ROLE OF 3 TESLA MRI IN EVALUATION OF ANKLE JOINT AND FOOT PATHOLOGIES

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ABSTRACT

Introduction - MRI has been used to assess various foot and ankle pathologies. With its distinct ability to evaluate osseous, ligamentous, tendinous, and muscular pathologies of the foot and ankle, it helps in the diagnosis of pathological conditions of the same. The objective of the study was to assess the role of 3 Tesla Magnetic Resonance Imaging in the identification, delineation and classification of ankle joint and foot pathologies.

Materials and Methods - The study was carried out among participants visiting Department of Radiology, Yenepoya Medical College Hospital, and Mangalore during the time period of June 2019 to October 2021. It was an observational descriptive study carried out on a total of thirty five individuals. The participants were included based on predetermined selection criteria.

Results - The non-traumatic and traumatic conditions were profiled in the study. Non traumatic pathologies included infective, inflammatory and neoplastic conditions. A total of 22 participants (62.9%) had traumatic pathology. Trauma was highest in occurrence among males (16 in number) constituting 61.5% of the study population. Infectious etiology was present among eleven participants with composition of 31.4%. Inflammatory conditions were seen in five participants which constituted 14.3%. A total

of four males had neoplastic condition (11.6%). Neoplastic conditions were absent in female participants.

Key words: 3 Tesla MRI, ankle joint, foot pathologies, soft tissue contrast.

Introduction

Magnetic resonance (MR) imaging has opened new horizons in the diagnosis and treatment of many musculoskeletal diseases of the ankle and foot. It demonstrates abnormalities in the bones and soft tissues before they become evident at other imaging modalities.[1] The exquisite soft-tissue contrast resolution, noninvasive nature, and multi planar capabilities of MR imaging make it especially valuable for the detection and assessment of a variety of soft-tissue disorders of the ligaments (eg, sprain), tendons (tendinosis, peritendinosis, tenosynovitis, entrapment, rupture, dislocation), and other soft-tissue structures (eg: anterolateral impingement syndrome, sinus tarsi syndrome, compressive neuropathies [eg: tarsal tunnel syndrome, Morton neuroma], synovial disorders).[2]

MR imaging has also been shown to be highly sensitive in the detection and staging of a number of musculoskeletal infections including cellulitis, soft-tissue abscesses, and osteomyelitis.[3] In addition, MR imaging is excellent for the early detection and assessment of a number of osseous abnormalities such as bone contusions, stress and insufficiency fractures, osteochondral fractures, osteonecrosis, and transient bone marrow edema. MR imaging is increasingly being recognized as the modality of choice for assessment of pathologic conditions of the ankle and foot.[4]

MRI has the unique capability to evaluate osseous, ligamentous, tendinous, and muscular pathologies of the foot and ankle which are often difficult to diagnose, with a single imaging study before they become evident in other imaging modalities.[5] Injuries to

specific soft-tissue structures can be accurately assessed on MRI, allowing appropriate therapeutic intervention and rehabilitation. MR imaging has also been shown to be highly sensitive in the detection and staging of a number of musculoskeletal infections including cellulitis, soft-tissue abscesses, and osteomyelitis.[6]

Tumours involving the foot and ankle are relatively less common and may be challenging to diagnose. MRI provides excellent anatomical detail and allows for soft tissue characterization which plays an important role in formulating a differential diagnosis. It allows for local staging and description of the relationship of a lesion to adjacent anatomical structures (e.g. fascia, bone, muscle, neurovascular structures).[7, 10]

MR imaging is increasingly being recognized as the modality of choice for assessment of pathologic conditions of the ankle and foot.

METHOD

The study was carried out to evaluate the ankle joint and foot pathologies using 3 Tesla MRI among participants visiting hospital during the time period of June 2019 to October 2021. The study used observational method as research design. It was a descriptive study carried out at the Department of Radiology, Yenepoya Medical College Hospital, Mangalore. Institutional ethical approval was obtained before the initiation of the study.

Participants

The study was carried out on a total of thirty five individuals. The participants were included based on predetermined selection criteria.

Inclusion Criteria

Patients of all age groups undergoing magnetic resonance imaging for traumatic and non traumatic ankle and foot pathologies (including infectious, inflammatory and neoplastic

etiology).

Exclusion criteria

i. Patients with metallic implants.

ii. Patients in delirium.

Instrumentation

Study tool used was routine MRI sequences (T1 and T2 weighted) with Fatsat / STIR sequence using an advanced 3.0 Tesla MRI machine (SIGNA™ Pioneer - General Electric).

