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Original Research Paper

"A STUDY ON CORRELATION OF CLINICAL FINDINGS, RADIOGRAPHIC STAGING, AND MAGNETIC RESONANCE IMAGE OF AVASCULAR NECROSIS OF FEMORAL HEAD IN A TERTIARY CARE TEACHING HOSPITAL"

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ABSTRACT:

Background: The hip joint is a large weight-bearing joint with high mobility that can be involved in a variety of pathological disorders.These include anomalies caused by trauma, infection, avascular necrosis, neoplastic involvement, and synovial-based diseases.

OBJECTIVES:

1. To assess the sensitivity and specificity of MRI in diagnosing AVN.

2. To correlate the features of AVN in conventional radiography and MRI.

MATERIAL & METHODS: Study Design: A prospective hospital-based observational study. **Study area:** Department of Radio Diagnosis, Subbaiah Institute of medical sciences, Shivamogga, Karnataka. **Study Period:** 1 year. **Study population:** Patients who present with complaints of pain in the hip joint, restricted hip joint movements and suspected clinically to be AVN are referred fromthe Department of Orthopaedics to the Department of Radiodiagnosis and Imaging. **Sample size:** The study consisted of 60 subjects. **Sampling method:** Simple random technique.

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Results: Sensitivity of X-ray in diagnosing AVN in early stages (Stage I and II) is less than that of MR imaging i.e.33% and 77.8%, but in late stages (Stage III and IV) both show equal sensitivity i.e. 100%.

CONCLUSION: The study shows that MRI of the hip joint provides an informative, diagnostic, non-invasive, quick, and accurate imaging technique for assessing hip pain and identifying various hip joint pathologies.

Keywords: avascular necrosis,Ficat classification, Double Line Sign

INTRODUCTION:

The hip joint is a large weight-bearing joint with high mobility that can be involved in a variety of pathological disorders.These include anomalies caused by trauma, infection, avascular necrosis, neoplastic involvement, and synovial-based diseases. Because of its close relationship with systemic illnesses, it was one of the first joints in the body to be assessed by MRI. Painful hips are a frequent, debilitating musculoskeletal condition that affects people of all ages. The differential diagnosis is extensive, posing a diagnostic difficulty, encompassing juxta-articular and intra-articular aetiologies, as well as referred pain primarily from the spine or sacroiliac joints[1].

MRI gives important information on occult bony and cartilage injuries such as stress fractures, bone marrow oedema, and osteoarthritis[2]. MRI has also been effective in the diagnosis of femoro-acetabular impingement (FAI), arthropathies, trauma, osteomyelitis, and primary musculoskeletal tumors. Additionally, intravenous or intra-articular gadolinium can

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be used to assess synovial disease, labral pathology, mild femoral head alterations, and articular cartilage derangement.

A high-resolution, non-arthrographic approach can provide preoperative information on the presence and anatomical location of labral and cartilage anomalies. Furthermore, MRI may allow the referring physician to determine whether patients will require an arthroscopic versus open surgical procedure. Although bone scintigraphy utilizing single photon emission computed tomography (SPECT) may be nearly as accurate as MRI, MRI provides a more specific diagnosis in patients with hip discomfort of unknown etiology[3].

Avascular necrosis (AVN) of the femoral head is becoming a common cause of musculoskeletal impairment. AVN is not a single disease entity, but rather the result of a combination of variables that cause a decrease in circulation to a specific area of bone and subsequent death. Many favor the more precise name "Avascular Necrosis" over the broader classification "Osteonecrosis". The most prevalent cause is a displaced transcervical hip fracture resulting in mechanical interruption of the femoral head's blood supply.AVN is frequent in the younger population, particularly in the third and fifth decades of life, and affects primarily men. Because of the higher frequency in young adults, early identification and treatment are critical, as delay increases treatment costs and morbidity[4,5].

The active interface between infarcted and viable bone was visible on MRI as a low signal intensity band. Conventional radiography showed the reactive interface as a lucent zone on the plain images.[6.] Hips with bone marrow oedema had a considerably greater necrotic volume compared to those without[7].Joint preservation operations (such as core decompression) are performed in early (stage I/II), and joint replacement in advanced stages (stage III/IV).[8.] Core decompression can be ineffective and unexpected in terms of illness development.[9]. A quantitative staging approach for avascular necrosis may enable for more

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accurate evaluation of progression or remission, as well as a better comparison of various therapeutic options[10].

