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TO ASSESS UTILITY OF MAGNETIC RESONANCE IMAGING IN AVASCULAR NECROSIS OF FEMORAL HEAD: A CROSS-SECTIONAL STUDY

Radiology

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ABSTRACT

Background: Avascular necrosis (AVN) of the femoral head is a common entity, characterized by bone death within the epiphysis of the femur secondary to interruption of its blood supply. MRI is used in the evaluation of AVN of femoral head because it is highly sensitive and specific for the diagnosis as it establish the diagnosis of AVN in symptomatic patients before radiographic changes become apparently visible. MRI has recently emerged as the most sensitive, specific, and widely used diagnostic tool for avascular necrosis of femural head. In most reports, MRI can diagnose very early lesions with a greater than 90 percent specificity and sensitivity based on histology or eventual regression. Screening of asymptomatic, high-risk patients may enable early intervention. The present study was planned to assess the role of MRI in the evaluation of clinically suspected cases of avascular necrosis of femoral head. **Methodology:** A prospective observational study was conducted among 50 Patients of both sexes and age groups with clinical suspicion of AVN of femoral head attended to Department of Radiodiagnosis of SAIMS & PG Institute, Indore for the duration of 15 months. Patients qualifying the inclusion and exclusion criteria were enrolled after taking written informed consent from patients or patient's relatives. Patients who did not give the consent and in whom MRI is contraindicated were excluded from the study. **Results:** The mean age of the subjects was 38.1 ± 13.085 years [range- 19 to 72 years]. The majority of the subjects were aged less than 40 years. Forty-four percent of subjects had involvement of the femur of only one side whereas 36% of subjects had involvement of both the femur. On T1 weighted MRI, most of the subjects showed no abnormality (36.8%), and 30.9% of the subjects showed hypointense areas. On T2 weighted MRI, 88.2% of the subjects showed hypointense areas, and on STIR MRI, the largest percentage of subjects showed heterogeneous areas (36.8%). The majority of the subjects had Grade IIIC AVN (31.6%), followed by those with Grade IVC. Subchondral signal abnormality was the most common MRI finding, present in 41.2% of subjects. The double line sign was present in 16.2% of subjects, and bone marrow edema was present in 48.5% of subjects, both significantly associated with AVN (p-value < 0.05). **Conclusion:** Our study findings conclude that MRI can detect early AVN changes in asymptomatic patients, which is crucial because early diagnosis is critical to preventing or delaying disease progression. Therefore, it should be the investigation of choice for screening patients at high risk for developing AVN. Promoting awareness and education regarding early diagnosis and possible prevention and delay in disease progression through MRI evaluation has long-term advantages for both individual health and the healthcare system.

KEYWORDS

MRI, Femoral head, AVN, SPECT

INTRODUCTION

Avascular necrosis (AVN), also known as osteonecrosis, can be defined as cellular death of bone due to loss of blood supply because of any reason. This loss of blood supply results in relentless progression of disease resulting in pain, loss of function and collapse. [1] AVN is a common hip pathology and usually involves epiphyseal ends of long bones particularly femur and humeral heads but small bones such as scaphoid and talus are also commonly involved. [1] A typical hip joint experiences a variety of stressors from an individual's daily activity. As it is one of the major weight-bearing joints of the body, its normal function is necessary for peaceful and enjoyable day-to-day life. Joint destruction is typically the outcome of AVN, even if patients are initially asymptomatic [2]. The clinical features usually depend upon the bone involved but the cardinal symptoms in AVN involving any bone is Pain which progress relentlessly.[3]