Procedure

Informed consent was obtained from the all the eligible participants for the study. MRI was performed on a 3.0 T MR scanner. MRI examination of the ankle joint was performed in the axial, coronal, and sagittal planes parallel to the table top.

MRI examination of the foot was performed in the oblique axial, oblique coronal, and oblique sagittal planes. Field of view (FOV) included the entire ankle/hind foot up to the level of the metatarsal bases. The patients were positioned in supine position with the medial malleolus cantered in the coil to evaluate the hindfoot and the ankle joint. The foot was allowed to rest in a relaxed position, in 10°–20° of plantar flexion and 10°–30° of external rotation. The placement of localisers was as follows. An axial localizer was placed at the level of tibiotalar joint for obtaining sagittal images with images obtained perpendicular to transmalleolar line covering from the medial malleolar to the lateral malleolar soft tissues.

A sagittal localizer was placed for collecting axial images from the posterior soft tissues to the metatarsal bases, with pictures obtained parallel to the long axis of the calcaneum. A

short axis coronal localizer was placed at the level of the midmetatarsals for acquiring sagittal midfoot/forefoot images perpendicular to a best fit transmetatarsal line encompassing the medial to the lateral soft tissues or a reduced FOV for higher resolution when imaging a focal area of interest. A short axis (coronal) at the level of the midmetatarsals for collecting long axis axial pictures with images obtained parallel to a best fit transmetatarsal line spanning the soft tissues from dorsal to plantar. A sagittal localizer (at the second or third metatarsal level) was placed for creating short axis coronal images of the forefoot with pictures obtained perpendicular to a line parallel to the second or third metatarsals that cover from the naviculocuneiform articulation through the toes.

The data was described using basic descriptive statistics. The Chi-square test of significance was used to determine whether there is a link between the research variables. The significance level for the test was set at 5%. The statistical analysis was performed using IBM SPSS version 20.0.0.

S. No	Image Plane	TR (Time to Repeat) in msec	TE (Time to Echo) in msec	Slice Thickness (mm)	Field of View (FoV)	Flip Angle	Band Width
i.	Axial T1WI FSE	711.0	42.0	4.0	15.0	111	50
ii.	Coronal T1WI FSE	550.0	42.0	4.0	16.0	111	62.50
iii.	Sagittal T1WI FSE	483.0	42.0	3.5	15.0	111	62.50
iv.	Axial T2WI FSE	4910.0	102.0	4.0	15.0	111	50.0
v.	Coronal T2WI FSE	6293.0	85.0	3.0	14.0	111	41.67
vi.	Axial STIR	3500.0	46.5	3.5	30.0	80	125.0
vii.	Coronal STIR	3500.0	49.5	3.5	36.0	80	62.50

viii.	Sagittal STIR	3500.0	106.1	4.0	20.0	80	62.50
ix.	Axial PDFS	2889.0	40.0	4.0	15.0	111	41.67
x.	Sagittal PDFS	2200.0	40.0	3.5	15.0	111	41.67
xi.	Coronal PDFS	2372.0	40.0	4.0	16.0	111	31.25
xii.	Sagittal MERGE	550.1	6.9	3.0	15.0	20.0	62.50

Table 1: *MRI Ankle Parameters- Yenepoya Medical College*

RESULTS

A total of thirty five participants took part in the study. The mean age of the participants was 41.29 years. The average age of male participants was 42.12 years compared to the females (38.89 years). A total of 26 males participated in the study which constituted 74.3% of the overall population of the study. A total nine females (25.7%) took part in the study.

Group	Gender	Frequency	Percent	Mean Age of participants
	Male	26	74.3%	42.12 years
	Female	9	25.7%	38.89 years
Total		35	100%	41.29 years

Table 2: Demographic Data of the participants

Condition		Male		Female		Total	
		N	%	N	%	N	%
Acute/Chronic	Acute	9	34.6%	4	44.4%	13	37.1%
	Chronic	17	65.4%	5	55.6%	22	62.9%
Total		26	100.0%	9	100.0%	35	100.0%

***Table 3*:** Cross tabulation of Acute and Chronic condition

Categorization of pathologies

The non traumatic and traumatic pathologies were profiled in the present study. The same has been depicted in the following table (Table 4). Traumatic, infective, inflammatory and neoplastic pathologies were compiled.