It is critical to detect the disease as soon as possible, to determine the prognosis prior to collapse, and to implement appropriate interventions to prevent progression to painful arthritis[11,12]. The amount and position of the necrotic region, as well as the Ficat stage, can be used to predict the outcome of core decompression in femoral head osteonecrosis [13,14]. Because it is simple to understand and therapeutically relevant, the Ficat classification is presently one of the most popular categorization schemes[15].

OBJECTIVES:

1. To assess the sensitivity and specificity of MRI in diagnosing AVN.

2. To correlate the features of AVN in conventional radiography and MRI.

3. To evaluate the staging of AVN on conventional radiography and MRI.

4. To assess the specificity of double line sign in the diagnosis of AVN.

MATERIAL & METHODS:

Study Design: A prospective hospital-based observational study.

Study area: Department of Radio Diagnosis, Subbaiah Institute of medical sciences, Shivamogga, Karnataka.

Study Period: 1 year.

Study population: Patients who present with complaints of pain in the hip joint, restricted hip joint movements and suspected clinically to be AVN are referred fromthe Department of Orthopaedics to the Department of Radiodiagnosis and Imaging.

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Sample size: The study consisted of 60 subjects.

Sampling method: Simple random technique.

Inclusion criteria:

1. Patients with the clinical signs and symptoms of hip joint pathology (hip joint pain with movement restriction).

2. Patients who are either positive or negative for AVN on conventional radiograph.

Exclusion Criteria:

1. Patients with known contraindications to MRI:

a. Metallic prosthesis

b. Prosthetic valves

c. Pacemakers

d. Aneurysmal clips

2. Patients who are claustrophobic.

Ethical consideration: Institutional Ethical committee permission was taken prior to the commencement of the study.

Study tools and Data collection procedure:

Equipment:

• X-ray machines - 300mA and 500mA.

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• MRI – Evaluation of cases will be done in the Department of Radiodiagnosis using SIEMENS AVANTO 1.5 TESLA MRI.

Procedure

• No specific patient preparation is required prior to the study.

• All patients are imaged using a surface coil with the patient in a supine position without knee rest and both hips will be examined simultaneously.

• No contrast injection is used.

• The duration of each study is approximately 40 minutes.

• Sequences that will be used for study are :

o Axial T1W,T2W

o Coronal T1W, T2W, STIR

o Sagittal T2W.

Statistical analysis: Data was analysed using SPSS 21.0 software. Descriptive parameters were represented as mean with SD or median. Continuous variables were compared using unpaired t-test/Mann Whitney u test. Chi-square or t-test will be used to determine significant outcome differences. Categorical data was represented as frequency with percentage. For all tests, a p-value of <0.05 was considered statistically significant.

OBSERVATIONS & RESULTS:

This study comprised of 60 patients suffering from hip joint pain (120 hip joints), 49 of these patients had changes relative to avascular necrosis of femoral head, of which 30 patients had bilateral involvement whereas only 19 showed unilateral involvement. Total number of

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femoral heads showing changes of AVN on MR imaging were 79 as compared to 59 positive heads on X-Ray imaging. Most of the hip joints with AVN showed changes related to stage I with 30.3% followed by stage II and III with 22.8% each. In the present study, findings like sclerosis, mottled appearance, and Perthes like lesion associated with milder symptoms were most commonly seen in younger age group (11–20yrs) while destruction, necrosis and arthrosis associated with severe symptoms were seen in mid age group (21–30yrs).

As all the patients presented with hip joint pain, additional clinical presentations were also determined. The most frequent clinical presentation following hip joint pain was lower back pain (n= 20, 33%), followed by limited movements (n= 15, 25%), hip joint swelling (n= 14, 23%) and hip pain with constitutional symptoms (n= 18, 6%). Based on the findings obtained by MRI, the final diagnoses were as the following: avascular necrosis (n=49, 82%), osteoarthritis (n=2, 3.33%), septic arthritis (n=4, 6.66%) and normal patients without any signs on MR imaging (n=5, 8.33%).