An increasing number of musculoskeletal disabilities are caused by avascular necrosis of the femoral head, which presents a significant diagnostic and treatment challenge. The most commonly affected site is the femoral head and patients usually present with hip and referred knee pain. [2] An ischemic damage to the femoral head is represented by femoral head AVN. It causes ischemia of femoral head resulting in death of osteocytes eventually causing collapse of femoral head. The disease starts unilaterally and progression to contralateral hip femoral head with bilateral involvement in up to 72% of the patients.[4] By convention, the term avascular (ischemic) necrosis Whereas "bone infarct" is typically reserved for metaphyseal and diaphyseal involvement, the term "avascular (ischemic) necrosis" is typically applied to areas of epiphyseal or subarticular involvement.[2] The pathophysiology of avascular AVN is not entirely understood but various factors causing AVN have a common final effect of loss of blood supply to the affected bone or a part of it. The hallmark of avascular necrosis is the death of osseous cells as a result of compromised blood vessels.[5] Avascular necrosis occurs in femoral head as it has single terminal blood supply from epiphyseal arteries that traverse from the femoral neck to supply the head. These arteries may be squeezed externally, thrombi or emboli might obstruct them, or trauma can disrupt them. The potential causes that predispose to osteonecrosis are long term steroids use, alcoholism, immuno-suppression, trauma causing femoral head and neck fractures, hip dislocation, inflammatory diseases like pancreatitis, connective tissue disease, rheumatoid arthritis, radiation therapy and haematological disorders like sickle cell anaemia, haemophilia, polycythemiaru-bravera and metabolic and endocrine disorders like pregnancy, diabetes, Cushing's syndrome, Gaucher's disease, etc.[5,6] Early identification of femoral head avascular necrosis enables conservative treatment to be successful in reducing discomfort and maintaining normal joint function. Once subchondral fracture has occurred, more aggressive therapeutic measurements such as total joint replacement are necessary, with a significant increase in morbidity.[2] Radiologic staging of the disease is of pivotal importance allowing the identification and risk stratification in pre-collapse stages, prognosis, adequate treatment planning, and post- operative follow-up.[7] Diagnostic imaging modalities used in detecting AVN include conventional radiography, computed tomography, magnetic resonance imaging (MRI), and nuclear medicine hybrid techniques like skeletal scintigraphy, and single photon emission computed tomography (SPECT).[2] Moreover, the increasing number of conservative or mini-invasive treatments has prompted the need of more advanced imaging techniques. Since its introduction, magnetic resonance (MR) imaging has attracted the attention of investigators searching for a sensitive, non-invasive test for the early detection of AVN than plain film radiography; CT scan or skeletal scintigraphy in the diagnosis of AVN[8] MRI is considered the gold standard technique in the early stages of AVN with a sensitivity of more than 99%.[9] The diagnostic test is non-invasive and free from the risk of ionizing radiation. Its outstanding soft tissue resolution and multiplanar imaging provide useful information for the early detection of AVN. MRI images clearly depict the size of the lesion, and gross estimates of the stage of disease and thus it is the investigation of choice for the accurate staging.[10] When a patient exhibits symptoms, MR imaging is mostly used to diagnose AVN before radiographic changes become noticeable. In high-risk, asymptomatic patients or in the asymptomatic contralateral hips of patients with known AVN, MR imaging can also show early

stages of the disease.[1] The sensitivity for identifying the disease in its early stages with plain film is as low as 41%.[11] Stages 0 and 1 AVN are not detectable on plain film. There may be a one to five- year interval between the development of radiographic abnormalities and the start of symptoms. A normal radiography result may not always indicate the absence of illness. This has been supplanted by the classification system of Steinberg et al, which incorporates MRI and scintigraphic findings.[12] Avascular necrosis in stage 0 (preclinical and preradiologic) can only be proposed if the contralateral hip has already been diagnosed with it. Since the invention of MRI, a patient's stage 1 (preradiologic) condition is determined by both positive MRI findings and normal radiograph results. In the early stages, there may not be any alteration in the normal signal intensity of the femural head. The first sign of AVN is nonspecific, with diffuse areas of decreased signal intensity in the high-signal-intensity fatty marrow on T1-weighted images. Focal findings along the anterosuperior aspect of the femural head are more specific, with low-signal- intensity bands or lines surrounding the area corresponding to ischemic bone on T1- and T2-weighted images. The "double-line sign" on T2-weighted images is highly specific for AVN, representing the reactive interface between normal marrow and infarcted marrow. The aim of diagnostic imaging procedures in avascular femoral head necrosis is to provide the patient with a stage-adapted therapy. Therefore, a differentiated diagnostic work- up is needed. Native radiography of the hip in two planes is still the first step. Over the past years, the diagnosis of femoral head necrosis has experienced tremendous improvement due to the use of MRI scans. Because of these improvements the correct stage can be diagnosed early and the appropriate therapy can be initiated immediately. Magnetic resonance imaging has recently emerged as the most sensitive, specific, and widely used diagnostic tool for avascular necrosis of femural head. In most reports, MRI can diagnose very early lesions with a greater than 90 percent specificity and sensitivity based on histology or eventual regression. Screening of asymptomatic, high-risk patients may enable early intervention.[13,14] In advent of same, the present study was planned to assess the role of magnetic resonance imaging (MRI) in the evaluation of clinically suspected cases of avascular necrosis of femoral head.