A total of 62.9% of the participants had pathologies attributed to trauma. Highest occurrence of **traumatic conditions** were seen in males (16 in number), constituting 61.5% of the study population.

Conditions	**Status**	**Male**		**Female**		**Total**	
		N	Frequency (%)	**N**	Frequency (%)	**N**	Frequency (%)
Traumatic	Absent	10	38.5%	3	33.3%	13	37.1%
	Present	16	61.5%	6	66.7%	22	62.9%
Infective	Absent	16	61.5%	8	88.9%	24	68.6%
	Present	10	38.5%	1	11.1%	11	31.4%
Inflammatory	Absent	24	92.3%	6	66.7%	30	85.7%

	Present	2	7.7%	3	33.3%	5	14.3%
Neoplastic	Absent	22	84.6%	9	100%	31	88.6%
	Present	4	15.4%	0	0.0%	4	11.6%

Table 4: *Cross tabulation of traumatic and non- traumatic conditions.*

Infectious etiology was identified in 10 males (38.5%) and 11 females (31.4%). A total of 11 participants had infectious etiology, constituting 31.4% of the total participants. **Inflammatory etiology** was present in 2 males (7.7%) and 3 females (33.3%), constituting 14.3% of the total participants. **Neoplastic etiology** was seen in 4 males (15.4%) which attributed to 11.6% of the total participants. Neoplastic conditions were absent among all the female participants.

Clinical Profile

The recording of symptoms and signs was carried out on all the study participants prior to MR imaging of the foot and ankle.

Clinical Profile		Male		Female		Total	
		Number	%	Number	%	Number	%
1.	Pain	10	3.8%	3	33.%	13	82.0
2.	Swelling in Joint	5	3.8%	2	22.2%	7	20.0
3.	Road Traffic Accident	3	7.7%	1	0.0%	4	16.0
4.	Discharging Sinus	1	3.8%	2	0.0%	2	12.0
5.	Twisting Injury	2	3.8%	1	0.0%	3	12.0
6.	Fall from Height or stairs	2	3.8%	0	0.0%	2	6.0

7.	Difficulty or inability to walk	1	3.8%	0	0.0%	1	4.0
8.	Ulceration over the heal	1	3.8%	0	0.0%	1	2.0
9.	Blackish discoloration	1	7.7%	0	0.0%	1	2.0
10.	Fever	0	0.0%	1	11%	1	2.0

***Table 5*:** Clinical profile of participants

Pain was the most common presenting symptom, seen in 82% of the total participants, forming the highest occurring presenting clinical feature. 16% of participants presented with history of road traffic accident, ie., 3 males and 1 female. Swelling in joint was reported among 20.0% of the participants. Discharging sinus and twisting injury was reported among 12.0% of the participants.

Site of Osseous Lesion:

Site of the osseous lesion was assessed in the study. The details of the same have been depicted in the table 6. The occurrence of osseous lesion at sites of lower tibia, lower fibula, talus, calcaneum, navicular, cuboid, cuneiform, metatarsals, phalanges and os trigonum was profiled among the participants.

Site of Osseous Lesion		Total	
		Number	Frequency (%)
1.	Lower Tibia	13	82.0
2.	Lower Fibula	7	20.0
3.	Talus	4	16.0
4.	Calcaneum	2	12.0
5.	Navicular	3	12.0
6.	Cuboid	2	6.0
7.	Cuneiforms	1	4.0
8.	Metatarsals	1	2.0
9.	Phalanges	1	2.0
10.	Os Trigonum	1	2.0

Table 6: Site of Osseous Lesions and Frequency of occurrence

The MRI findings of osseous lesions among the participants were profiled in the study. It was observed that marrow edema was the most frequent osseous finding, seen in 34.0% of the participants.

MRI Findings- Osseous Lesions		N	Frequency (%)
1.	Marrow edema		34.0
2.	Subchondral Cysts		10.0
3.	Contusions		10.0
4.	Destruction		8.0
5.	Bony prominence		2.0

6.	Erosion		12.0
7.	Fracture (Comminuted- 2; Transverse- 2; Micro -1)		12.0
8.	Focal Lesions		8.0
9.	Subchondral Compression		6.0
10.	Serpinginous area of altered signal intensity		2.0
11.	No lesions		20.0

Table 7: Type of Osseous site of lesion and its occurrence

Site of Tendon Lesions

Tendon Lesion	N	Frequency (%)
Achilles tendon	6	18%
Flexor tendons	11	30%
Extensor tendons	2	6%
Peroneus tendons	12	36.7%
Nil	17	48.6%

*****Multiple responses allowed

Table 8: Site of Tendon lesions and its occurrence

The tendon lesions and occurrence sites were analyzed among the participants of the study (Table 8). It was observed that 17 of the participants did not have any tendon lesions (48.6%). Peroneus tendon was the most frequently injured tendon (36.7%) in our study.

