Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

Magnetic Resonance Imaging in Evaluation of Avascular Necrosis of Femoral Head

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Abstract

Introduction: Avascular necrosis (AVN) of the femoral head is one of the common causes of pain and disability of hip. Impaired blood supply and increased intraosseous pressure are predominantly responsible for the necrotic process, which eventually results in collapse of the femoral head. Magnetic resonance imaging (MRI) is the preferred investigation for the evaluation of AVN.

Aims and Objectives: This study aims to assess the role of MRI in the evaluation of clinically suspected cases of AVN of hip and to describe the imaging features along with proper staging.

Materials and Methods: In this prospective study, 100 patients of all age groups with clinically suspected cases of AVN of femoral head were evaluated by MRI hip in the Department of Radiodiagnosis, Gandhi Medical College and Hamidia Hospital over a period of 1 year. Detailed history and associated risk factors were asked from all patients. MRI hip was then performed on 1.5 Tesla Hitachi ECHELON SMART - 523 MRI machine using the required protocol and sequences. The imaging findings were studied and proper staging was given.

Results: In our study of 100 cases of AVN, 132 femoral heads were involved (unilateral 68 and bilateral 32 cases). The most common risk factor associated was alcohol consumption. The most common quadrant of femoral head affected was anterosuperior (49.3%). The most common stage of AVN was found to be Grade III – 39.4% (Ficat and Arlet classification), Type C – 47% (Mitchell's classification), and Stage IIIC – 37.8% (Steinberg classification). MRI could detect early AVN in 50 femoral heads, in which radiographs were normal.

Conclusion: This study concludes that MRI is the modality of choice for diagnosing and staging AVN. Early diagnosis and appropriate treatment is associated with better outcome.

Key words: Avascular necrosis, Hip, Magnetic resonance imaging

INTRODUCTION

A normal hip joint is subjected to various stresses during daily activities of an individual. 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.

Avascular necrosis (AVN) of the femoral head is one of the common causes of painful hip in a young adult. Impaired blood supply and increased intraosseous pressure are predominantly responsible for the necrotic process. The natural course of this disease is one of the relentless progressions with eventual collapse of the femoral head followed by secondary osteoarthritic changes in the hip.[1] Bilateral presentation is frequently seen and males are more commonly affected. Contralateral hip may be affected in about 55% of the patients within 2 years.[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.[3] Diagnostic imaging modalities used in detecting AVN include conventional radiography, computed tomography, magnetic resonance imaging (MRI), and nuclear medicine hybrid techniques.[4] Moreover, the increasing number of conservative or mini-invasive

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www.ijss-sn.com

Month of Submission : 08-2019
Month of Peer Review : 09-2019
Month of Acceptance : 10-2019
Month of Publishing : 10-2019

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treatments has prompted the need of more advanced imaging techniques. MRI is considered the gold standard technique in the early stages of AVN with a sensitivity of more than 99%.[5] It is non-invasive diagnostic test without the risk of ionizing radiation and provides valuable information in detecting early AVN due to its excellent soft tissue resolution and multiplanar imaging. Hence, the aim of our study is to diagnose AVN of femoral heads and to study the spectrum of imaging findings depicted on MRI for proper staging, which helps in subsequent treatment.

MATERIALS AND METHODS

The study is a prospective study on 100 patients with clinically suspected cases of AVN referred to the Department of Radiodiagnosis, Gandhi Medical College and Hamidia Hospital, Bhopal. The study was undertaken over a period of 1 year after taking written informed consent from all patients. A detailed history with a special emphasis on risk factors for AVN such as history of trauma, alcohol or steroid intake was asked. Relevant clinical notes and laboratory parameters for hemoglobinopathies were reviewed in all patients undergoing MRI for AVN.

Inclusion Criteria

The following criteria were included in the study:

1. Patients with clinically suspected case of AVN of hip with unilateral or bilateral hip pain
2. Patients of all age groups and both sexes.

Exclusion Criteria

The following criteria were excluded from the study:

1. Patients with contraindication for MRI such as cardiac pacemakers, ferromagnetic metallic implants, cochlear implants, and aneurysmal clips
2. Patients with claustrophobia
3. Patients who refused consent.

