Magnetic Resonance Imaging Evaluation of Musculoskeletal Diseases of Ankle and Foot

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ABSTRACT

Background

Ankle and foot pain is a common clinical problem, that may be due to a variety of soft tissue and osseus abnormalities. Magnetic resonance imaging plays vital role for diagnosing internal derangement of the ankle joint, assessing soft tissue structures around the ankle such as tendons, ligaments, nerves and osseus structures.

Method

Retrospective magnetic resonance imaging evaluation of the ankle and foot was done in 100 patients using 0.3T and 1.5T magnetic resonance imaging. Clinical history included pain, swelling of the ankle and foot, trauma, twisting injury, palpable mass and difficulty in walking.

Result

Fifty two patients were male and 48 patients female aged 6 months to 70 years. Ligaments tear were the commonest and seen in 22% patients. Tenosynovitis found in 17%, Pigmented villonodular synovitis (PVNS) in 3%, Achilles tendon abnormality in 8%, stress fracture-9%, osteomyelitis-8%, soft tissue vascular malformation in 5%, soft tissue and bone tumor-4%, marrow edema-20%, osteoarthritis-10%, Osteochondral lesion of talus-8%, sinus tarsi syndrome-3%, posterior impingement-5%, plantar fasciitis-2%, Sever disease-2%, peroneus tendon split-2%. The commonest clinical presentation was pain and swelling of the ankle in 42 patients, twisting/inversion injury of the ankle in 23 patients followed by traumatic injury with difficulty in walking in 20 patients and palpable mass in 8 patients. Ligaments injury were mostly associated with inversion/twisting injury.

Conclusion

Magnetic resonance imaging is advantageous for assessing soft tissue structures around the ankle and foot, such as tendons, ligaments, nerves, masses and occult osseus lesions. It provides a quick, non-invasive tool for the diagnosis of related injuries and guide for the further treatment planning.

KEY WORDS

Ankle, Foot, Magnetic resonance imaging, Musculoskeletal

INTRODUCTION

Ankle and foot pain is a common clinical problem,that may be due to a variety of soft tissue and osseous abnormalities. Standard first line investigations include assessment of osseous structures with plain radiograph and common soft tissue problems with high frequency ultrasonography. However due to inherent limitation of assessment of deeper soft tissue and subtle soft tissue and osseous abnormalities with these imaging modalities, MR imaging is gold standard problem solving non-invasive imaging tool. MR imaging is particularly advantageous for assessing soft-tissue structures around the ankle such as tendons, ligaments, nerves, and fascia and for detecting occult bone injuries. It provides a quick, noninvasive tool for the diagnosis of related injuries, which are often difficult to diagnose with alternative modalities.

METHODS

Retrospective evaluation of the ankle and foot MRI performed in 100 patientsusing 0.3T and 1.5T MRI in the radiology department of a tertiary care center. Clinical history included pain and swelling of the ankle, heel and foot, trauma, twisting/inversion injury, palpable mass, difficulty in walking with restriction of the joint movement etc. X-ray of the ankle and foot was available in most of the patients prior to MRI. Patients who had undergone any prior surgery of the ankle and foot were excluded from the study.

Standard imaging protocol included T1, T2 and STIR images of the ankle in all three orthogonal planes (axial, coronal and sagittal), and oblique axial, coronal and sagittal images of the foot. Post gadolinium T1 weighted images were obtained in patients with soft tissue mass. Additional fat suppressed proton density (PD) was obtained in examination performed with 1.5 T MRI. All patients with soft tissue and bone tumors underwent excisional biopsy.

RESULTS

Out of all study cohort (n=100), 52 were male and 48 female with age range from 6 months to 70 years. Clinical history included acute injury, twisting and inversion of the ankle, pain and swelling, and difficulty in walking etc. The commonest clinical presentation was pain and swelling of the ankle in 42 patients, twisting/inversion injury of the ankle in 23 patients followed by traumatic injury with difficulty in walking in 20 patients and palpable mass in 8 patients. Ligaments injury were mostly associated with inversion/twisting injury.

Ligaments tear

Ligament tear was the most common cause of ankle pain with varied history like twisting or inversion injury, minor trauma, sports injury and stress factor. There were 22 (22%) patients with ligaments tear (table 1). Complete and partial tear of the anterior talofibular ligament was commonly seen. Eight patients had tear of more than one ligament. Disruption or non-visualization of the ligament was seen in complete tear, where as the ligament was thickened, attenuated and elongated in partial tear.

