CHAPTER **42**

MAGNETIC RESONANCE IMAGING EVALUATION OF SOFT TISSUE TUMORS

Mickey D. Stapp, DPM

INTRODUCTION

Soft tissue masses are frequently encountered in the podiatric physician's practice. Most are relatively common and the presumed diagnosis is made on the basis of the history and clinical findings. Definitive diagnosis is made only with pathologic examination. Soft tissue masses that have been present for longer periods of time with slow progression in size can be presumed to be benign. Such common masses are plantar fibromas, ganglion cysts, and intermetatarsal neuromas. These soft tissue masses are so commonly encountered that magnetic resonance imaging (MRI) would be rarely indicated. Of course, if these have an unusual presentation by history or examination, an MRI may be helpful.

Soft tissue masses that have an unclear etiology, short duration, rapid growth, or physical changes, and do not have typical findings on clinical examination should undergo an MRI examination. Plantar masses not consistent with plantar fibromas, and dorsal soft tissue masses not consistent with ganglion cysts may require MRI evaluation. Although MRI may be best suited in evaluation of soft tissue masses, it is only suggestive of potential diagnoses. A definitive diagnosis can not be made until an incisional or excisional biopsy has been performed.

OTHER IMAGING MODALITIES

Standard radiographs should be obtained in new patients presenting with reports of pain without obvious structural deformity and with obvious soft tissue masses. Standard radiographs have generally poor soft tissue visualization, but are obtained in soft tissue masses to evaluate for underlying bony changes or involvement, foreign bodies, soft tissue outlines, and any changes in density associated with the soft tissue mass.

Ultrasound can be useful in determining the location and size of soft tissue masses. They are generally non-specific but with clinical knowledge of the characteristics of soft tissue masses can be more predictive. Ultrasound has significant benefit in needle-guided biopsy, drainage, or injection of soft tissue masses.

Computed tomography (CT) imaging has poor soft tissue visualization. It is best utilized when examination of joint surfaces, cortical margins, and subtle changes within the osseous structures is desired. CT can confirm the presence of fat and calcifications within a soft tissue mass.

Proton emission tomography (PET) scanning has not been proven to characterize soft tissue masses more specifically than MRI. It is best utilized in full body scanning identifying metastasis of malignancies. Combining PET scanning with CT imaging improves the ability to identify musculoskeletal neoplasm.

MRI EVALUATION

Magnetic resonance imaging is still the study of choice for evaluation of soft tissue masses. The signal characteristics and the location of the soft tissue mass will help potentially identify the mass. Still at best, MRI offers only suggestive diagnoses. MRI can define the tumors margins and location. It is best for assisting in developing a surgical plan for excision or biopsy of a soft tissue mass. MRI is best at distinguishing between a benign versus a potentially malignant soft tissue mass. Gadolinium enhancement may also improve the ability of an MRI in differentiating a malignant lesion from other benign cystic structures.

Magnetic resonance imaging produces a number of different types of images that are used to assist in identifying abnormal anatomy. The TE and TR are manipulated to produce what is known as a T1-weighted image and a T2-weighted image. Further manipulation can produce ECHO images, STIR images, and fat suppression images. T1-weighted images are best for demonstrating normal anatomy. This normal anatomy is then used to compare with subsequent imaging techniques to help identify abnormal anatomy. In T1 images, fat, including the marrow of bone, is hyperintense or shows a high signal, appearing brighter than surrounding tissues. Fluid appears hypointense or shows a low signal on T1 images, appearing darker than surrounding tissues (Figure 1).

Figure 1. T1-weighted image demonstrating normal foot and ankle anatomy.

Figure 2. T2-weighted image demonstrating normal foot and ankle anatomy.

On T2-weighted images, fat now appears hypointense and fluid appears hyperintense. Therefore the fat, including the marrow of bone, becomes dark much like the surrounding cortical bone. In the T1-weighted image, the cortical bone, due to its relatively low percentage of water, appears hypointense. Fluid, such as in cystic structures, edema, abscesses, and that associated with inflammation will appear hyperintense, or brighter than surrounding tissues on T2-weighted imaging (Figure 2). Fat suppression or STIR images will suppress fat, making it much more hypointense, and accentuates fluid. This is generally utilized in fatty tumors or soft tissue masses within areas of fat.