Table 1: Distribution of patients according to diagnosis

PresenceofAVN	Numberof Cases	Percentage
AVNPresent	49	82
AVNAbsent	11	18
Total	60	100

AVN -Avascular Necrosis

Table 2: Sex-wise distribution of patients with AVN

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Sex	Numberof Cases	Percentage
Male	35	71
Female	14	29
Total	49	100

Table 3: Age wise distribution of patients with AVN

Agegroup	Numberof patients (n=49)	Percentage
0-10	**2**	**4.1**
11-20	**10**	**20.4**
21-30	**13**	**26.5**
31-40	**15**	**30.6**
41-50	**6**	**12.2**
51-60	**3**	**6.1**

Idiopathic cases of AVN were found to be most common in 57% of cases. Of the associated risk factors, causes like steroids and trauma was observed in 10.2%, alcohol in 18.3%, sickle cell anaemia and pancreatitis was found in 2.04% each.

Table 4: X-ray characteristics with age wise distribution

		AgeRange	

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Radiographic Changes	No. ofHips	0 -10	11 –20	21-30	31 –40	41 –50	51 –60	Symptom Severity
Sclerosis	28	1	9	12	2	3	1	Minimal
Mottling	19	1	7	6	2	2	1	Minimal
Perthe'sLike Lesion	1	0	1	0	0	0	0	Mild to moderate
CrescentSign	12	1	4	3	2	1	1	Mild to moderate
Flattening	10	0	3	4	2	1	0	Mild to moderate
TotalDestruction	10	0	3	5	1	1	0	Moderateto severe
Necrosis	15	0	5	6	2	2	0	Moderateto severe
Acetabular Changes	8	0	2	4	2	0	0	Moderateto severe
Migration	10	0	2	4	2	1	1	Moderateto severe
PeriostealReaction	7	0	3	3	0	0	1	Moderateto severe

In the present study, many cases have shown multiple findings on X-Ray.

Amongst the four patterns, band pattern was most commonly involving stage I and II, while ring pattern showed predominance in stage III and in- homogenous pattern in stage IV.

Table 5: Segment of AVN, MR characteristics with staging

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Segmentof AVN	StageI		StageII		StageIII		StageIV		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Supero-Lat	4	16.7	7	38.9	7	38.9	8	42.1	26	32.9
Supero-Med	8	33.3	10	55.6	11	61.1	11	57.9	40	50.6
Infero-Med	0	0	1	5.5	0	0	0	0	1	1.3

Most common location (Segment) of AVN lesion in femoral head was superomedial aspect (50.6%) followed by superolateral aspect (32.9%). Most of the femoral heads in the study showed less than 25% involvement. Similar pattern was seen in stage wise distribution except in stage IV where most of the femoral heads showed more than 75% involvement.

Many cases have shown multiple findings. Marrow oedema was the most common MR finding in whole study and it predominantly involved stage III and IV (100%). Joint effusion was seen in almost all the stages of AVN but most strikingly seen in stage IV cases (68.4%). Stage II came out as the most commonly involved stage with finding of double line sign with 77.8% hip joints followed by stage III with 66.7%.

Table 6: MR characteristics with staging

MRFindings	StageI (n=24)		StageII (n=18)		StageIII (n=18)		StageIV (n=19)		Total(n=79)	
	No.	%	No.	%	No.	%	No.	%	No.	%
FattyMarrow	17	71	14	77.8	16	88.9	10	52.6	57	72.1
NeckWidening	0	0	1	5.5	2	11.1	10	52.6	13	16.5
MarrowOedema	9	37.5	15	83.3	18	100	19	100	61	77.2
JointEffusion	8	33.3	8	44.4	9	50	13	68.4	38	48.1
Double LineSign	4	16.7	14	77.8	12	66.7	2	10.5	32	40.5
JointNarrowing	0	0	0	0	4	22.2	16	84.2	20	25.3
Collapse	0	0	0	0	0	0	19	100	19	24
Acetabular	1	4.2	0	0	2	11.1	9	47.4	12	15.2

Many cases have shown multiple findings. Marrow oedema was the most common MR finding in whole study and it predominantly involved stage III and IV (100%). Joint effusion was seen in almost all the stages of AVN but most strikingly seen in stage IV cases (68.4%).

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Stage II came out as the most commonly involved stage with finding of double line sign with 77.8% hip joints followed by stage III with 66.7%.

Table 7: Sensitivity of MRI and X-ray in various stages of AVN

Stage	No.Of Hips (n=79)	X-Ray	%	MRI	%
StageI	24	8	33.33	24	100
StageII	18	14	77.8	18	100
StageIII	18	18	100	18	100
StageIV	19	19	100	19	100

Sensitivity of X-ray in diagnosing AVN in early stages (Stage I and II) is less than that of MR imaging i.e.33% and 77.8%, but in late stages (Stage III and IV) both show equal sensitivity i.e. 100%.