Table 1. Ligament Tear

Ligaments	No. of patients
Anterior talofibular	16
Calcaneofibular	4
Cervical	4
Posterior talofibular	3
Anterior tibiofibular	3
Deltoid	2
Spring	1

Table 2. Tenosynovitis

Tendons	No. of patients
Posterior tibial	9
Flexor digitorum longus	8
Flexor hallucislongus	7
Peroneus longus and brevis	4

Tenosynovitis

In 17 (17%) patients, tenosynovitis of the different tendons was found (table 2), whereas synovitis of the ankle joint was seen in 10 (10%) patients. Tubercular synovitis of the ankle was diagnosed in one.

Tenosynovitis of the posterior tibial tendon was the most common and seen in 9 patients, followed by flexor digitorum longus and flexor hallucis longus tendons. The tendon sheaths were distended by fluid in all the cases showing low signal intensity on T1 WI and hyperintensity on T2 WI and STIR sequences.

Pigmented villonodular synovitis

Pigmented villonodular synovitis was the cause for ankle pain in three patients, in which two had diffuse form and one had focal nodular. There was associated intraosseus cyst in the patients with diffuse PVNS with marked swelling of the joint. MRI showed heterogeneous intermediate signal intensity of the lesion on T1 weighted sequences, low-to high signal intensity on T2 Weighted sequences. Associated erosion of the adjacent bones was seen in the patient with diffuse form.

Achille's tendon injury

Eight patients (8%) had Achille's tendon ailments. Five patients had Achille's tendon tear, out of which three had complete rupture and two had partial tear of the tendon. Complete tear of the tendon showed high signal fluid filled tendinous gap on fluid sensitive MR sequences. Partial tear showed intrasubstance high signal intensity with incomplete interruption of the tendon fibers.Achilles

tendinitis as evident by thickened low signal intensity tendon was demonstrated in three patients. Two patients were sportsmen and one had rheumatoid arthritis.

Retrocalcaneal bursitis

Retrocalcaneal bursitis was found in three patients with heel pain. A fluid collection between the posterior calcaneus and the insertion of the Achilles tendon was seen, which showed low signal intensity on T1 weighted sequences and high signal intensity on T2 weighted and STIR sequences.

Stress fracture

Stress fracture was found in 9 (9%) patients. (table 3). Linear hypointensity and diffuse or localized low marrow signal intensity on T1 weighted images, hyperintensity on T2 and STIR sequences were seen. Associated collection or hemorrhage in the surrounding soft tissue in some of the cases.

Table 3. Stress fracture

Bones	No. of patients
Metatarsals	4
Tibia	3
Calcaneus	1
Phalanx	1

Fracture of the bones at the ankle and foot causing ankle and heel pain was found in 9 patients. The commonest bone to be fractured was talus in 4 patients, followed by calcaneus in two. Salter Harris fracture of the tibia was present in one.

Osteomyelitis

Eight (8%) patients had osteomyelitis of different bones with soft tissue swelling causing ankle and heel pain. In addition two patients had septic arthritis. (table 4). Calcaneus osteomyelitis was the commonest and seen in 4 patients. Marrow edema was seen in these cases in the involved bones showing low signal intensity on T1 WI and hyperintensity on fat suppressed images. Intraosseous abscess was present in two patients and there were osseous destruction and associated abscess. In one case there was sinus tract along the site of penetrating injury.

Table 4. Osteomyelitis

Bones	No. of patients
Calcaneus	3
Calcaneus & talus	1
Talus	1
Cuboid & 4th Metatarsal	1
Phalanx	1
Multiple tarsals	1

Soft tissue mass and vascular malformation

Soft tissue vascular malformations of the foot were detected in five (5%) patients. MRI showed ill defined mass of heterogeneous signal intensity on T1 WI and high signal intensity on T2 WI and STIR with few flow voids compatible with feeding vessels.

Soft tissue and bone tumor localized to ankle and pain were detected in 4 (4%) patients. Sarcoma with diffuse mass at the ankle and foot was seen in one patient. Simple bone cyst of the calcaneus, 4 thmetatarsal were seen in two cases, whereas one had Giant Cell Tumour (GCT) of the calcaneus.