NON-NEOPLASTIC SOFT TISSUE LESIONS

Non-neoplastic soft tissue lesions are not tumors but lesions thought to arise from some traumatic or inflammatory origin or are proliferations of synovial tissue. Traumatic or inflammatory originated lesions include ganglions, bursas, intermetatarsal neuromas, rheumatoid nodules, epidermoid cysts, and foreign body granulomas. Synovial proliferative lesions include pigmented villonodular synovitis (PVNS) and giant cell tumors.

Ganglion cysts are the most common soft tissue mass. They represent a mucoid cystic degeneration of soft tissue near or communicating with a joint or tendon sheath. They are believed to be a result of repetitive trauma. Most ganglion cyst appear on the dorsum of the foot and ankle and occasionally on the medial or lateral borders of the foot or ankle. Rarely do the cystic structures appear on the plantar surface of the foot. On MRI evaluation, ganglion cysts are well defined but may be lobulated or septated. They will appear hypointense on T1-weighted images and hyperintense on T2-weighted images (Figure 3).

Bursas typically occur at pressure points on the plantar surface of the foot, and are often associated with hyperkeratotic skin lesions in the same location. On MRI evaluation, bursas appear as a well-defined fluid collection. Due to the fluid collection, bursas appear hypointense on T1-weighted imaging and hyperintense on T2-weighted imaging.

Intermetatarsal neuromas are typically found in the third intermetatarsal space between the third and fourth metatarsal heads. Perineural fibrosis and nerve degeneration are seen pathologically. With MRI imaging, neuromas show an intermediate signal relative to surrounding muscle on T1-weighted image, but are hyperintense relative to fat on the T2 image. Intermetatarsal neuromas show intense enhancement with gadolinium (Figure 4).

Rheumatoid nodules occur in the subcutaneous tissues in 20% of patients with rheumatoid arthritis. They may also be seen in rheumatic fever, systemic lupus erythematosus, and other seronegative arthropathies. These lesions typically occur at sites of repeated minor trauma and are most often seen clinically beneath the metatarsal head region secondary to the often-associated forefoot derangement of rheumatoid. They are solid masses and appear isointense on T1-weighted imaging. With gadolinium contrast, there may be peripheral enhancement secondary to inflammatory changes associated with the lesion.

Epidermoid cysts are epithelial lined cyst filled with keratin. They are well defined and circumferential on MRI. They appear isointense to slightly hyperintense on T1-weighted images and hyperintense on T2. The more

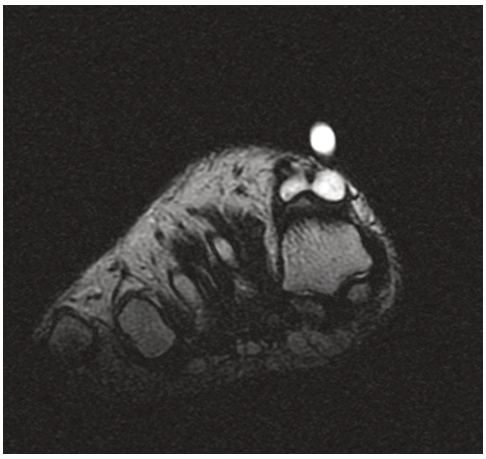

Figure 3. STIR image of a ganglion cyst arising from the extensor hallucis longus tendon.

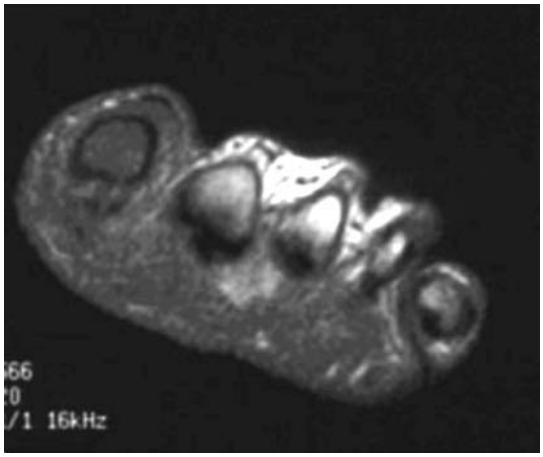

Figure 4. Gadolinium enhanced fat suppression T2-weighted image demonstrating a second intermetatarsal neuroma.

