MRI OF TARSAL TUNNEL PATHOLOGY

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INTRODUCTION

Recently, magnetic resonance imaging (MRI) has taken a prominent role in the evaluation of musculoskeletal disease of the extremities. MR imaging of the wrist has been shown to provide an effective means of imaging the carpal tunnel, and has become a valuable tool in the preoperative evaluation of carpal tunnel syndrome. Similarly, several recent papers have suggested that MR imaging may be of comparable value in imaging the tarsal tunnel.[1-3] MR imaging can accurately depict the contents of the tarsal tunnel, including the posterior tibial nerve and its terminal branches. Pathological entities affecting these neural structures including soft tissue masses, varicosities, fibrosis, tendon sheath thickening and tenosynovitis, as well as secondary intrinsic changes such as swelling and inflammation, can be readily identified.

NORMAL MRI ANATOMY

Detailed anatomic MR images of the normal ankle have been achieved and reported in all the body planes.[1-8] Images obtained from cadaveric specimens and healthy volunteers are quite similar with the exception of vascular flow voids and enhancement phenomena found in live subjects. In general, the transverse (axial) and sagittal (longitudinal) planes offer the most easily appreciated and readily interpreted information. The frontal (coronal) plane images are more difficult to interpret, and therefore, are least helpful.

Transverse (Axial) Plane

The transverse (axial) plane images are favored by most radiologists, and provide the best cross-sectional depiction of the tarsal tunnel's boundaries and contents. The roof of the tarsal tunnel, the flexor retinaculum (or laciniate ligament), is usually identified as a continuation of the deep fascia. It appears as a thickened low intensity band radiating from the medial malleolus in a fan-like manner to insert and blend with the periosteum of the calcaneus posteriorly and the abductor hallucis inferiorly. The floor of the tarsal tunnel is thus formed by the medial wall of the calcaneus and talus.

The tarsal tunnel is further divided by very thin low intensity fibrous septa which run from the undersurface of the flexor retinaculum to the periosteum of the calcaneus. These septa form four separate compartments for the underlying structures. From anterior-medial to posterior-lateral, the structures within these compartments include Tom, Dick, ANd, Harry, namely the Tibialis posterior tendon, the flexor Digitorum longus tendon, the posterior tibial neurovascular bundle (Artery, venae comitantes, and Nerve), and the flexor Hallucis longus tendon. The cross-sections of the tendons appear as low signal intensity (dark) ovals, while the nerve is an intermediate signal intensity (gray) round structure. At the proximal portion of the tarsal tunnel, one can see all these structures embedded in high signal intensity fat (Fig. 1A, 1B).

The posterior tibial nerve typically branches into the medial and lateral plantar nerves beneath the flexor retinaculum. Occasionally, this division will occur proximal to the retinaculum, but although anatomic texts describe it, there have been no surgically documented cases of the separation occurring distal to the retinaculum. The medial calcaneal nerve is the final terminal branch and may arise from the posterior tibial

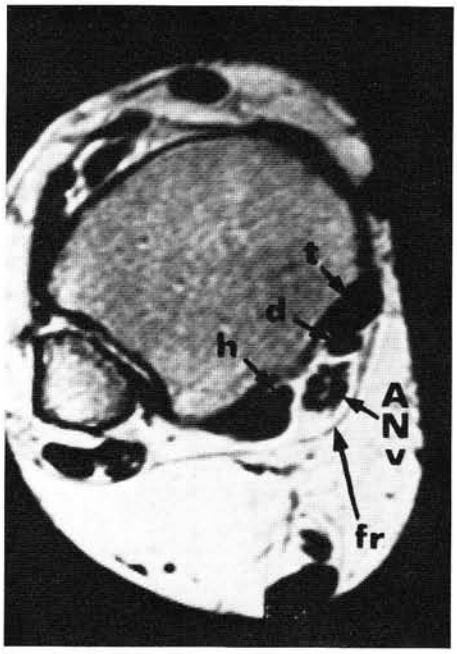

Fig. 1A. Transverse (axial) section of lower leg (i.e., just proximal to the ankle joint) in normal subject. T1-weighted image. [KEY: fr = flexor retinaculum; t = tibialis posterior tendon; d = flexor digitorum longus tendon; h = flexor hallucis longus tendon; ANv = posterior tibial artery, nerve, and venae comitantes.