Marrow edema

Marrow edema was seen in 20(20%) patients. The affected bones showed low marrow signal on T1 weighted images, high signal intensity on T2WI and STIR. Marrow edema of the talus was commonly seen, in 14 patients. Marrow edema of the talus, tibia and metatarsals are associated with ligaments injury in 8 patients. In 10 patients of osteoarthritis, marrow edema was found in 6 cases.

Osteoarthritis

Degenerative osteoarthritis was seen in 10 (10%) patients causing ankle and foot pain. There were chondral loss, osteophytes formation and associated subchondral marrow edema.

Osteochondral lesion of talus

Osteochondral lesion of the talus occurred in 8 (%) patients. The medial dome was commonly affected and seen in 6 patients.

Sinus tarsi syndrome

Sinus tarsi edema was seen in 3 (3%) patients. Two patients had tear of the cervical ligament and one had strain. The sinus tarsi showed low signal with obliteration of sinus tarsi fat on T1 WI and marrow oedemacentred around the sinus tarsi on STIR.

Posterior impingement

Posterior impingement due to ostrigonum was seen in 5 (5%) patients. Marrow oedema in the lateral talar tubercle, ostrigonum was demonstrated showing low signal on T1 and high signal on STIR. Posteriorly, there were inflammatory soft tissue changes with capsular thickening and fluid in the posterior synovial recess.

Plantar fasciitis

In two patients (2%), plantar fasciitis was the cause for heel pain. The cause of plantar fasciitis was non-specific. Calcaneal spur was not seen in X-ray in both patients. There was thickening of central band of plantar fascia by more than 4 mm with adjacent soft tissue inflammatory changes.

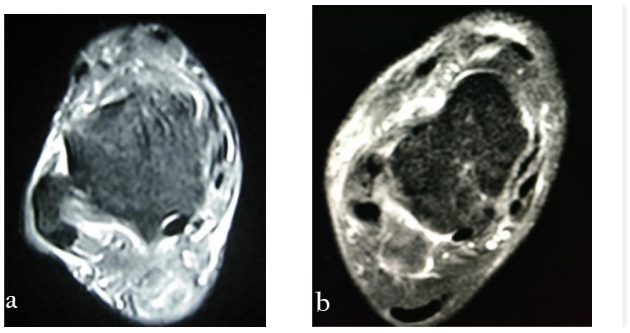

Figure 1a. STIR axial image shows complete tear of anterior talofibular ligament with joint effusion, b. Partial tear of the anterior talofibular ligament

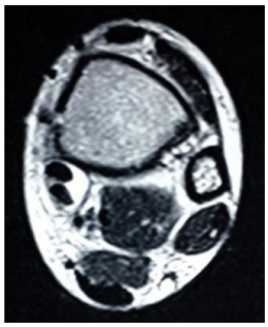

Figure 2. T2 axial image- acute tenosynovitis of the flexor digitorum longus and posterior tibial tendon.

Figure 3. T1 sagittal image of a 14 year boy- Osteochondral lesion of talus

Figure 4. T2 sagittal image shows complete rupture of Achille's tendon with wide gap.

Figure 5. Large irregular soft tissue mass at the ankle and foot causing pressure erosions of adjacent bones in a patient of PVNS.

Figure 6. Severe disease (calcaneal apophysitis). STIR sagittal image shows hyperintensity of calcaneal apophysis.

Figure 7. T1 sagiital image shows flexor digitorum accessorius longus muscle at the medial aspect of ankle posteroinferior to flexor hallucis longus.

Figure 8. Stress fracture of calcaneus. Linear vertical fracture line in the calcaneus on T1 sagittal image.

Sever disease

Sever disease (calcaneal apophysitis) was seen in two (2%) patients. MR imaging showed edematous changes within the calcaneal apophysis, that is hypointense on T1 weighted images, high signal intensity on T2 weighted and STIR images (fig 6).

Peroneus tendon split

Peroneus tendon split was seen in two patients. There was peroneal subluxation in one case.

Joint effusion.

Reactive joint effusion was seen in the ankle in 33 (33%) patients with different ankle ailment. One patient had synovial chondromatosis showing multiple small loose bodies in joint which were hypointense on both T1 and fluid sensitive sequences.