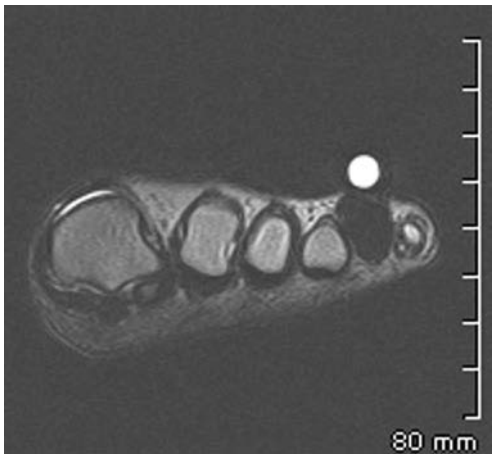

Figure 5. T2-weighted image demonstrating the hypointensity of a foreign body granuloma between the fourth and fifth metatarsal heads.

Figure 6. T2-weighted image demonstrating the hyperintensity of a foreign body granuloma deep to the first intermetatarsal space. Note the sinus tract extending dorsally and the well-demarcated hypointense area at the base of the sinus tract representing the foreign body.

dense the cyst or the more calcifications present, the more likely scattered foci of hypointensity will be noted. These cysts are only mildly enhanced with gadolinium.

Foreign body granulomas can appear very nonspecific on MRI. They are typically heterogeneous in composition. On T1-weighted imaging, foreign body granulomas appear hypointense. They may be hypointense to hyperintense on T2-weighted imaging depending on the amount of scarring and fibrosis within the granuloma (Figure 5). A distinct low signal area within a surrounding hyperintense area on the T2-weighted image may represent the foreign body (Figure 6).

Pigmented villonodular synovitis is a synovial proliferation with hemosiderin deposits. These typically occur in synovial linings of joints or tendon sheaths. In approximately 50% of cases, bony erosions will be evident. Due to the hemosiderin deposits, PVNS appear similarly hypointense on both T1 and T2 images. With inflammatory changes, hyperintense areas may surround or be present within the mass. These soft tissue masses enhance greatly with gadolinium (Figure 7).

Giant cell tumors are another synovial proliferative disorder. They represent an extra-articular form of PVNS. They also are hypointense on T1 and may be hypointense to hyperintense on T2 images. Because they have minimal fluid content, they are only minimally hyperintense on T2 imaging. Accentuation of low signal areas on the T2 image is again due to hemosiderin deposits. They also enhance with gadolinium (Figure 8).

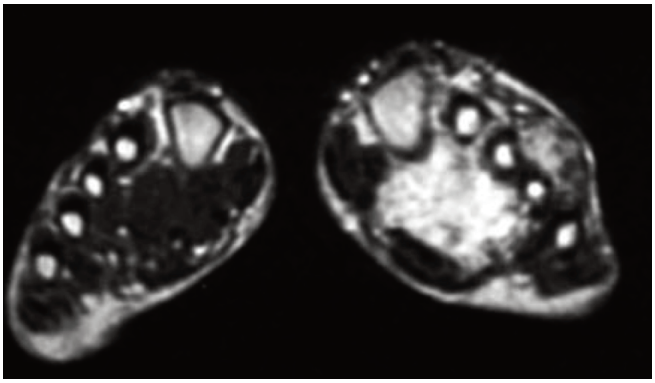

Figure 7. T2-weighted image of both feet demonstrating the hyperintensity of a pigmented villonodular synovitis in the plantar muscular of the arch.

Figure 8. T2-weighted image of a giant cell tumor arising from the flexor hallucis longus tendon.