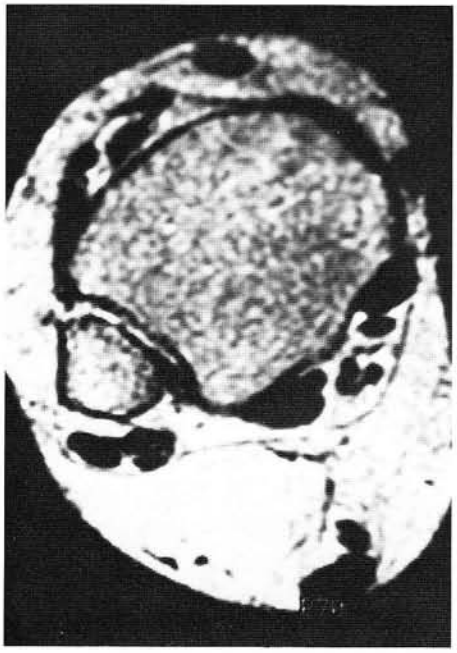

Fig. 1B. T2-weighted image.

nerve prior to its bifurcation or the lateral plantar nerve after bifurcation. In the former case, it may course proximal to the flexor retinaculum, and in the latter case it generally pierces the retinaculum inferiorly.

The ability to image these terminal nerves varies and requires good MRI resolution and contrast. Due to their smaller size, these nerves may blend with the adjacent vasculature and be difficult to image. Usually however, the medial and lateral plantar nerves will be visualized lateral to the vascular structures. The medial plantar nerve is most easily identified as it maintains a fairly consistent course along the medial aspect of the flexor hallucis longus tendon.

More distally, the medial plantar nerve continues in close proximity to the flexor hallucis longus tendon. It passes through the "abductor hiatus" or canal between the abductor hallucis muscle and flexor digitorum brevis muscle. The lateral plantar nerve may occasionally be identified as it passes between the abductor hallucis muscle and the quadratus plantae muscle en route to the plantar vault. The calcaneal branch is very difficult to image in this plane, except near its origin.

Sagittal (Longitudinal) Plane

Although the boundaries of the tarsal tunnel are not readily demonstrated on the sagittal (longitudinal) plane images, the longitudinal course of the nerve and its branches are most easily seen in these sections. With thin sections (e.g., 3-mm sections) and no gap between the sections, the level of division of the posterior tibial nerve and origin of the medial calcaneal branch may be seen in this plane.

As in the transverse plane, the sagittal plane MRI appearance of the tendons is as low intensity (dark) structures. The nerve appears as an intermediate intensity (gray), curvilinear, branching structure just posterior-lateral to the tibialis posterior and flexor digitorum longus tendons, and just medial to the flexor hallucis longus tendon (Fig. 2A-D).

In the normal patient, the posterior tibial artery appears as a low signal intensity structure due to vascular flow void (i.e., blood with a velocity of greater than 5 cm per second will not generate a signal as the excited nuclei within the blood vessel have moved from the imaging plane by the time data is collected).[9] The venae comitantes will usually demonstrate a high signal intensity on T2-weighted images due to flow enhancement. Thus, the intermediate signal