MRI hip was performed on 1.5 Tesla MRI Hitachi ECHELON SMART - 523 machine with the help of dedicated surface coil. Patients were asked to lie in a supine position and both hips were scanned simultaneously using hip protocol. The sequences obtained were T1 weighted, T2 weighted, short-tau inversion recovery, proton-density fat saturation coronal with sagittal images, and T1-weighted and T2-weighted axial images. Based on MRI findings, modified Fiat and Arlet, Steinberg, and Mitchell classifications were determined in all the cases for staging of AVN.

RESULTS

In our study of 100 patients with clinically suspected case of AVN with hip pain, we observed the following results:

- The age range was from 10 to 74 years. The maximum number of cases, i.e., 28 was in the age group of 21–30 years [Table 1].
- There was a male predominance with 69 male patients and 31 female patients [Table 2].
- The most common risk factor for AVN was alcohol consumption seen in 46 cases (40%), followed by post-traumatic AVN cases 17 (17%), sickle cell disease associated with multiple bony infarcts was seen in 16 cases (16%), and idiopathic cases were 14, while six patients had a history of steroids intake and one patient had received radiotherapy [Table 3].
- The total number of femoral heads affected was 132, of which 68 cases were unilateral and 32 were bilateral [Table 4].
- The most common MRI findings in AVN of femoral head were abnormal focal subchondral signal abnormality (geographic pattern) which was seen in 72 patients. The other common MRI findings were bone marrow edema, double-line sign, subchondral cyst, subarticular collapse of femoral head, osteophytes, and joint effusion [Table 5].
- The most common quadrant of femoral head involved was the anterosuperior quadrant which was affected in 65 femoral heads (49.3%) [Table 6].
- According to Ficat and Arlet classification of AVN, of 132 femoral heads, Grade III was most commonly encountered which was present in 52 femoral heads (39.4%) [Table 7].
- According to Mitchell classification based on MRI signal characteristics within the center of the lesion, Type C (signal analogous to that of fluid) was the most common seen in 62 femoral heads (47%) [Table 8].
- According to Steinberg classification based on MRI findings, Stage IIIC was the most common stage seen in 50 femoral heads (37.8%) [Table 9].

DISCUSSION

In our prospective study of 100 patients with clinically suspected cases of AVN, 69 patients were male and 31 patients were female with male:female ratio of 2.2:1. The mean age of patients was 38.35 years which was similar to the study conducted by Reddy *et al.*[6] where the mean age was 37.63 years. It was 35.3 in the study conducted by Kumar *et al.*[7] and 47.5 years in the study by Gupta *et al.*[8] Most of the patients in our study belong to the age group of 31–40 years which was similar to the study conducted by Kakaria *et al.*[1] as risk factors for AVN such as alcohol and trauma occur more frequently in this age group. In our study, 46 patients gave a positive history of alcohol intake. In the study conducted by Kakaria *et al.*,[1] 35% of patients gave a history of alcohol intake. The exact mechanism of

how alcohol leads to AVN is not known; however, several studies have concluded that excessive fatty substances are produced and get deposited in small blood vessels of bone. This blockage leads to decreased blood flow to femoral head causing bone death. Jacob *et al.*[9] concluded that alcoholism-induced bone necrosis is caused by fat embolism linked to coexistent hyperlipidemia. Thus, alcohol intake can be considered as high-risk factor for the development of AVN.

In our study, a history of steroid intake was present in 6% of patients. In the study conducted by Reddy *et al.*,[6] 6.67% of patients had a history of steroid use. Wu *et al.*[10] in his study concluded fat hypertrophy, intravascular coagulation, and fat emboli as important risk factors of steroid-induced ischemic bone necrosis which may develop during initial 1 year of steroid intake.

In this study of 100 patients, unilateral AVN was seen in 68 patients while bilateral cases were 32; thus, the total number of femoral heads affected was 132. Unilateral AVN was mostly associated with a history of trauma.