Table 8: Statistical analysis of AVN from the comparison of Radiographyand MR Imaging data

Imaging Modality	Sensitivity	Specificity	PositivePredictive Value	NegativePredictive Value
Radiography	62	75.6	83	51
MRImaging	100	100	100	100

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CASE1:AVNleftfemoralhead

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Figure1:CoronalT1andT2MRimagesshowingmixedsignalintensitiespredominantlyhypointenseonT1WandhyperintenseonT2Wnotedinleftfemoralhead.Altered contourofleftfemoral headnoted.

Coronal STIRMR image showing hyperintense signal intensities in left femoralhead.Jointspacerelativelymaintained.Minimalsofttissueedema noted.X-Ray pelvis AP view showing well defined areas of mixed sclerosis and lyticlesions,whichshow anarrow zoneoftransitionandsubchondralundermining(“crescent sign”)with flatteningofleftfemoralhead.Rightfemoral headnormal.

CASE2:AVNleftfemoralhead

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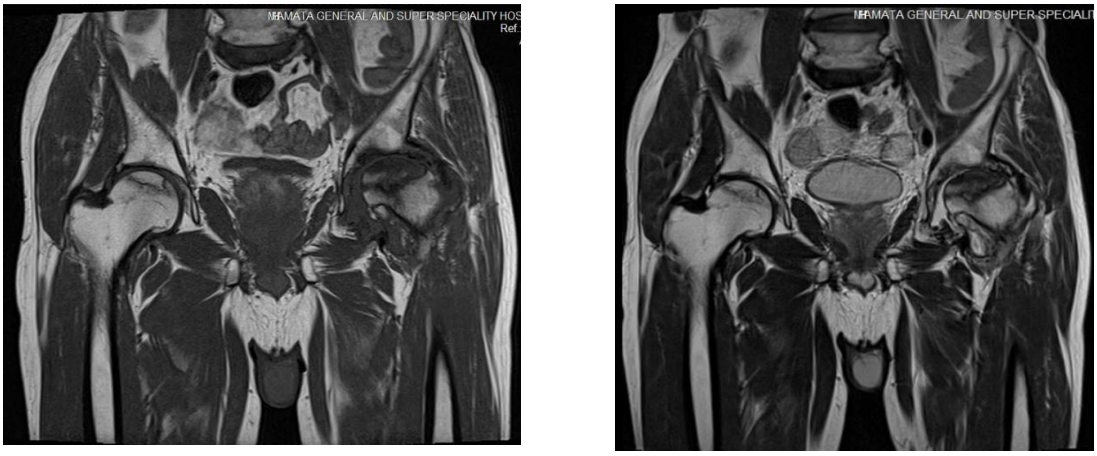
Figure 2 : Coronal T1 and T2 MR images showingabsent epiphysis suggestiveofcollapsedleft femoralheadandscleroticacetabularborders.CoronalSTIRMRimage showingcompletecollapseofleftfemoralheadwithmarrowedemachanges intheleftfemoralneck.Minimaljointeffusionnoted.X-RayPelvisAPviewshowing completecollapseofleftfemoralheadwithsclerosisofarticularsurfacesofa cetabulumand femoralmetaphysis.

CASE3:AVNB/Lfemoralheads



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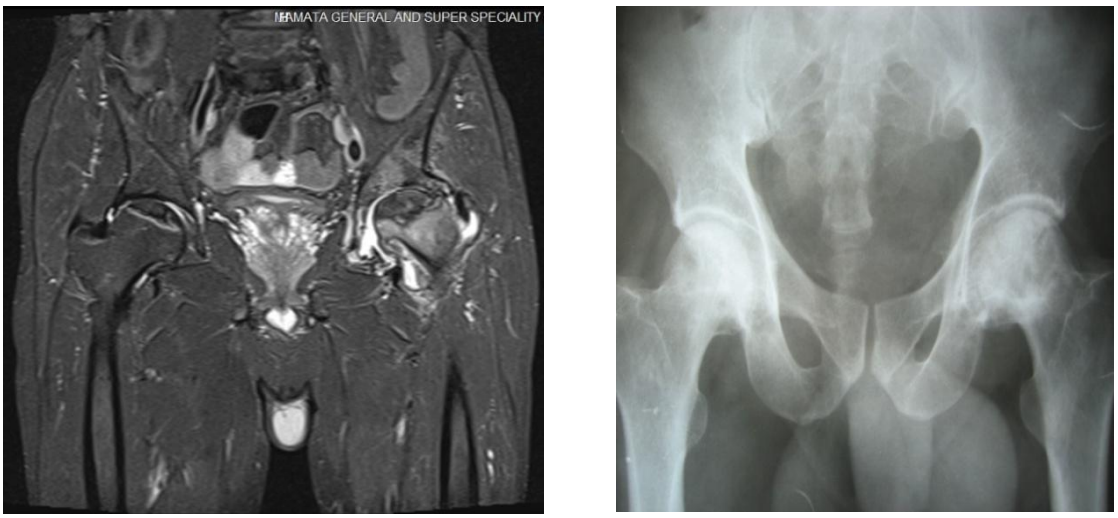