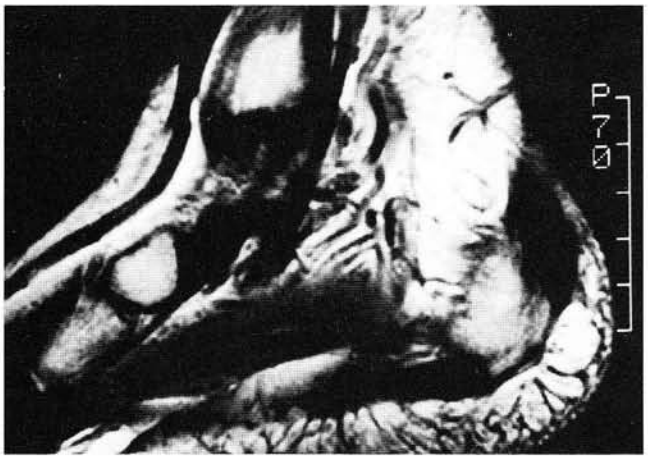

Fig. 2A.

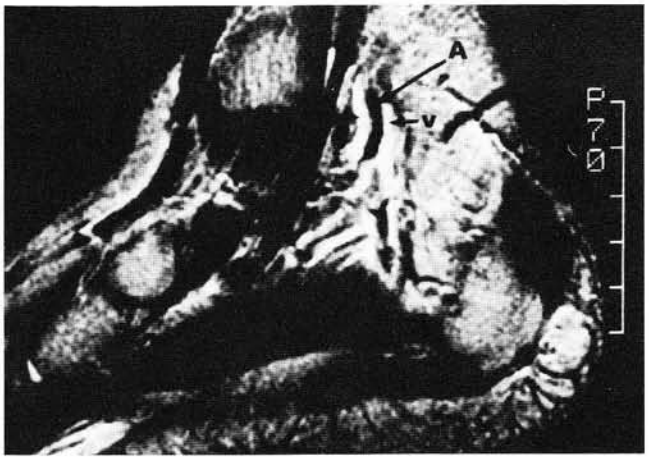

Fig. 2B.

Sagittal (longitudinal) sections of tarsal tunnel. T1-weighted **A.** and T2-weighted. **B.** Images of medial tarsal tunnel. The tibialis posterior tendon and flexor digitorum longus tendons can be noted passing just posterior to the tibia and medial malleolus. The posterior tibial artery and venae comitantes are serpiginous structures readily appreciated just posterior to these tendons. Note the vessels continue and pass deep to the abductor hallucis muscle.

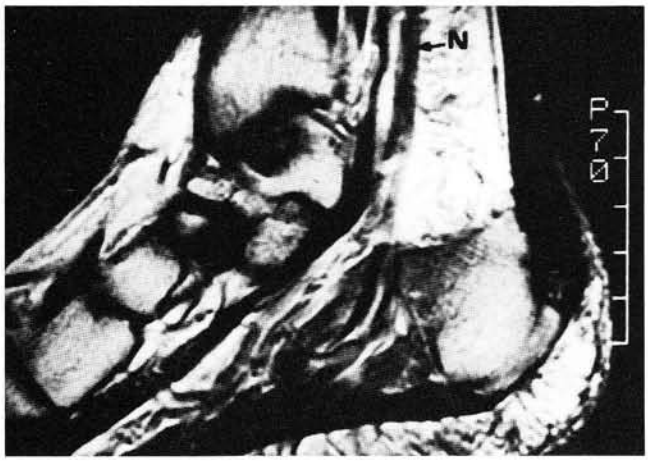

Fig. 2C.

Fig. 2D.

T1-weighted **C.** and T2-weighted. **D.** Images of lateral tarsal tunnel. The flexor hallucis longus tendon is noted passing through the posterior talar tubercles and under the sustentaculum tali of the calcaneus. The posterior tibial nerve is noted just medial to this tendon. Note the division of the nerve just posterior to the talus. [KEY: A = artery; v = venae comitantes; N = nerve]

intensity nerve and its terminal branches can usually be distinguished.

More distally, as the medial and lateral plantar nerves turn obliquely to enter the plantar compartments of the foot, the nerves are traced only with difficulty. Frontal (coronal) plane sections may have some use in evaluating these nerves distal to the tarsal tunnel (e.g., if entrapment of the medial plantar nerve is suspected in the plantar vault of the foot) (Fig. 3).