Other lesions

Isolated adductor hallucis brevis myositis was seen in one patient. There was diffuse enlargement of the muscle showing signal abnormality in the form of low signal on T1 WI and high signal intensity on T2 WI and STIR.

Os naviculare syndrome was the cause of heel pain associated with difficult movement found in one patient. Edema of the accessory navicular bone was seen with intact posterior tibial tendon.

There was a case with accessory muscle (Flexor digitorum accessory longus muscle) causing tarsal tunnel syndrome (fig 7). One patient with pesplanus had tenosynovitis of posterior tibial tendon, flexor digitorum longus, flexor hallucis longus tendons and posterior impingement with osteoarthritis of talonavicular joint.

DISCUSSION

MR imaging has been pivotal in the study of musculoskeletal disease due to its high soft tissue contrast resolution and multiplanar capabilities. MR imaging is particularly advantageous for assessing soft tissue structures such as tendons, ligaments, nerves and fascia, and for detecting occult bone injuries.[1-3]

Lateral ankle sprains represent 16%-21% of all sports related traumatic lesions. The anterior talofibular ligament is the weakest ligament and therefore the most frequently torn.[1] This study concurs the published data with72 % (n=16) patients having ATFL tears among all patient with ligamentous injuries (n=22). The MR imaging criteria for the diagnosis of acute rupture of the lateral collateral ligament complex include morphologic and signal intensity alterations within and around the complex. Injuries of the anterior talofibular ligament are easily seen on routine axial ankle MR images (fig 1 a,b). Discontinuity, detachment, thickening, thinning or irregularity of the ligament may be encountered. Heterogeneity with increased intrasubstance signal intensity on fat suppressed or T2 weighted images is indicative of intra-substance oedema or haemorrhage.[2,4,5] Chronic tear often manifests as thickening, thinning, elongation, and wavy or irregular contour of the ligament.

The accuracy of MRI in detecting injuries of the lateral collateral ligament has not yet been clearly established. The accuracy of 3D fast imaging with steady state precision in detecting acute tears of the anterior talofibular (ATFL) and calcaneofibular (CFL) ligaments is reported to be 94.4%.[6] MR arthrography has been shown to have an accuracy of 100% and 82% in detecting chronic talofibular and calcaneofibular ligament tears, respectively, whereas conventional MRI has been reported to have an accuracy of 59% in diagnosing chronic lateral ligament tears.[5] In a study by Joshy et al. MRI showed 100% specificity for the diagnosis of ATFL and CFL tears and osteochondral lesions. However sensitivity was low particularly for CFL tears. Accuracy of MRI in detecting ATFL tear was 91.7%, CFL tear was 87.5% and osteochondral lesion was 83.3%.[7] Medial joint line bone bruising following an acute ankle inversion injury was significantly associated with a complete ATFL tear, longer delay in the return to normal walking and sports activity as well as persistent medial joint line pain. Its presence should prompt detailed assessment of the lateral collateral ligament complex, particularly the ATFL.[8]

Tenosynovitis is characterized by a considerable amount of synovial fluid causing distention of the tendinous sheath (fig 2). This condition demonstrates decreased signal intensity on T1-weighted MR images and increased signal intensity on T2-weighted images surrounding the low-signal-intensity tendon. Tendinitis is characterized by variable tendinous thickening with increased signal intensity on T1-weighted or proton-density–weighted MR images. Tendinous signal intensity is normal or only slightly increased on T2-weighted images. In this study, 17 patients with similar imaging characteristics were seen with involvement of posterior tibial in 9, flexor digitorumlongus in 8 and flexor hallucis longus in 7 patients.

The MR imaging characteristics of sinus tarsi syndrome include the obliteration of fat in the sinus tarsi space. The space itself is replaced by either fluid or scar tissue, and the ligaments may be disrupted.[9,10] We had three cases of sinus tarsi syndrome associated with cervical ligament injury showing edematous changes in STIR and T1 weighted images.

Preoperative MR imaging is useful for distinguishing partial from complete rupture of the Achille's tendon and assessing the site and extent of the tear. Clinical misdiagnosis has been reported in up to 25% of patients with complete tears of the Achilles tendon due to swelling that obscures the tendon gap and retained weak plantar flexion (false-negative Thompson test). At MR imaging, partial Achilles tendon tears demonstrate heterogeneous signal intensity and thickening of the tendon without complete interruption.[1] There was complete disruption of the ligament with gap in three cases (fig 4). Partial tear in two patients demonstrated thickening of the tendon with small intrasubstance linear signal abnormality with preserved continuity.