Figure 3: Coronal T1 and T2 MR images showing subchondral collapse in the leftfemoral head surrounded by a hypointense line. A crescentic hypointense line isnotedintherightfemoralhead.

Coronal STIRMR image showing subchondral collapse of left femoral head withmarrow edema of left femoral neck. Hyperintense crescent line noted in the rightfemoralhead.Minimal jointeffusionnoted.

X-Ray Pelvis AP view showing mixed sclerotic and lytic areas in left femoral headwith altered femoral head contour. Joint space relatively preserved.right hip jointappearsnormal.

CASE4:AVNofRight femoralhead

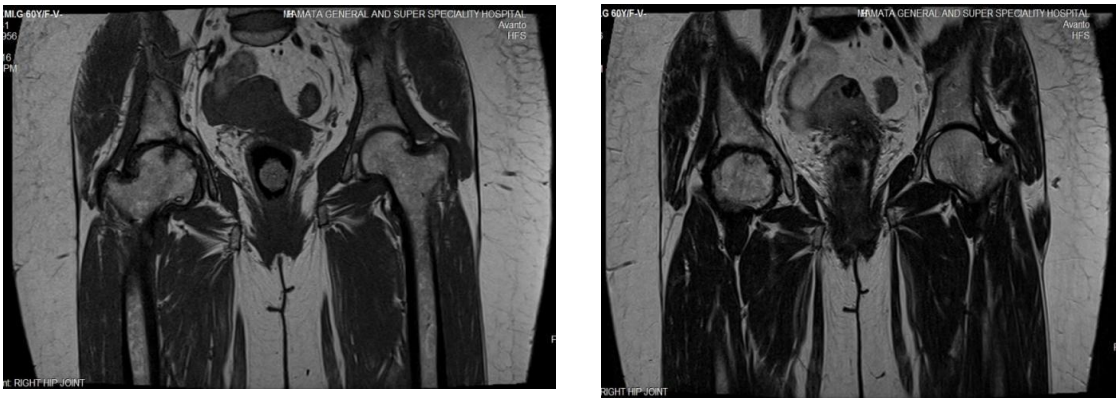

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Figure 4: Coronal T1 and T2 MR images showing a altered signal intensity in thesuperior aspect of right femoral head predominantly hypointense on T1 and mixedsignalintensity onT2.

CoronalSTIRMRimageshowinghighsignalintensitywithminimalcontourirregularityofright femoralhead.Jointspace relativelypreserved.

X-RayPelvis APview showing normalfindings inboththehipjoints.

DISCUSSION:

MRI is the most sensitive means of diagnosing avascular necrosis. The excellent spatial and contrast resolution provided by MR imaging, facilitates early detection and evaluation of avascular necrosis of femoral head. MRI helps in differentiation of AVN from other causes of hip pain. MRI is also effective in assessing joint effusions, marrow conversion, edema, and articular cartilage congruity, none of which is possible with bone scintigraphy, standard radiographs or CT. Early detection of AVN of the femoral head allows conservative

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treatment by core decompression to be effective, with alleviation of pain and preservation of normal joint function. The principal role of MRI is in establishing the diagnosis of AVN in symptomatic patients with normal radiography and scintigraphy. In this study, out of 60 patients who came with hip joint pain, 49 patients are diagnosed to have avascular necrosis of femoral head on MR imaging. The study was done using SIEMENS AVANTO 1.5 TESLA MRI machine in the Department of Radiodiagnosis.