The MRI findings of the tendon lesions were as shown in the table 9.

MRI Findings- Osseous Lesions		N	Frequency (%)
1.	Tenosynovitis		32.0
2.	Complete Rupture		14.0
3.	Encased		2.0
4.	Partial Thickness Tear		6.0
5.	Tendinopathy		14.0
6.	No lesions		48.0

Table 9: MRI Findings- Tendon Lesions

Site of the ligamentous Pathologies

The site of the ligamentous pathologies was assessed from the data obtained. The findings of the same have been added in table 10. The occurrence of anterior talofibular ligament pathology was highest constituting 18.0% of the participants, followed by calcaneofibular ligament (8.0%) and posterior talofibular ligament (6.0%) pathology. The occurrence of deltoid ligament complex pathology, tibiocalcaneal ligament and tibionavicular ligament pathology was least with 2.9% occurrence rate in each category.

Site of Ligamentous Pathologies		Total	
		Number	Frequency (%)
1.	Anterior Talofibular Ligament	6	18.0
2.	Posterior Talofibular Ligament	2	6.0
3.	Calcaneofibular ligament	3	8.0
4.	Deltoid Ligament Complex	1	2.9
5.	Tibiocalcaneal Ligament	1	2.9
6.	Tibionavicular Ligament	1	2.9

***Table 10*:** Site of Ligamentous Pathologies

The MRI findings of the ligament pathologies are as shown in table 11. Full thickness tear was observed in 18% of the study participants.

MRI Findings- ligamentous pathologies		N	Frequency (%)
1.	Full thickness tear	6	18.0
2.	Partial Tear	3	8.0
3.	Grade I Sprain	4	12.0

***Table 11*:** MRI Findings- Ligament Pathologies

Distribution of Ligamentous pathologies in various ligaments of the ankle joint are provided in table 12.

Ligament		Full Thickness Tear	Partial Tear	Grade I sprain
1.	Anterior Talofibular Ligament	4	2	3
2.	Posterior Talofibular Ligament	1	1	1
3.	Calcaneofibular Ligament	2	1	1
4.	Deltoid Ligament Complex	0	0	1
5.	Tibiocalcaneal Ligament	1	0	0
6.	Tibionavicular Ligament	1	0	0

Table 12: Distribution of ligamentous pathologies

Site of the Joint pathology among the study participants

Site of Joint Lesion		**Total**	
		Number	Frequency (%)
1.	Tibiotalar Joint		48.0
2.	Subtalar Joint		38.0
3.	Metatarsotarsal Joint		4.0
4.	Metatarsophalangeal Joint		4.0
5.	Talonavicular Joint		12.0
6.	Calcaneocuboid Joint		4.0
7.	Calcaneonavicular Joint		2.0

Table 13: Site of Joint lesions and its occurrence

The joint pathologies and occurrence sites were analyzed among the participants of the study. The findings of the same have been depicted in the table 13. The involvement of tibiotalar joint was highest with an occurrence among 48.0 % of the participants. Subtalar joint was involved in 38.0% of the participants. The least involved joint was calcaneonavicular joint among the participants of the study.

The MRI findings of joint pathology has been shown in table 14.

MRI Findings- Joint pathology		N	Frequency (%)
1.	Effusion	20	58.0
2.	Reduced Joint Space	3	8.0
3.	Dislocation	1	2.9
4.	Subchondral Erosions	1	2.9
5.	Synovial Pannus	5	14.0
6.	Periarticular Collection	1	2.9
7.	Joint distension	1	2.9
8.	Osteophyte Formation	1	2.9
9.	No lesions	11	32.0

Table 14: MRI Findings- Joint pathology

Soft tissue pathology

MRI Findings- Soft tissue pathology		N	Frequency (%)
1.	Edema		62.0
2.	Soft Tissue Lesion		16.0
3.	Dot in circle sign		2.0
4.	Foreign Body		4.0
5.	Cystic Lesion with Phleboliths		2.0
6.	Ulceration		4.0
7.	Thickened plantar fascia		4.0
8.	Retrocalcaneal bursitis		4.0
9.	Abscess formation		10.0
10.	Myositis		2.0
11.	Effaced Kager's fat Pad		4.0
12.	No lesions		22.0