BENIGN SOFT TISSUE TUMORS

Benign soft tissue tumors of the foot or ankle may include lipoma, plantar fibroma, hemangioma, schwannoma, neurofibroma, glomus tumor, and dermatofibroma. Lipomas and plantar fibromas are the most common of these soft tissue tumors in the foot and ankle. Many of these may be aggressive in nature and some of these have been reported to undergo malignant transformation. Lipomas are the most common of all soft tissue tumors of the body. They are histologically composed of aggregates of mature adipocytes. The diagnostic hallmark with lipomas on MRI is the fact that they appear isointense to fat in all sequences. In T1 imaging fat and the lipoma appear hyperintense and in T2 imaging, fat and the lipoma appear hypointense. The difference is that the lipoma typically appears well capsulated and differentiated from any surrounding normal fat (Figures 9, 10).

Plantar fibromas are the most common benign soft tissue tumor of the foot. They are a localized fibroblastic proliferation with nodular thickening of the plantar fascial ligament. Due to the dense highly bound nature of these tumors, they appear hypointense on both T1 and T2 imaging. This is diagnostic when located within the plantar fascia (Figure 11).

Hemangiomas of the foot and ankle are relatively rare but represent the most common benign soft tissue tumor of vascular origin. They represent an overgrowth of vascular channels often with skeletal muscle. On MRI, they appear as a lobulated irregular mass with serpentine channels, fat, and phleboliths. Hemangiomas appear hypointense to moderately intense on T1-weighted images and hyperintense on T2-weighted images. There may be areas of hypointensity on T2 images secondary to the phleboliths (Figure 12).

Schwannomas are benign tumors arising from Schwann cell of peripheral nerve sheaths. They are well defined and well encapsulated, and positioned eccentrically on a nerve. They demonstrate an intermediate intensity on T1 imaging, and hyperintensity on T2 imaging.

Neurofibromas are also benign tumors arising from a peripheral nerve. They are not well encapsulated like Schwannomas, and may appear cystic and infiltrative. Neurofibromas will appear as a fusiform enlargement of peripheral nerve with hypointensity on T1-weighted imaging and intermediate to hyperintensity on T2-weighted imaging.

Glomus tumors are benign tumors of the neuromyoarterial glomus body. They tend to be well defined on MRI. They are hypointense on T1 imaging, hyperintense on T2 imaging, and strongly enhance with gadolinium.

Dermatofibromas are benign lesions within the dermis. The same lesion is called a cutaneous fibrous histiocytoma if in the superficial subcutaneous layer. Due to its dense nature, dermatofibromas show a low to intermediate signal intensity on both T1 and T2 images (Figures 13, 14).

Figure 9. T1-weighted image of a lipoma in the plantar aspect of the foot showing the isointensity of the mass to surrounding fat.

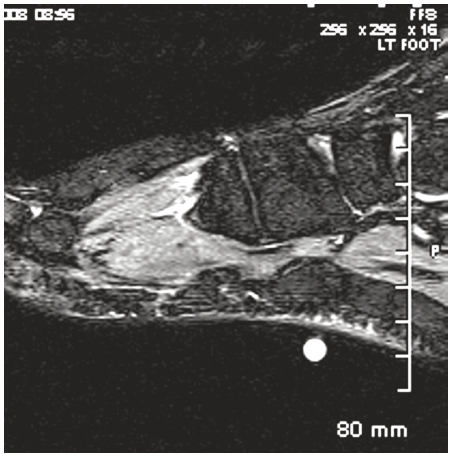

Figure 10. T2-weighted image of the same lipoma shown in Figure 9, demonstrating the isointensity of the mass to the surrounding fat.

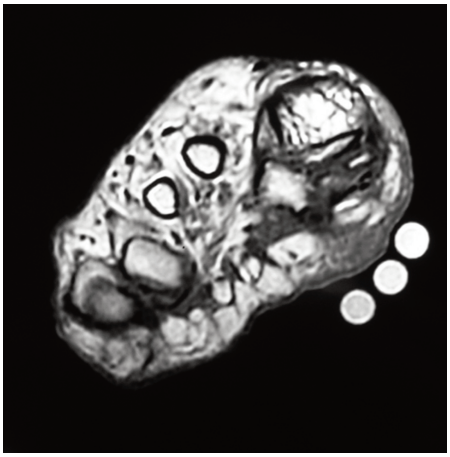

Figure 11. T1-weighted image of a plantar fibroma.

Figure 12. T2-weighted image of an intramuscular hemangioma.