This study comprised of 60 patients suffering from hip joint pain. Netam SS and coworkers[16] studied 55 patients and Khaladkar and coworkers[17] included 45 patients.Male to female ratio of avascular necrosis is approximately 3 to 1 in the present study compared to 5-8 to 1 in other studies. Most common cause of avascular necrosis in the present study is idiopathic. Alcohol usage and trauma are more common in males which explains the sex ratio in the present study.In the present study, 49 out of 60 patients had avascular necrosis which accounts for 81.6% .This finding is consistent with the study done by Netam SS and coworkers[16] where 49 out of 55 patients had avascular necrosis which accounts for 80%.Similar findings are also seen in the study done by Khaladkar and coworkers[17] where 36 out of 45 patients had avascular necrosis accounting for 89%.

In the present study, maximum number of patients with avascular necrosis are noted in the age group of 31- 40 yrs with a percentage of 30.6% and 21- 30 yrs with a percentage of 26.5%. These findings were consistent with the study performed by Khaladkar and coworkers[17] where the maximum number of patients with avascular necrosis were noted in the age group of 31- 40 yrs with a percentage of 30.5% and 21-30 yrs with a percentage of 25%.In the present study, out of 49 cases of avascular necrosis, 19 cases were affected on unilateral side accounting for 39% and 30 cases were affected on bilateral sides accounting for 61%. These findings are consistent with the study performed by Khaladkar and coworkers[17]where out of 36 cases of avascular necrosis,14 cases were affected on unilateral

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side accounting for 38.8% and 22 cases were affected on bilateral sides accounting for 61.2%.

Maximum number of cases in this study presenting with sclerosis, mottling and perthes like lesion belonged to younger age group (11–20 yrs) whereas lesions like destruction and necrosis belonged to mid age group (21–30 yrs). These findings were consistent with those previously experienced by Iwegbu CG and coworkers[18] and Lee RE and coworkers[19].Present study revealed the presence of fatty conversion in the marrow of femoral head and intertrochanteric marrow which was most commonly seen in the heads with stage III (88.9%), followed by stage II (77.8%) and stage I (71%). Overall, among the involved femoral heads with AVN nearly 72% cases were positive for this finding.Other studies showing similar femoral head involvement pattern are the one from Donald G. Mitchell and coworkers[20] where this very finding involved nearly 80% of cases of avascular necrosis. David J. Sartoris and coworkers[21] also noticed early conversion of normal marrow signal to fatty marrow in the patients with ischemic necrosis and remarked it to be caused by diminished vascularity.

In present study, femoral head was divided into four quadrants and the involvement of quadrants was evaluated and found that it was superomedial aspect which was most commonly involved in each stage and also in whole study. Superomedial aspect involvement comprised of 50.6% of all the cases. Similar involvement of superomedial aspect was also seen by YoshioTakatori and coworkers[22] . Although, other authors simply considered antero-superior aspect to be most common in showing involvement rather than dividing it into medial and lateral, they include Helena Gabriel and coworkers[23] and James J. Guerra and coworkers[24]. Michael A. Mont[25] also experienced anterolateral region to be most commonly involved but also remarked that no area is necessarily spared.

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In the current study, it was found that marrow oedema involving the head and neck region of femoral head was not the prominent finding of initial stages of AVN but it developed in later stages with the increased severity of the symptoms and in radiologically pre and post collapse stages (Stage III and IV). But as the patient is likely to be evaluated for AVN after the onset of pain and other symptoms, marrow oedema becomes evident in first MR scan and hence it is counted as finding of an early ischemic change.

In the present study out of 79 hip joints confirmed to have AVN, only 48.1% cases showed this finding of joint effusion on MRI. Donald G. Rao MV and coworkers[26] studied MR images in 36 hips with documented avascular necrosis and 80 hips without evidence of joint disease were studied to determine the amount and appearance of fluid in the joint. 21 out of 36 hips with avascular necrosis which accounts for 58.3% had significant joint effusions and joint effusions are greater after flattening of femoral head16. In the study done by Khaladkar and coworkers, 49 out of 58 hip joints with avascular necrosis which accounts for 84.4% had joint effusion on MR images.

Early diagnosis and therapy are crucial for the management of avascular necrosis. This study firmly establishes the ability of MR to allow early detection and staging of AVN of femoral head even in radiologically negative patients. By plain X-ray we were able to detect only 59 hips showing one or the other finding of AVN as compared to 79 hips detected by MR imaging. Two X-Rays with positive findings showed no abnormality on MR. Most of the undiagnosed hips by X-ray were from stage I and some from stage II. X-ray and MR both showed equal ability to detect hips involved in Stage III and IV of AVN (100%). This confirms the earlier reports of others who have described MR as being more sensitive than plain radiography like the work done by A. Banerjee and coworkers; David J. Sartoris and coworkers[21]; Beverly G. Coleman and coworkers[27] and William G. Totty and coworkers in addition to above finding Donald G. Mitchell and coworkers[20] also stated that MRI is a

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promising modality for characterizing the extent and severity of the necrotic process and its complication.