***Table 15*:** MRI Findings- Soft tissue pathology

Classification of pathologies in Achilles Tendon

Pathology		Insertion	Pre-insertion	Middle Free Tendon	Proximal Free Tendon
1.	Complete	1	1	3	0
2.	Partial	1	1	1	0
3.	Tendinopathy	1	5	5	4

Table 16: Classification of pathologies in Achilles tendon

Ligament		Full Thickness Tear	Partial Tear	Grade I sprain
7.	Anterior Talofibular Ligament	4	2	3
8.	Posterior Talofibular Ligament	1	1	1
9.	Calcaneofibular Ligament	2	1	1
10.	Deltoid Ligament Complex	0	0	1
11.	Tibiocalcaneal Ligament	1	0	0
12.	Tibionavicular ligament	1	0	0

Table 17: Distribution of ligamentous pathologies

DISCUSSION

In an observational study conducted on 47 patients in a tertiary centre, maximum number of pathologies was detected in the age group of 41 to 60 years (46.80% of the patients). Most common structure involved were joints, it was involved in 28 patients (59.57%). Traumatic etiology was more common in their study and seen in 18 patients (38.29%) followed by degenerative etiology in 11 patients (23.40%). Lateral ligament complex was most frequently injured ligament representing 83.33%. Achilles tendon was the most commonly injured ankle tendon.[11]

In another observational study conducted on 70 patients in a tertiary centre, traumatic etiology was more common, seen in 24 patients (34.2%) followed by Infective/inflammatory etiology seen in 18 patients (25.7%) while least common was neoplastic seen in 6 patients (8.5%). Degenerative etiology was seen in 13 patients (18.5%) and other miscellaneous causes was seen in 9 patients (12.8%).[12]

In our study, A total of 62.9% of the participants had pathologies attributed to trauma. Highest occurrence of **traumatic conditions** were seen in males (16 in number), constituting 61.5% of the study population. **Infectious etiology** was identified in 10 males (38.5%) and 11 females (31.4%). A total of 11 participants had infectious etiology, constituting 31.4% of the total participants. **Inflammatory etiology** was present in 2 males (7.7%) and 3 females (33.3%), constituting 14.3% of the total participants. **Neoplastic etiology** was seen in 4 males (15.4%) which attributed to 11.6% of the total participants. Neoplastic conditions were absent among all the female participants.

CONCLUSION

Magnetic resonance imaging (MRI) is the primary imaging modality of choice due to its excellent soft tissue contrast for optimal detection of pathologies of the tendons, ligaments

and other soft tissue structures of the ankle joint complex and the foot. It holds advantage over conventional radiography and computed tomography for early detection and assessment of osseous abnormalities. However, both the former modalities may provide additional information, which may act as an adjunct along with MRI to reach a most probable diagnosis.[13]

Osteomyelitis of the ankle joint complex and foot demonstrates a polymorphic pattern with variable appearance on MRI. Its etiology consists of diabetes, TB, mycetoma and secondary to trauma. Osteomyelitis may be complicated by Charcot osteoarthropathy and bone infarcts. Extraspinal manifestations of TB is rare with foot being the least common site. The dot-in-circle sign on MRI is characteristic and pathological for mycetoma. Plantar fasciitis shows female predilection and on MRI may show thickened plantar fascia and bone marrow abnormality in calcaneus.

Soft tissue tophi and punched out cortical erosions are highly characteristic of gout.Neoplasms of the ankle joint and foot are predominantly benign rather than malignant.

Hemangioma is usually congenital; however, can occur secondary to trauma. Lateral ankle ligament complex is more frequently injured than deltoid ligamentous complex. MRI provides valuable information in evaluation of ligaments than all other modalities.

Anterior talofibular ligament is the weakest of all ligaments of the ankle joint complex and is the first ligament to be injured followed by the calcaneofibular ligament. Posterior talofibular ligament is the strongest of lateral ligament complex and is rarely injured except in severe ankle trauma.

Osteochondritis dissecans of the ankle joint complex most commonly involves the talar dome and is usually associated with injuries to the lateral ankle ligament complex. Achilles tendon is the strongest ligament of the body; however, it is frequently injured. Acute rupture and chronic Achilles tendinopathy are usually seen at middle free tendon (main body). Insertional rupture is usually associated with insertional tendinopathy and Haglund's deformity.

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