PATHOLOGIC MRI FINDINGS

Since the posterior tibial nerve is confined within a fibro-osseous tunnel, tarsal tunnel syndrome may occur when the nerve is compressed either intrinsically or extrinsically. Further, biomechanical tension placed upon the nerve may cause symptomatology. Two recent reports have described the wide variety of pathology which may cause tarsal tunnel syndrome.[10, 11] To attempt better differentiation of this pathology, two studies have specifically evaluated the use of MR imaging in patient's with suspected tarsal tunnel syndrome.[1, 2]

In 1990, Erickson et al.[1] reported 6 patients with symptoms suggestive of tarsal tunnel syndrome studied with MRI. They found causes of compression in all cases including 2 neurilemomas, 1 ganglion arising from the flexor hallucis

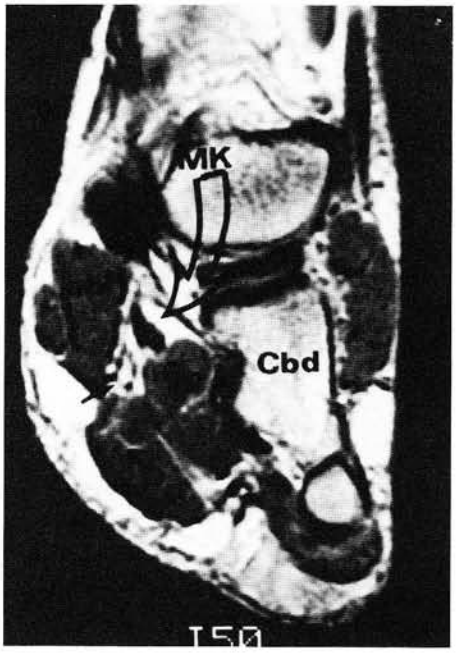

Fig. 3. T1-weighted frontal (coronal) image through midtarsal joint area. The medial plantar artery and nerve are seen in the abductor hiatus (small arrow). [KEY: Cbd = cuboid; abH = abductor hallucis muscle; Qp = quadratus plantae muscle; FDB = flexor digitorum brevis muscle; MK = master knot of Henry]

longus tendon sheath, 2 cases of post-traumatic fibrosis (1 with an associated neuroma), and 1 case of extensive tenosynovitis involving all three tendons within the tarsal tunnel. Except for the case of tenosynovitis, which responded to conservative treatment, all the cases were confirmed surgically. These researchers concluded that MR imaging may be used to "identify those patients with a definite space-occupying lesion" and may help "before surgery by providing a diagnosis and an operative map."

In 1991, Kerr and Frey[2] reported a larger study involving 33 feet in 27 patients with tarsal tunnel syndrome. MR imaging demonstrated a mass in 5 feet (2 hemangiomas, 1 ganglion, 1 neurilemoma, and 1 neurofibrosarcoma), dilated veins or varicosities in 8 feet, fracture or soft tissue injury in 5 feet, post-traumatic fibrosis in 2 feet, flexor hallucis longus tenosynovitis in 6 feet, and abductor hallucis muscle hypertrophy in 1 foot. In 6 feet, MR imaging was determined to be normal. The presence and extent of the pathology as shown by MR imaging was confirmed in 17 of 19 patients that went to surgery. The missed lesions were a small ganglion and venous varicosities. The investigators summarized their study by stating they "found MR imaging useful for localizing a variety of compressive and traction-producing lesions and to determine the extent and relationship to the posterior tibial nerve and its branches. The information provided by MR imaging enhances surgical planning by indicating the extent of decompression required."

It is the author's current recommendation that an MR imaging study of the tarsal tunnel include both T1-weighted (TR 600/TE 20) and T2-weighted (TR 2,000/TE 80) transverse (axial) and sagittal (longitudinal) plane images of the lower leg and rearfoot. Ideally, the images should be obtained in 3-mm or less slice thicknesses with no interspace gap. This protocol will maximize contrast, resolution, and sensitivity of the study. The T1-weighted image provides the greatest anatomic detail while the T2-weighted image aids primarily in the identification and/or characterization of soft tissue masses, inflammation, and fluid accumulations.