Beltran J and coworkers compared MRI and conventional radiographs in 49 hips with AVN. They showed that MRI detected AVN in 25% of the hips during the pre-radiological stage of the disease where conventional radiographs were normal[28]. Coleman BG and coworkers[29] retrospectively reviewed radiographs and clinical records of 24 patients to correlate the morphologic appearance on magnetic resonance (MR) images of radiographically negative avascular necrosis (AVN) of the femoral head with that on computed tomographic (CT) and radionuclide scans. They found that out 27 hips were Involved In AVN and 18 hips had pre radiological disease and core decompression was performed. Afterward, progression of disease occurred in only one hip.

In the present study, out of 79 hip joints with avascular necrosis, 32 hip joints have shown the characteristic “double line” sign onT2 weighted images which accounts for 40.5%. In the study performed by Khaladkar and coworkers[17], out of 58 hip joints with avascular necrosis, 33 hip joints have shown the double line sign which accounts for 56.8%. Kokubo and coworkers[30] in his 133 MR examinations of AVN of hip, the Double Line Sign was found in 63 MR examinations (47%). In all the above studies performed, this sign was negative in the cases which were not AVN.

CONCLUSION:

The study shows that MRI of the hip joint provides an informative, diagnostic, non-invasive, quick, and accurate imaging technique for assessing hip pain and identifying various hip joint pathologies.

REFERENCES:

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1. Tibor LM, Sekiya JK. Differential diagnosis of pain around the hip joint. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2008 Dec 31;24(12):1407-21.

2. Verbeeten KM, Hermann KL, Hasselqvist M, Lausten GS, Joergensen P, Jensen CM, Thomsen HS. The advantages of MRI in the detection of occult hip fractures. European radiology. 2005 Jan 1;15(1):165-9.

3. Bluemke DA, Zerhouni EA. MRI of avascular necrosis of bone. Topics in Magnetic Resonance Imaging. 1996 Aug 1;8(4):231.

4.Khaladkar MS, Randhawa S, Singh G, Aditi G, Rajesh K, Rajeshwar S. Rapid magnetic resonance imaging protocol for detecting femoral head avascular necrosis: A case series-it's utility in the general population in developing countries. Medical Journal of Dr. DY Patil University. 2015 Mar 1;8(2):189.

5. Hungerford DS, Zizic TM. Alcoholism Associated Ischemic Necrosis of the Femoral Head: Early Diagnosis and Treatment. Clinical orthopaedics and related research. 1978 Jan 1;130:144-53.

6. Beltran J, Burk JM, Herman LJ, Clark RN, Zuelzer WA, Freedy MR, Simon S. Avascular necrosis of the femoral head: early MRI detection and radiological correlation. Magnetic resonance imaging. 1987 Jan 1;5(6):431-42.

7. Ito H, Matsuno T, Minami A. Relationship between bone marrow oedema and development of symptoms in patients with osteonecrosis of the femoral head. American Journal of Roentgenology. 2006 Mar 8;186(6):1761-70.

8. Beltran J, Knight CT, Zuelzer WA, Morgan JP, Shwendeman LJ, Chandnani VP, Mosure JC, Shaffer PB. Core decompression for avascular necrosis of the femoral head: correlation between long-term results and preoperative MR staging. Radiology. 1990 May;175(2):533-6.

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9. Markel DC, Miskovsky C, Sculco TP, Pellicci PM, Salvati EA. Core decompression for osteonecrosis of the femoral head. Clinical orthopaedics and related research. 1996 Feb 1;323:226-33.

10. Steinberg ME, Hayken GD, Steinberg DR. A quantitative system for staging avascular necrosis. Bone & Joint Journal. 1995 Jan 1;77(1):34-41.

11. Arlet J. Nontraumatic Avascular Necrosis of the Femoral Head: Past, Present, and Future. Clinical orthopaedics and related research. 1992 Apr 1;277:12-21.

12. Steinberg ME. Diagnostic imaging and the role of stage and lesion size in determining outcome in osteonecrosis of the femoral head. Techniques in Orthopaedics. 2001 Mar 1;16(1):6-15.