In tendinosis MR imaging findings include increased signal intensity and thickening at the insertion site of the Achilles tendon, intrasubstance calcifications, Haglund deformity, calcaneal marrow edema, and distended retrocalcaneal and Achilles bursitis.There were three patients with imaging characteristics of tendinosis in this study but without associated aforementioned abnormality.

Chronic ankle instability associated with superior peroneal retinacular laxity is considered a predisposing factor for chronic peroneal tendon dislocation. MR imaging allows direct assessment of the position of the tendons relative to the fibular retromalleolar groove. Dislocation is best demonstrated on axial images, which show the tendons to be located anterior and lateral to the distal fibula.[11,12] There were two cases of peroneal split in which, one had associated tendon dislocation.The positive predictive value of MRI for peroneal tendon tears with positive clinical findings was 48% (95% confidence interval = 35% to 61%).[13]

Stress fractures and insufficiency fractures occur frequently in the ankle and foot and predominantly involve the second metatarsal, the calcaneus, and less frequently, the navicular bone and talus.[14-16] MR imaging shows poorly defined, abnormal signal intensity of the bone marrow similar to that of a bone contusion with an ill-defined area of hypointensity on T1-weighted images and hyperintensity on T2-weighted images and fat-suppressed images. As the stress persists and a fracture develops, MR imaging will show an irregular, hypointense line within the area of edema and hyperemia.[16,17] Similar imaging characteristic of stress fracture were found in this study. The metatarsals were the frequent sites followed by distal tibial stress fractures as the cause of the ankle and foot pain. Ill defined marrow edema features were seen in most of the cases stress injury on T1 and fat suppressed sequences, where as in the calcaneum and distal tibia there was typical linear hypointensity. Stress fractures generally involve the

posterosuperior or posterior calcaneus and have a vertical orientation (fig 8). Patients typically complain of diffuse heel pain and tenderness over the medial and lateral aspects of the heel.[18,19]

Osteochondral fractures of the ankle are usually seen in the talar dome, most frequently in the middle third of the lateral border and in the posterior third of the medial border (fig 3). Inversion injuries with dorsiflexion of the foot lead to an osteochondral lesion of the lateral aspect of the talardome, often associated with a lateral collateral ligament tear. An inversion injury to the ankle with the foot in plantar flexion and lateral rotation of the tibia on the talus lead to a posteromedial talar dome lesion.[20,21] In this study, there were six patients with medial third of the talar dome involvement in eight patients of osteochondral lesions. The MRI grading of osteochondral lesions in the talus was useful and showed a fairly good correlation with arthroscopic classification in 42 ankles.[22]

In a series by Hembre et al. most of the osteochondral lesions were located medially and centrally on the talar dome (54.5%), with the second highest frequency found laterally and centrally (31.2%). With the numbers available there was no statistical difference between the sizes of the lesions based on location. No strong correlations were found between lesion location and demographic data.[23]

There were three patients diagnosed as pigmented villonodular synovitis, two patients had diffuse and one had focal forms. Associated pressure erosions were seen in the tarsal bones. It can be present in any joint, tendon sheath, or bursa but is most frequently seen in the knee, hip, ankle, and elbow. PVNS has characteristic MR imaging features due to the paramagnetic effect of hemosiderin, which produces focal areas of hypointensity with all pulse sequences, mixed with hypointense areas on T1-weighted images and hyperintense areas on T2-weighted images (fig. 5). The short T2 relaxation times produced by hemosiderin in the tissues are better observed with high-field-strength magnets.[24,25]

MR imaging is useful in distinguishing plantar fasciitis from other causes of heel pain and in excluding plantar fascia tears. On sagittal and coronal MR images, the normal plantar fascia appears as a thin, hypointense structure extending anteriorly from the calcaneal tuberosity. The plantar fascia has a normal thickness of 3.22 mm ± 0.53 and flares slightly at the calcaneal insertion. When inflammatory changes take place, it becomes thickened (up to 7–8 mm) and demonstrates intermediate signal intensity on T1-weighted and proton-density–weighted images and hyperintensity on T2-weighted images.[26,27] Two cases of plantar fasciitis showed thickened fascia more than 4 mm and increased signal on fat suppressed sequences in this study.

