonopathy and fasciosis there is a number of myriad of diagnoses that may accompany a painful flatfoot condition and ancillary imaging can play a big role in streamlining the diagnosis and tailoring the treatment plan. Given cases complicated by chronic pain and remote surgery the need for detailed imaging is not just a luxury it is essential to optimal patient care. The specialized anatomical information that these ancillary imaging modalities provide can mean the difference between therapeutic success and futility.

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