Objectives

To assess the utility of magnetic resonance imaging in avascular necrosis of femoral head.

MATERIAL AND METHODS

This study was done under department of Radiodiagnosis, SAMC & PGI, Indore, Madhya Pradesh for a period of 15 months after the approval from the ethical committee. 50 Patients of both sexes and age groups with clinical suspicion of AVN of femoral head referred from various department of our institute to Department of Radiodiagnosis of SAIMS & PGI for MRI were subjected to MRI after taking written informed consent. Patients qualifying the inclusion and exclusion criteria were enrolled after taking written informed consent from patients or patient's relatives.

Sample Size

A sample size of 50 patients was taken for the study. In our institute, we get on an average 2-3 cases per month of AVN FEMORAL HEAD for which MRI is being done. Therefore, we were able to achieve our sample size of 50 patients in period of 15 months).

Inclusion Criteria

Patients undergoing Magnetic resonance imaging with clinically suspicious of avascular necrosis of femoral head diseases within the study duration.

Exclusion Criteria

1. People who are not willing to give consent.
2. Patients in whom Magnetic Resonance Imaging is contraindicated.
3. Patients on life support systems.
4. Patient with claustrophobi

Methodology

Patients qualifying the inclusion and exclusion criteria were enrolled after taking written informed consent from patients or patient's relatives. The study was done on a Siemens 1.5 T MAGNETOM Symphony with Tim technology MR Machine. Routine MR pulse sequences, Sagittal-axial T1WI, Sagittal-axial T2WI, Coronal STIR were obtained. The Images were analyzed by experienced radiologist and relevant data will be noted in a Proforma. The findings were recorded on pre-structured proforma for the study and descriptive statistics will be carried out to identify characteristics of the collected data Histopathological examination was also conducted.

Statistical Analysis

The data was coded and entered into Microsoft excel 2010, analyzed by using excel 2010 and SPSS 20.0 for Windows (SPSS inc). The results of the study were tabulated and statistically analyzed. Descriptive statistics was carried out to identify the characteristics and features of collected data. Mean and Percentage was used to represent the data. Chi square test was applied to identify the association between variable, P value < 0.05 will be considered statically significant. Sensitivity, Specificity, Positive predictive value, Negative predictive value was calculated.

OBSERVATION AND RESULTS

The present study included 50 subjects. Eighteen subjects had bilateral involvement of hips whereas 32 subjects showed unilateral involvement of hips. The present study included 68 femurs from 50 subjects. Eighteen subjects had bilateral involvement of hips whereas 32 subjects showed unilateral involvement of hips. The mean age of the subjects was 38.1 ± 13.085 years [range- 19 to 72 years]. The majority of the subjects were aged less than 40 years. There were more males than females [86% vs. 14%].

Table 1. Distribution Of Study Subjects Based On Age.

Age group	Number of subjects	Percentage
19- 30 years	14	28.0
31- 40 years	17	34.0
41- 50 years	11	22.0
51- 60 years	4	8.0
61- 70 years	2	4.0
71- 80 years	2	4.0
Total	50	100.0

Table 2. Distribution Of Study Subjects Based On Laterality And Side Of Femur Involved.