Table 1: Age distribution

Age groups (in years)	Number of cases	Percentage
1–10	1	1
11–20	18	18
21–30	26	26
31–40	28	28
41–50	16	16
51–60	8	8
61–70	3	3

Table 2: Gender distribution in patients of AVN

Gender	Number of patients	Percentage
Male	69	69
Female	31	31

AVN: Avascular necrosis

Table 3: Risk factors for AVN

Risk factors	Number of patients (*n*=100)	Percentage
Idiopathic	14	14
Steroids	6	6
Alcohol	46	46
Trauma	17	17
Sickle cell disease	16	16
Radiotherapy	1	1

AVN: Avascular necrosis

The most common quadrant of femoral head involved in our cases of AVN was anterosuperior, seen in 65 femoral heads (49.3%) followed by anteromedial compartment seen in 40 femoral heads (30.4%). Gabriel *et al.*[11] in his study observed that MRI finding along the anterosuperior aspect of femur is specific for AVN. Nishii *et al.*[12] in his study showed that the location and size of the lesion are the prognostic indicators of collapse and large necrotic lesions have likelihood to involve anterosuperior aspect of femoral head.

In our study, the most common MRI finding of AVN was focal subchondral abnormality seen in 92 femoral heads (69.7%), followed by diffuse marrow edema seen in 72 femoral heads (54.5%), double-line sign (55 femoral heads, 41.6%) which is seen on T2-weighted image and consists of inner bright line representing granulation tissue with surrounding dark zone representing adjacent sclerotic bone, subchondral cysts (42 femoral heads, 31.8%), subarticular collapse of femoral heads (24 femoral heads, 18.2%), osteophytes (15 femoral heads, 11.3%), and joint effusions (52 femoral heads, 39.4%). Sixteen patients of AVN with sickle cell disease were associated with multiple bone infarcts [Figure 1].

According to Ficat and Arlet[13] classification of AVN, we observed that Grade I AVN (10 femoral heads, 7.5%) revealed diffuse marrow edema in the femoral head [Figure 2] and Grade II AVN (40 femoral heads, 30.4%) revealed focal geographical area of signal alteration in subchondral region of femoral head with double-line sign [Figure 3]. In the double-line sign, there is a combination of a hypointense peripheral border (sclerosis) and a hyperintense inner border (granulation tissue). Grade III AVN (52 femoral heads, 39.4%) revealed disruption of the normal contour of the femoral head with eventual cortical collapse [Figure 4]. Grade IV AVN (30 femoral heads, 22.7%) revealed subarticular collapse of femoral head associated with advanced degenerative changes of hip [Figure 5]. Thus, Grade III AVN was the most common seen in our studies. MRI was found to be highly sensitive in the evaluation of early AVN, i.e., Grade I and Grade II (10 and 40 femoral heads, respectively) which plain radiographs failed to detect.

Mitchell classification[14] of AVN is divided into four stages based on MRI signal within the center of the lesion.

Table 4: Unilateral versus bilateral AVN

Total number of patients having AVN	Number of patients having unilateral AVN	Number of patients having bilateral AVN	Number of femoral heads affected by AVN
100	68	32	132

AVN: Avascular necrosis

Table 5: MRI findings in AVN

MRI findings	Number of femoral heads	Percentage
Focal subchondral signal abnormality (geographic pattern)	92	69.7
Bone marrow edema	72	54.5
Subchondral cyst	42	31.8
Subarticular collapse of femoral head	24	18.2
Osteophytes	15	11.3
Joint effusion	52	39.4
Double-line sign	55	41.6

Double-line sign seen on T2-weighted sequence which consists of inner bright line representing granulation tissue and surrounding dark zone representing adjacent sclerotic bone. AVN: Avascular necrosis, MRI: Magnetic resonance imaging

Table 6: Distribution according to the location of lesion in femoral head

Location/quadrant	Number of femoral heads affected (*n*=132)	Percentage
Anterosuperior	65	49.3
Anteromedial	40	30.4
Anterolateral	5	3.7
Complete	22	16.6

Table 7: Distribution of AVN cases according to Ficat and Arlet classification

Grade	Number of femoral heads affected (*n*=132)	Percentage
Grade I	10	7.5
Grade II	40	30.4
Grade III	52	39.4
Grade IV	30	22.7

AVN: Avascular necrosis

Table 8: Distribution of AVN cases according to Mitchell classification (based on signal intensity within the lesion of femoral head)

Type	Total number of femoral heads affected (*n*=132)	Percentage
Type A	11	8.3
Type B	25	19
Type C	62	47
Type D	34	25.7

AVN: Avascular necrosis

- Stage A – Signals similar to fat
- Stage B – Signals similar to blood
- Stage C – Signals similar to fluid
- Stage D – Signals similar to fibrosis.