Lesions which are primarily fibrous in origin (e.g., posttraumatic fibrosis, neurofibromas) will generally demonstrate low signal intensity on both T1-weighted and T2-weighted images. Conversely, fluid containing lesions (e.g., ganglions, hemangiomas, neurilemomas, varicosities, tenosynovitis) will typically demonstrate low or intermediate signal intensity on T1-weighted images and comparatively high signal intensity on T2-weighted images (Fig. 4A, 4B).

Perhaps one of the greatest values of MRI in evaluating suspected tarsal tunnel syndrome is its potential to document varicosities or dilated veins within the tarsal tunnel. Venous insufficiency is often a contributing factor to tarsal tunnel syndrome and tarsal tunnel decompression surgery often includes ligation of enlarged, tortuous veins.

In his review of the literature, Cimino[10] tabulated varicosities as causing tarsal tunnel syndrome in 16 of the 122 cases (13%) with reported etiologies. In their study of 87 cases, Grumbine et al.[11] listed 7 cases (8%) as being directly caused by venous insufficiency. However, cases with anatomical abnormalities, tumors, or multiple pathologies were excluded from their study. Many of these may have included venous insufficiency. Demonstrating the potential value and sensitivity of MR imaging, Kerr and Frey[2] found dilated veins or varicosities to be the most common MRI finding - 8 of 27 positive findings (30%) - in their study. Although not previously reported,

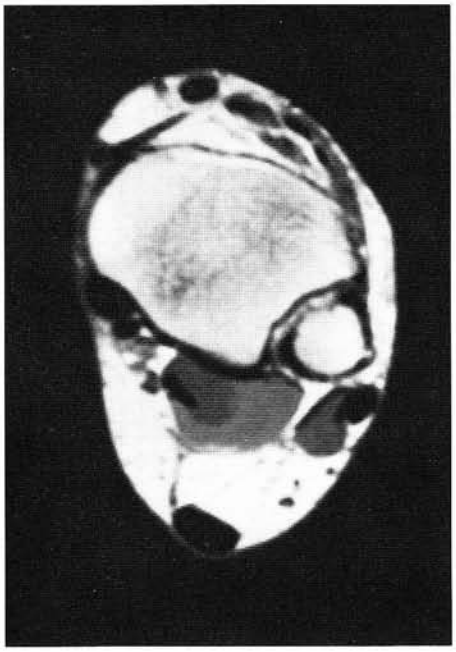

Fig. 4A. Ganglion of the flexor hallucis longus tendon sheath. Transverse (axial) sections performed in the lower leg (i.e., just proximal to the ankle joint). T1-weighted image.

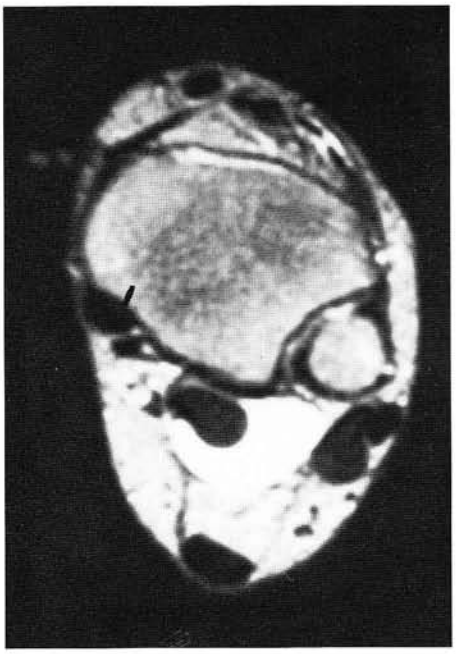

Fig. 4B. T2-weighted image. Note the ganglion demonstrates comparatively low signal intensity (dark gray) on the T1-weighted image and high signal intensity (white) on the T2-weighted image. The neurovascular bundle is located just medial to the FHL tendon.