Laterality	Number of subjects	Percentage
Unilateral	32	44.0
Bilateral	18	36.0
Total	50	100.0
Side affected	Number of subjects	Percentage
Right	21	42.0
Left	11	22.0
Both	18	36.0
Total	50	100.0

Table 3. Distribution Of Study Subjects Based On Findings Of T1, T2 Weighted MRI Imaging And STIR MRI.

Finding	T1 weighted MRI		T2 weighted MRI		STIR MRI	
	Number of subjects	Percentage	Number of subjects	Percentage	Number of subjects	Percentage
Hyperintense	14	20.6	6	8.8	2	26.4
Isointense	6	8.8	2	2.9	23	33.8
Hypointense	21	30.9	60	88.2	2	2.9
Heterogenous	2	2.9	0	0.0	25	36.8
No abnormality detected	25	36.8	0	0.0	0	0.0
Total	68	100.0	68	100.0	68	100.0

Table 4. Distribution Of Study Subjects Based On The Extent Of The Crescent Area Involved.

Crescent extent	Number of subjects	Percentage
No involvement	30	44.1
<15%	2	2.9
15-30%	11	16.2
>30%	25	36.8
Total	68	100.0

In the majority of the subjects, there was no involvement of the crescent area involved (44.1%). However, among those with involvement, the majority had involvement of >30%.

Table 5. Distribution Of Study Subjects Based On ARCO, FICAT & ARLET Grading Of Femoral Head With AVN

ARCO grade	Number of subjects	Percentage

IIA	1	2.6
IIB	1	2.6
IIC	1	2.6
IIIA	4	10.5
IIIB	5	13.2
IIIC	12	31.6
IVA	2	5.3
IVB	1	2.6
IVC	10	26.3
V	1	2.6
Total	38	100.0
FICAT & ARLET grade	Number of subjects	Percentage
Grade II	9	23.7
Grade III	15	39.5
Grade IV	14	36.8
Total	38	100.0

In the study, Flattening of head of femur was present in 42.6% of subjects. Joint effusion was present in 35.3% of subjects, Joint destruction was seen in 11.8% of the subjects, Dysplastic acetabulum was present in 4.45 of subjects, Dysplastic femoral head was present in 4.4% of the subjects and Subchondral cysts were present in 10.3% of subjects.

In the study, Subchondral signal abnormality was present in 41.2% of subjects, Double line sign was present in 16.2% of subjects, Bone marrow edema was present in 48.5% of subjects and The head of the femur was preserved in 83.8% of subjects.

Table 6. Comparison Of Findings Of T1 Weighted Imaging Among Subjects With And Without AVN Of Femoral Head.

T1 weighted MRI imaging		Avascular necrosis		Total	Chi-square value	df	p-value
		Yes	No				
Hyperintense	Number	14	0	14	50.972	4	<.001*
	Percentage	36.8%	0.0%	20.6%			
Isointense	Number	6	0	6			
	Percentage	15.8%	0.0%	8.8%			
Hypointense	Number	17	4	21			
	Percentage	44.7%	13.3%	30.9%			
Heterogenous	Number	0	2	2			
	Percentage	0.0%	6.7%	2.9%			
No abnormality detected	Number	1	24	25			
	Percentage	2.6%	80.0%	36.8%			
Total	Number	38	30	68			
	Percentage	100.0%	100.0 %	100.0 %			

Chi-square test. *p-value <.05 was considered statistically significant.

Table 7. Comparison Of Findings Of T2 Weighted Imaging Among Subjects With And Without AVN Of Femoral Head.

T2 weighted MRI imaging		Avascular necrosis		Total	Chi-square value	df	p-value
		Yes	No				
Hyperintense	Number	5	1	6	3.845	2	.146
	Percentage	13.2%	3.3%	8.8%			
Isointense	Number	0	0	0			
	Percentage	0.0%	0.0%	0.0%			
Hypointense	Number	2	0	2			
	Percentage	5.3%	0.0%	2.9%			
Heterogenous	Number	0	0	0			
	Percentage	0.0%	0.0%	0.0%			
No abnormality detected	Number	31	29	60			
	Percentage	81.6%	96.7%	88.2%			
Total	Number	38	30	68			
	Percentage	100.0 %	100.0 %	100.0 %			

Table 8. Comparison Of Findings Of T2 Weighted Imaging Among Subjects With And Without AVN Of Femoral Head.