In our study, Stage C was the most common finding seen in 62 femoral heads (47%) [Figure 6] followed by Stage D comprising 34 femoral heads (25.7%) [Figure 7]. Stage A representing early disease and Stage D representing late disease. Similar findings were seen in a study conducted by Goyal *et al.*[15]

Table 9: Distribution of AVN cases according to Steinberg classification of AVN based on MRI findings

Grade	Number of femoral heads affected (*n*=132)	Percentage
Grade IA	2	1.5
Grade IIA	6	4.5
Grade IIB	13	9.8
Grade IIC	15	11.7
Grade IIIA	1	0.7
Grade IIIB	7	5.4
Grade IIIC	50	37.8
Grade IVA	2	1.5
Grade IVB	1	0.7
Grade IVC	2	1.5
Grade VA	0	0
Grade VB	2	1.5
Grade VC	2	1.5
Grade VI	29	21.9

AVN: Avascular necrosis, MRI: Magnetic resonance imaging

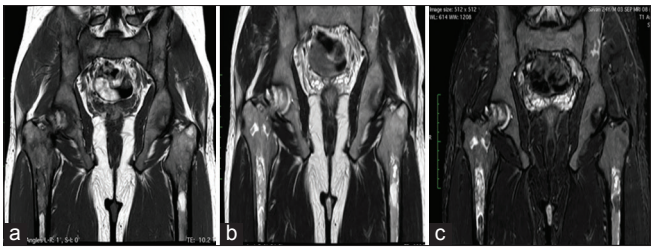

Figure 1: Case of sickle cell disease showing multiple bone infarcts in bilateral femur, associated with advanced stage of osteonecrosis in bilateral femoral heads. (a) T1 coronal. (b) T2 coronal. (c) Short-tau inversion recovery coronal

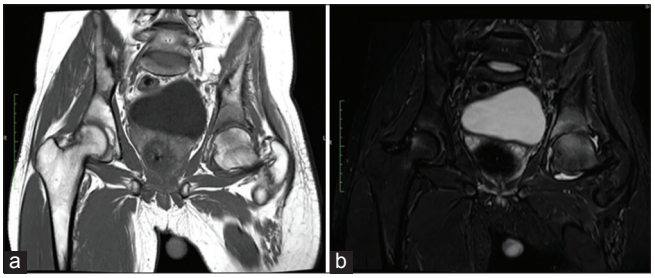

Figure 2: Case of Grade 1 avascular necrosis (Ficat and Arlet classification) of the left femoral head showing diffuse marrow edema. (a) T1 coronal. (b) Short-tau inversion recovery coronal

Steinberg *et al.*[16] classified AVN from Stage 0 to Stage VI based on the imaging findings and further quantified the extent of involvement of hip as follows:

- Stage 0 – Normal radiograph, normal bone scan
- Stage I – Normal radiograph, abnormal bone scan/MRI
- Stage II – Sclerosis and/or cyst formation in femoral head
  a. Mild: <15% head involvement
  b. Moderate: 15–30%
  c. Severe: >30%

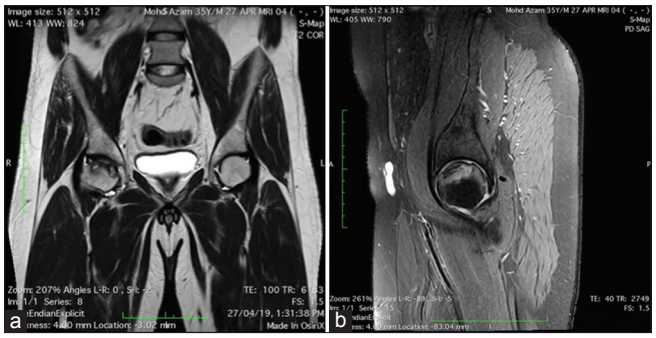

Figure 3: Case of Grade II avascular necrosis (Ficat and Arlet classification) showing focal subchondral area of signal alteration in anterosuperior quadrant of the right femoral head with double-line sign (seen on T2-weighted sequence and consists of inner bright line representing granulation tissue and surrounding dark zone representing sclerosis). (a) T2 coronal. (b) Proton-density (fat sat) sagittal