13. Seiler 3rd JG, Christie MJ, Homra L. Correlation of the findings of magnetic resonance imaging with those of bone biopsy in patients who have stage-I or II ischemic necrosis of the femoral head. JBJS. 1989 Jan 1;71(1):28-32.

14. Yoon TR, Song EK, Rowe SM, Park CH. Failure after core decompression in osteonecrosis of the femoral head. International orthopaedics. 2001 Feb 16;24(6):316-8.

15. Incavo SJ, Pappas CN. Diagnosis and classification of avascular necrosis of the hip. InSeminars in Arthroplasty 2004 Jul 31;15(3):140-144.

16. Netam SS, Singh R, Bichpuria S, Kumar S, Jain V. MRI in diagnosis and evaluation of AVN of femoral head in sickle cell disease and comparison with plain x ray. Journal of Evolution of Medical and Dental Sciences-JEMDS. 2015 Sep 24;4(77):13514-25.

17. Khaladkar MS, Randhawa S, Singh G, Aditi G, Rajesh K, Rajeshwar S. Rapid magnetic resonance imaging protocol for detecting femoral head avascular necrosis: A case series-it's

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 09, 2024

utility in the general population in developing countries. Medical Journal of Dr. DY Patil University. 2015 Mar 1;8(2):189.

18. Iwegbu CG, Fleming AF. Avascular necrosis of the femoral head in sickle- cell disease. A series from the Guinea Savannah of Nigeria. Bone & Joint Journal. 1985 Jan 1;67(1):29-32.

19. Lee RE, Golding JS, Serjeant GR. The radiological features of avascular necrosis of the femoral head in homozygous sickle cell disease. Clinical radiology. 1981 Jan 1;32(2):205-14.

20. Netam SS, Singh R, Bichpuria S, Kumar S, Jain V. MRI in diagnosis and evaluation of AVN of femoral head in sickle cell disease and comparison with plain x ray. Journal of Evolution of Medical and Dental Sciences-JEMDS. 2015 Sep 24;4(77):13514-25.

21. Sartoris DJ, Resnick D. MR imaging of the musculoskeletal system: current and future status. American Journal of Roentgenology. 1987 Sep 1;149(3):457-67.

22. Takatori YO, Kokubo TA, Ninomiya SE, Nakamura SH, Morimoto S, Kusaba I. Avascular necrosis of the femoral head. Natural history and magnetic resonance imaging. Bone & Joint Journal. 1993 Mar 1;75(2):217-21.

23. Gabriel H, Fitzgerald SW, Myers MT, Donaldson JS, Poznanski AK. MR imaging of hip disorders. Radiographics. 1994 Jul;14(4):763-81.

24. Guerra JJ, Steinberg ME. Distinguishing transient osteoporosis from avascular necrosis of the hip. JBJS. 1995 Apr 1;77(4):616-24.

25. Seyler TM, Marker DR, Ulrich SD, Fatscher T, Mont MA. Nonvascularized bone grafting defers joint arthroplasty in hip osteonecrosis. Clinical orthopaedics and related research. 2008 May 1;466(5):1125-32.

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 09, 2024

26. Mitchell DG, Rao V, Dalinka M, Spritzer CE, Gefter WB, Axel L, Steinberg M, Kressel HY. MRI of joint fluid in the normal and ischemic hip. American Journal of Roentgenology. 1986 Jun 1;146(6):1215-8.

27. Coleman BG, Kressel HY, Dalinka MK, Scheibler ML, Burk DL, Cohen EK. Radiographically negative avascular necrosis: detection with MR imaging. Radiology. 1988 Aug;168(2):525-8.

28. Beltran J, Burk JM, Herman LJ, Clark RN, Zuelzer WA, Freedy MR, Simon S. Avascular necrosis of the femoral head: early MRI detection and radiological correlation. Magnetic resonance imaging. 1987 Jan 1;5(6):431-42.

29. Coleman BG, Kressel HY, Dalinka MK, Scheibler ML, Burk DL, Cohen EK. Radiographically negative avascular necrosis: detection with MR imaging. Radiology. 1988 Aug;168(2):525-8.

30. Kokubo T, Takatori Y, Kamogawa M, Nakamura T, Ninomiya S, Yoshikawa K, Itai Y, Iio M, Mitamura T. Avascular necrosis of the femoral head: chronological change of MR images. Nihon IgakuHoshasen Gakkai zasshi. Nippon actaradiologica. 1990 Apr;50(4):355-66.