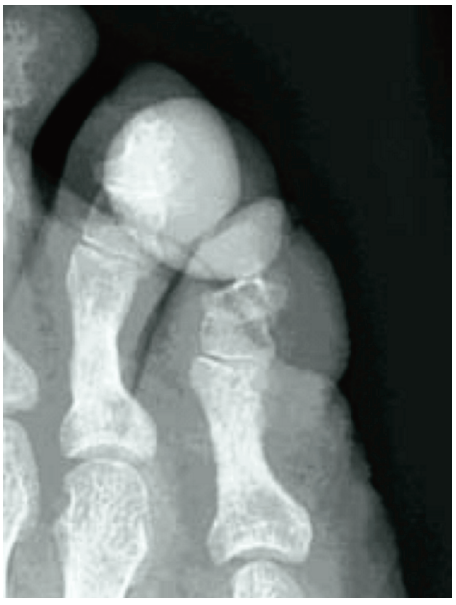

Figure 13. Radiograph demonstrating a well circumscribed calcific mass of the fourth toe.

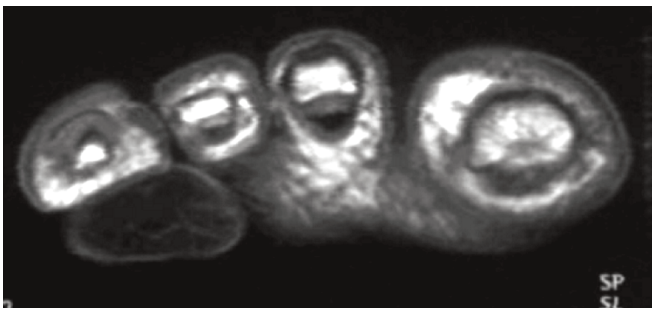

Figure 14. T1-weighted image of the same dermatofibroma shown in Figure 13 demonstrating an intermediate signal intensity.

MALIGNANT SOFT TISSUE LESIONS

Malignant soft tissue tumors are very rare to the foot and ankle. These tumors can be primary, arising within the foot or ankle, or secondary, arising from another area of the body and metastasizing to the lower extremity. Metatastic malignant melanoma is one such secondary neoplasm. Malignant melanoma is a neoplasm arising from melanocytes of the skin. Due to the melanin content, malignant melanomas show reversed findings as most other soft tissue neoplasms. Typically, soft tissue lesions are hypointense on T1 imaging and hyperintense on T2 imaging. Metastatic malignant melanomas show hyperintensity on T1 imaging and hypointensity on T2 imaging (Figures 15, 16).

Synovial cell sarcomas typically occur in patients younger than 45 years of age. They may appear as a heterogeneous mass with possible fluid levels and lobulated margins. Fibrous histiocytomas are a slow growing, low-grade neoplasm. They show an ill-defined mass in deep dermis and subcutaneous tissues with intermediate signals on both T1 and T2 images.

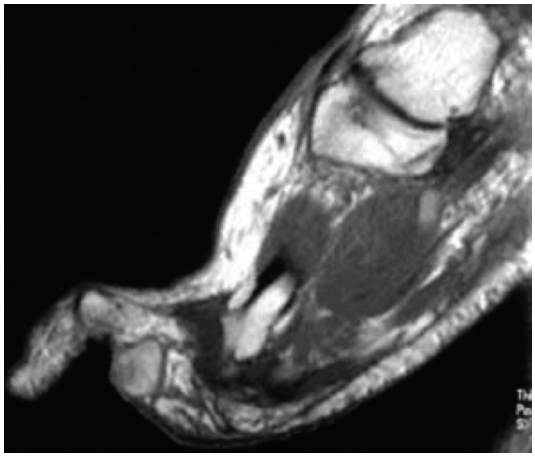

Figure 15. T1-weighted image demonstrating the hyperintensity of a metastatic malignant melanoma in the plantar tissues of the second intermetatarsal space.