The calcaneus is a frequent location of osteomyelitis of the foot in both children and adults. In children, the disease more frequently results from hematogenous spread, whereas in adults it is commonly secondary to spread from a contiguous soft-tissue septic focus in patients with diabetes mellitus, arteriosclerosis, and skin ulcerations. Osteomyelitis of the calcaneus may also be caused by a penetrating wound. MR imaging is useful for defining the extent of osteomyelitis with associated soft-tissue infection and for differentiating soft-tissue infection without osteomyelitis.[28] Osteomyelitis manifests as ill-defined areas of decreased marrow signal intensity on T1-weighted images that increase in signal intensity on T2-weighted or STIR images.[28,29] This study also showed frequent involvement of the calcaneus in eight cases of osteomyelitis with similar imaging findings.

MR imaging can demonstrate osseous and soft-tissue edema in anterior or posterior impingement. MR imaging is the most useful imaging modality in evaluating suspected soft-tissue impingement or in excluding other ankle pathology such as an osteochondral lesion of the talus. MR imaging can reveal evidence of previous ligamentous injury and also can demonstrate thickened synovium, fibrosis, or adjacent reactive soft-tissue edema.[30] There were five patients with posterior impingement of the ankle and they had os trigonum. In one patient associated pes planus was the compounding factor for the impingement. Bone contusions of the lateral talar tubercle and os trigonum are predominant MR imaging findings of posterior ankle impingement (PAI) syndrome. MR imaging clearly depicts the osseous and soft-tissue abnormalities associated with PAI syndrome and is useful in the assessment of this condition.[31]

CONCLUSION

Plain radiographs and high frequency ultrasound are usually the first line investigation modalities in patients with ankle and foot symptoms. However,MR imaging remains as a pivotal problem solving tool in complex cases, subtle abnormalities or detailed anatomical mapping of the disease process. MRI is a non-invasive, non-operator dependent and non-radiating imaging modality which allows precise diagnosis which is crucial in further management of these patients.