if varicose veins are suspected as the etiology of a tarsal tunnel syndrome, MR imaging may also be performed with compression of the superficial venous system. Prior to the imaging study, a pneumatic tourniquet may be applied around the mid-calf area and inflated to a pressure which occludes the superficial venous system without impeding either the arterial system or deep venous system (i.e., a pressure of 30 to 50 mmHg). In this manner, compression of the superficial venous system (i.e, the great and small saphenous veins and their tributaries) will cause engorgement of any incompetent veins within the deep venous system including the posterior tibial veins. The MR imaging study performed with the superficial venous system occluded will be even more sensitive to deep venous insufficiency (Fig. 5A-D).

Some caution must be given regarding MRI interpretation. Although MR imaging is considered to be very sensitive, it is NOT always very specific. The ability to differentiate between different pathologic processes (e.g., between a ganglion and tenosynovitis) is not always possible. Additionally, MR imaging of the tarsal tunnel necessitates a clinician and/or radiologist familiar with the anatomy of the lower extremity and the tarsal tunnel (i.e., the best MR imaging study is always subject to possible interpretation error). As the aforementioned researchers concluded, MR imaging is optimally suited for identifying lesions within the tarsal tunnel and determining the relationship of the lesion to the posterior tibial nerve and its branches.[1,2]

CONCLUSIONS/SUMMARY

Despite the correlative value of MR imaging of the tarsal tunnel, it remains only a supportive test for tarsal tunnel syndrome. The diagnosis of tarsal tunnel syndrome continues to be primarily founded on a sound historical interview and thorough physical evaluation including a good neurological examination. Like electromyography and nerve conduction velocities, MR imaging may be helpful in supporting or confirming the diagnosis. A clinical diagnosis of tarsal tunnel syndrome should not be reversed based solely on negative MRI findings, as it should not be excluded based solely on normal electro-diagnostic findings.

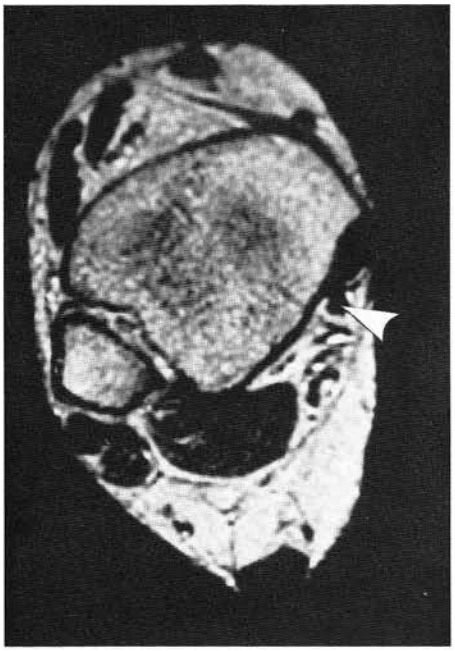

Fig. 5A.

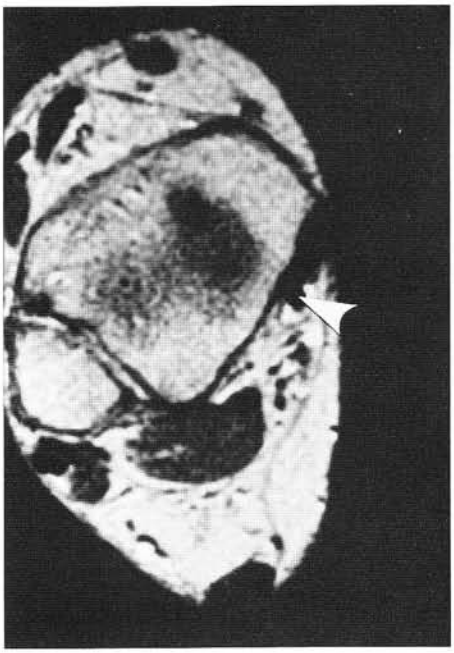

Fig. 5B.