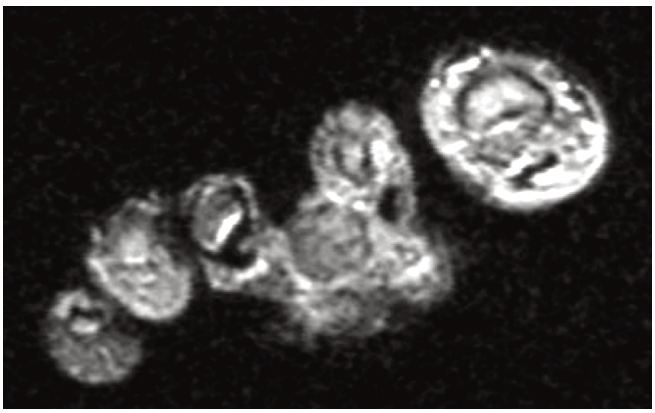

Figure 16. T2-weighted image of same lesion shown in Figure 15 demonstrating the hypointensity of the lesion.

Figure 17. Radiograph demonstrating a well circumscribed calcific mass in the plantar fat pad of the calcaneus.

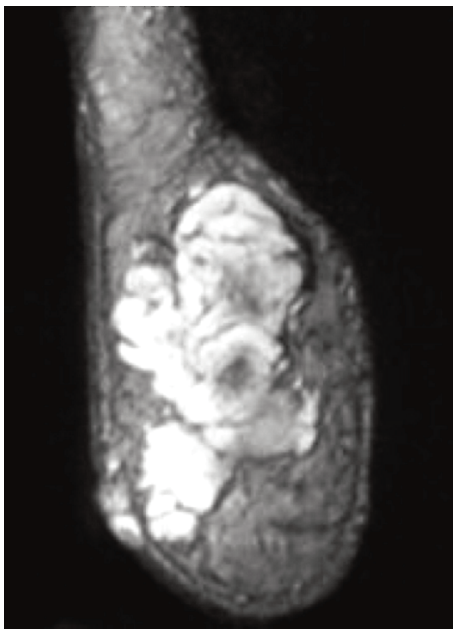

Figure 18. T2-weighted image of same mass shown in Figure 17 demonstrating the hyperintensity and extensive nature of a myxoid chondrosarcoma.

Myoid chondrosarcomas are low-grade soft tissue sarcomas. They appear isointense to muscle on T1 images and hyperintense on T2 images. They may show central areas of hypointensity due to calcifications. They will enhance markedly with gadolimium (Figures 17, 18).

CONCLUSION

Fortunately, soft tissue malignancies are very rare in the foot and ankle. For soft tissue masses that do not appear typical in clinical history or examination, MRI offers the most diagnostic assistance in determining the possible differential diagnoses and aiding in planning surgical approach to the soft tissue mass. For common soft tissue masses such as neuromas and plantar fibromas, MRI is often not necessary. If the mass is of short duration and/or shows rapid growth, then an MRI should be performed. Musculoskeletal radiologist should be consulted for review of the MRI whenever possible, and the diagnosis must be confirmed through pathologic review.

BIBLIOGRAPHY

Ashman CF, Klecker RF, Yu JS. Forefoot pain involving the metatarsal region: differential diagnosis with MR imaging. RadioGraphics 2001;21:1425-40.

Bancroft LW, Peterson JJ, Kransdorf MJ. Imaging of soft tissue lesions of the foot and ankle. Rad Clin N Am 2008;46:1093-103.

Jordan T, Bowman W, Ballinger C, Green D. Malignant Soft Tissue Lesions of the Foot and Ankle. In: Reconstructive Surgery of the Foot and Leg: Update 2006, Tucker (GA): The Podiatry Institute; 2006.

Levey DS, Park YH, Sartoris DJ. Imaging of pedal soft tissue neoplasms. J Foot Ankle Surg 1995;34:411-9.

Llauger J, Palmer J, Monill JM, et al. MR imaging of benign soft-tissue masses of the foot and ankle. RadioGraphics 1998;18:1481-98.

Pham H, Fessell DP, Femino JE, et al. Sonography and MR imaging of selected benign masses in the ankle and foot. Am J Rad 2003;180:99-107.

Roberts CC, Morrison WB, Liu PT. Imaging evaluation of foot and ankle pathology: self-asseessment module. Am J Rad 2008;90:S18-22.

Waldt S, Rechl H, Rummeny EJ, Woertler K. Imaging of benign and malignant soft tissue masses of the foot. Eur Radiol 2003;13:1125-36.