STIR MRI imaging		Avascular necrosis		Total	Chi-square value	df	p-value
		Yes	No				
Hyperintense	Number	13	3	16	48.888	3	<.001*
	Percentage	34.2%	10.7%	24.2%			
Isointense	Number	0	0	0			
	Percentage	0.0%	0.0%	0.0%			
Hypointense	Number	23	0	23			
	Percentage	60.5%	0.0%	34.8%			
Heterogenous	Number	0	2	2			
	Percentage	0.0%	7.1%	3.0%			
No abnormality detected	Number	2	23	25			
	Percentage	5.3%	82.1%	37.9%			
Total	Number	38	28	66			
	Percentage	100.0 %	100.0 %	100.0 %			

Table 9. Correlation Between MRI And Histopathological Findings.

MRI finding		Histopathological finding		Total
		Avascular necrosis present	Avascular necrosis absent	
Avascular necrosis present	Number	23	1	24
	Percentage	95%	0.0%	48%
Avascular necrosis absent	Number	1	25	26
	Percentage	4.1%	96%	52%
Total	Number	24	26	50
	Percentage	100.0%	100.0%	100.0%

Kappa correlation coefficient- 1.000, p-value <.001

DISCUSSION

The mean age of the subjects was 38.1 ± 13.085 years [range - 19 to 72 years]. The majority of the subjects were aged less than 40 years. These findings were consistent with the study conducted by Khaladkar MS et al., in which the age group varied from 11 to 70 years. Maximum belonged to age group 31-40 (30.5%), followed by 21-30 (25%) and 41-50 (22.2%).[15] In the present study, there were more males than females [86% vs. 14%] with a male to female ratio of 6:1. Our study was comparable to the study of Kalekar et al. in which 36 (72%) patients were male and 14 (28%) were female.[16] In the present study, for findings related to laterality of the femur head, 44% percent of subjects had involvement of the femur of only one side whereas 36% of subjects had involvement of both the femur. The most common was the involvement of femur of right side. In a study done by Turamari R U et al. on 80 patients presenting with unilateral or bilateral hip pain it was seen that 14 patients (17.5%) presented with bilateral abnormalities.[17] In respect to finding son T1 weighted MRI, most of the subjects showed no abnormality (36.8%), and 30.9% of the subjects showed hypointense areas. On T2 weighted MRI, 88.2% of the subjects showed hypointense areas, and on STIR MRI, the largest percentage of subjects showed heterogeneous areas (36.8%). The most common MRI finding in our study was Subchondral signal abnormality and it was present in 41.2% of subjects. Double line sign was present in 16.2% of subjects. Bone marrow edema was present in 48.5% of subjects. The head of the femur was preserved in 83.8% of subjects. In a study by Turamari et al. on 80 patients with painful hips, 28 cases were that of AVN. The dominant findings were focal subchondral signal abnormality (100%), marrow edema (40%), and double line sign (34.2%). These results are similar to our study. [17]In the majority of the subjects, there was no involvement of the crescent area involved (44.1%). However, among those with involvement, the majority had involvement of >30%. Flattening of head of femur was present in 42.6% of subjects. Joint effusion was present in 35.3% of subjects. Joint destruction was seen in 11.8% of the subjects. According to the ARCO grading, majority of the subjects had Grade IIIC AVN (31.6%), followed by those with Grade IVC. In a study done by Kamal D et al. shows 51.09% of patients with grade IV and 34.78% of patients with grade III AVN.[18] Saleem et al reported Stage II and III AVN was more common in age group of 21-30 years whereas stage IV AVN was more common in age group of 41-50 years. [1]

According to FICAT & ARLET grading, majority of the subjects had grade III (39.5%) and Grade IV AVN (36.8%). Gehlot PS et al in their study reported that stage-III was commonest in age group 21 to 40 years and 41 to 60 years of age and stage-III and IV being equally involved in age group of 61 and above years. This was comparable with results of our study.[10]