Patient with suspected tarsal tunnel syndrome secondary to venous insufficiency (i.e., varicosities). T2-weighted transverse (axial) sections performed just proximal (A-B) and distal (C-D) to the ankle joint. Images A and C are prior to tourniquet occlusion. The posterior tibial artery is noted as a low intensity (black) structure due to signal void. The posterior tibial venae comitantes are noted as high intensity structures due to flow enhancement. However, the venae comitantes are barely visible on these views. Images B and D are performed while the superficial venous system is occluded with a mid-calf tourniquet inflated to 50mm Hg. Note the veins are much more noticeable on either side of the artery. This strongly suggests that venous pathology may be the etiology of tarsal tunnel syndrome. In this case, extensive varicosities were confirmed at the time of surgery.

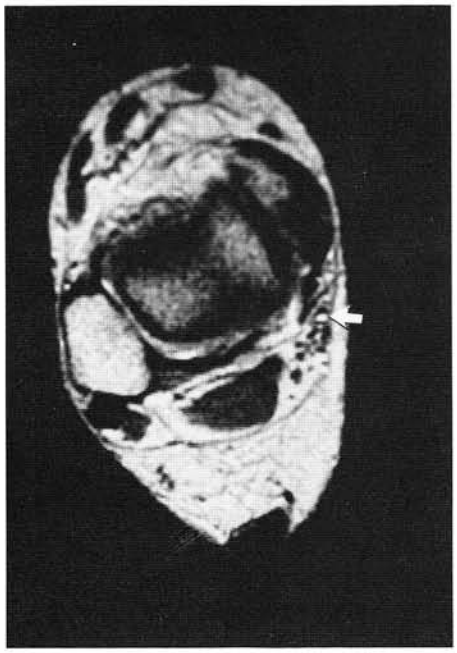

Fig. 5C.

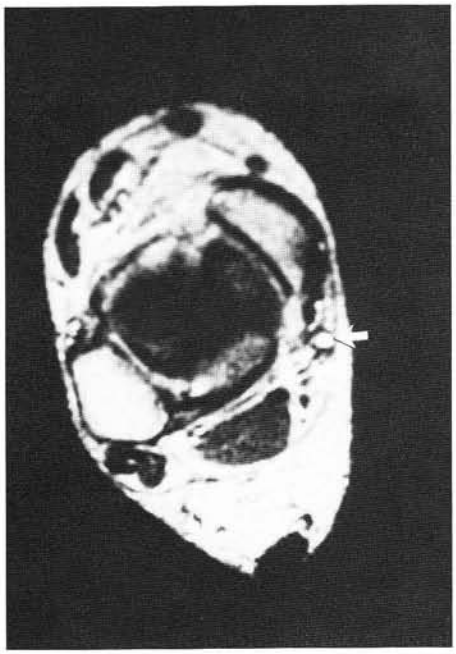

Fig. 5D.

Second, the information provided by MR imaging may be helpful if surgical decompression of the tarsal tunnel is contemplated. Both extrinsic and intrinsic lesions can be identified and their boundaries determined. Previously unsuspected lesions or causes of tarsal tunnel syndrome may be identified. Further, variable patterns of nerve branching and the relationship of the nerve to the artery and venae comitantes may be determined.

In summary, MR imaging is ideally suited to evaluation of the tarsal tunnel due to its excellent soft tissue contrast, ability to demonstrate neurovascular and musculotendinous structures, and sensitivity to soft tissue pathology. As the technology of these scanners continues to improve with better resolution, narrower anatomic sections, and even greater contrast, the resultant images created will be even more valuable in helping to confirm the diagnosis and etiology of tarsal tunnel syndrome.

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