REFERENCES

1. Rosenberg ZS, Beltran J, Bencardino JT. MR Imaging of the ankle and foot. *Radiographics.* 2000, 20(1): S153-S179
2. Mesgarzadeh M, Schneck CD, Tehranzadeh J, Chandnani VP, Bonakdarpour A. Magnetic resonance imaging of the ankle ligaments: emphasis on anatomy and injuries to lateral collateral ligaments. *Magn Reson Imaging Clin N Am.* 1994; 2:39-58.
3. Bencardino J, Rosenberg ZS, Delfaut E. MR imaging of sports injuries of the foot and ankle. *MagnReson Imaging Clin N Am.* 1999; 7:131-149.
4. Klein MA. MR imaging of the ankle: normal and abnormal findings in the medial collateral ligament. *AJR Am J Roentgenol.* 1994; 162:377-83.
5. Chandnani VP, Harper MT, Ficke JR, et al. Chronic ankle instability: evaluation with MR arthrography, MR imaging, and stress radiography. *Radiology.* 1994; 192:189-94.
6. Verhaven EF, Shahabpour M, Handelberg FW, Vaes PH, Opdecam PH. The accuracy of three-dimensional magnetic resonance imaging in the diagnosis of ruptures of the lateral ligaments of the ankle. *Am J Sports Med.* 1991; 19:583-7.
7. Joshy S, Abdulkadir U, Chaganti S, Sullivan B, Hariharan K. Accuracy of MRI scan in the diagnosis of ligamentous and chondral pathology in the ankle.*Foot Ankle Surg*. 2010 Jun;16(2):78-80.
8. Chan VO, Moran DE, Shine S, Eustace SJ. Medial joint line bone bruising at MRI complicating acute ankle inversion injury: what is its clinical significance? *Clin Radiol.* 2013 Oct;68(10):e519-23.
9. Klein MA, Spreitzer AM. MR imaging of the tarsal sinus and canal: normal anatomy, pathologic findings and features of the sinus tarsi syndrome. *Radiology.* 1993; 185:233-40.
10. Beltran J. Sinus tarsi syndrome. *Magn Reson Imaging Clin N Am.* 1994; 2:59-65.
11. Mota J, Rosenberg ZS. MRI of the peroneal tendons. *Top Magn Reson Imaging*. 1998; 9:273-85.
12. Schweitzer ME, Eid ME, Deely D, Wapner K, Hecht P. Using MR imaging to differentiate peroneal splits from other peroneal disorders. *AJR Am J Roentgenol.* 1997; 168:129-33.
13. Giza E, Mak W, Wong SE, Roper G, Campanelli V, Hunter JC.A clinical and radiological study of peroneal tendon pathology. *Foot Ankle Spec.* 2013 Dec;6(6):417-21.
14. Umans H, Pavlov H. Insufficiency fracture of the talus: diagnosis with MR imaging. *Radiology.* 1995; 197:439-42.
15. Torg JS, Pavlov H, Cooley LH, et al. Stress fractures of the tarsal navicular: a retrospective review of twenty-one cases. *J Bone Joint Surg [Am].* 1982; 63:700-12.
16. Stafford SA, Rosenthal KI, Gebhardt MC, Brady TJ, Scott JA. MRI in stress fracture. *AJR Am J Roentgenol.* 1986; 147:553-6.
17. Kathol MH, El-Khoury GY, Moore TE, Marsh JL. Calcaneal insufficiency avulsion fractures in patients with diabetes mellitus. *Radiology.* 1991; 180:725-29.
18. Kier R. Magnetic resonance imaging of plantar fasciitis and other causes of heel pain. *Magn Reson Imaging Clin N Am.* 1994; 2:97-107.
19. DiMarcangelo MT, Yu TC. Diagnostic imaging of heel pain and plantar fasciitis. *Clin Podiatr Med Surg.* 1997; 14:281-301.
20. Flick AB, Gould N. Osteochondritis dissecans of the talus (transchondral fractures of the talus): review of the literature and new surgical approach for medial dome lesions. *Foot Ankle*. 1985; 5:165-85.
21. De Smet AA, Fisher DR, Burnstein MI, Graf BK, Lange RH. Value of MR imaging in staging osteochondral lesions of the talus (osteochondritisdissecans): results in 14 patients. *AJR Am J Roentgenol.* 1990; 154:555-8.
22. Bae S, Lee HK, Lee K, Lim S, Rim NJ, Kim JS, Cho J. Comparison of arthroscopic and magnetic resonance imaging findings in osteochondral lesions of the talus. *Foot Ankle Int.* 2012 Dec;33(12):1058-62.
23. Hembree WC, Wittstein JR, Vinson EN, Queen RM, Larose CR, Singh K, Easley ME. Magnetic resonance imaging features of osteochondral lesions of the talus. *Foot Ankle Int.* 2012 Jul;33(7):591-7.
24. Jelinek JS, Kransdorf MJ, Utz JA, et al. Imaging of pigmented villonodularsynovitis with emphasis on MR imaging. *AJR Am J Roentgenol.* 1989; 152:337-42.
25. Lin J, Jacobson JA, Jamadar DA, Ellis JH. Pigmented villonodularsynovitis and related lesions: the spectrum of imaging findings. *AJR Am J Roentgenol.* 1999; 172:191-7.
26. Berkowitz JF, Kier R, Rudicel S. Plantar fasciitis: MR imaging. *Radiology.* 1991; 179:665-7.
27. Grasel RP, Schweitzer ME, Kovalovich AM, et al. MR imaging of plantar fasciitis: edema, tears and occult abnormalities correlated with outcome. *AJR Am J Roentgenol.* 1999; 173:699-701.
28. Narváez JA, Narváez J , Ortega R, Aguilera C, Sánchez A , Andía E. Painful heel. MRI findings. *Radiographics.* 2000:20(1):
29. Deely DM, Schweitzer ME. MR imaging of bone marrow disorders. *RadiolClin North Am.* 1997; 35:193-212.
30. Russo A, Zappia M, Reginelli A, Carfora M, D'Agosto GF, La Porta M, Genovese EA, Fono P. Ankle impingement: a review of multimodality imaging approach. *Musculoskelet Surg.* 2013 Aug;97Suppl 2:S161-8.
31. Bureau NJ, Cardinal E, Hobden R, Aubin B. Posterior ankle impingement syndrome: MR imaging findings in seven patients. *Radiology.* 2000 May;215(2):497-503.