The findings of T1 weighted MRI imaging showed that most of the subjects without AVN show no abnormality on T1 weighted imaging. Most of the subjects with AVN showed hypointense (44.7%),

hyperintense (36.8%) and isointense (15.8%) areas. The findings of T1 weighted MRI imaging were significantly different between subjects with and without AVN (p-value <.05). The findings of T2 weighted MRI imaging was non-significantly different between subjects with and without AVN (p-value >.05). The findings of STIR MRI imaging was non-significantly different between subjects with and without AVN (p-value >.05). The findings of T2 weighted MRI imaging including hypertense, Hyperintense, Isointense, Hypointense and Heterogenous areas was non-significantly different between subjects with and without AVN (p-value >0.05). In the present study, Subchondral signal abnormality, Double line sign were significantly associated with AVN (p-value <0.05). Incidence of preserved head of femur, joint effusion, joint destruction, dysplastic acetabulum, dysplastic femur head, marginal osteophytes and subchondral cysts were significantly associated with pathologies of femur head other than AVN (p-value <0.05). Bone marrow edema, flattening of head of femur were found to have no significant association with pathologies of femur with or without AVN (p- value >0.05). This was comparable to study done by Kaushal L et al and Turamari et al. Turamari et al. on 80 patients with painful hips, 28 cases were that of AVN. The dominant findings were focal subchondral signal abnormality (100%), marrow edema (40%), and double line sign (34.2%). These results are similar to our study.[17] Also, in a study done by Kaushal L et al., the dominant MRI findings were focal subchondral signal abnormality (96%), double line sign (48%). These findings are same as our study except for bone marrow edema which in seen in 92% cases in their study.[19] We also compared the diagnostic accuracy of MRI with histopathological findings and a statistically significant perfect correlation between MRI and histopathological findings in the diagnosis of avascular necrosis of femoral head (p-value <0.05). MRI demonstrated a high Sensitivity of 95.83%, specificity of 96.15%, positive predictive value of 95.83%, negative predictive value of 96.15%, and overall accuracy of 96% was observed for MRI in the diagnosis of vascular necrosis of femoral head. Tripathy et al. reported magnetic resonance imaging is the most sensitive diagnostic modality for ONFH. MRI has sensitivity of 90-100% and specificity of 100% in diagnosis of avascular necrosis (AVN). This was comparable to our study [20]. Since joint preserving measures have much better prognosis when diagnosis of AVN is made in early course of disease and since result of joint replacement therapy are poorer in young age groups, diagnosis of AVN as early as possible is critical to prevent or delay progression of disease. MRI is excellent for picking up early AVN changes that are far beyond to be seen on plain radiographs. Also, all the well-known manifestations of AVN can be well appreciated on MRI. It can be concluded from the findings that MRI possessed high diagnostic potential in early diagnosis of avascular necrosis of the femoral head as demonstrated high overall accuracy of 96%, Sensitivity of 95.83%, specificity of 96.15%, positive predictive value of 95.83%, negative predictive value of 96.15%.

CONCLUSION

There was a statistically significant perfect correlation between MRI and histopathological findings in the diagnosis of avascular necrosis of the femoral head (p-value < 0.05). MRI demonstrated a high sensitivity of 95.83%, specificity of 96.15%, positive predictive value of 95.83%, negative predictive value of 96.15%, and overall accuracy of 96% in diagnosing avascular necrosis of the femoral head. It can be inferred that MRI can detect early AVN changes in asymptomatic patients, which is crucial because early diagnosis is critical to preventing or delaying disease progression. Therefore, it should be the investigation of choice for screening patients at high risk for developing AVN. Promoting awareness and education regarding early diagnosis and possible prevention and delay in disease progression through MRI evaluation has long-term advantages for both individual health and the healthcare system.

Limitation of study: The only limitation we found in our study was that while analysing the scans we could have quantified the extent of the femoral head involvement through which we can predict the prognosis of the patient.

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