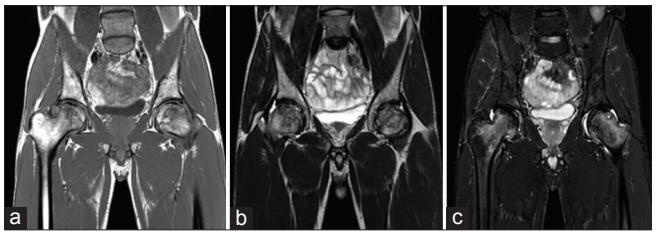

Figure 4: Case of bilateral avascular necrosis. Grade III (Ficat and Arlet classification) showing irregular articular surface of bilateral femoral heads with altered marrow signals and adjacent short-tau inversion recovery (STIR) hyperintense marrow edema. (a) T1 coronal. (b) T2 coronal. (c) STIR coronal

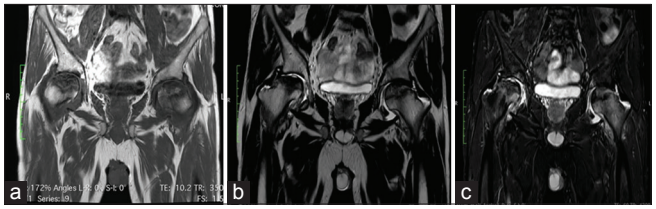

Figure 5: Partial collapse of the right femoral head and geographic area of altered signal intensity in the left femoral head noted, which is appearing hypointense on coronal T1- and T2-weighted images with adjacent short-tau inversion recovery (STIR) hyperintense marrow edema. Findings are suggestive of Grade IV avascular necrosis (AVN) on the right side and Grade II AVN on the left side (Ficat and Arlet classification) associated with bilateral hip joint effusion. (a) T1 coronal. (b) T2 coronal. (c) STIR coronal

- Stage III – Subchondral collapse (crescent) without flattening
  a. Mild: <15% of articular surface
  b. Moderate: 15%–30%
  c. Severe: >30%
- Stage IV – Flattening of femoral head without joint space narrowing
  a. Mild: <15% of surface has collapsed and depression is <2 mm

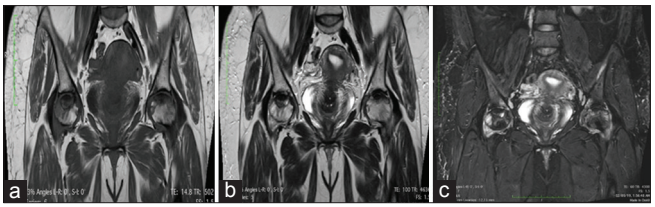

Figure 6: Coronal images showing hyperintense signal on T2-weighted images and hypointense signal on T1-weighted images within the necrotic foci in the right femoral head, suggestive of Type C avascular necrosis (Fluid and Mitchell's classification). (a) T1 coronal. (b) T2 coronal. (c) Short-tau inversion recovery coronal

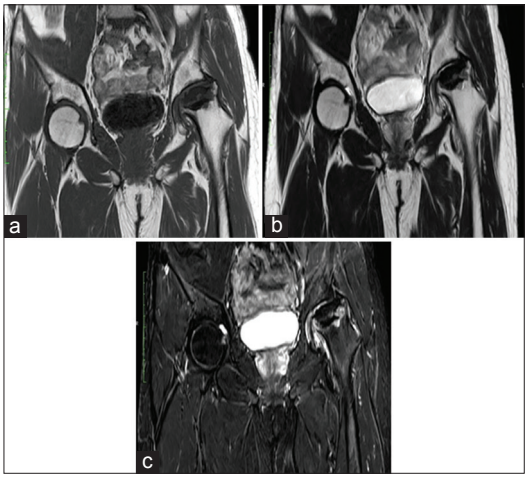

Figure 7: Coronal images showing hypointense signal on T1- and T2-weighted images in the left femoral head suggestive of Type D avascular necrosis (fibrosis and Mitchell's classification). (a) T1 coronal. (b) T2 coronal. (c) Short-tau inversion recovery coronal

  b. Moderate: 15%–30% collapsed or 2–4 mm depression
  c. Severe: >30% collapsed or >4 mm depression
- Stage V – Flattening of femoral head with joint space narrowing as for Stage IV plus estimate of acetabular involvement
  a. Mild
  b. Moderate
  c. Severe
- Stage VI – Advanced degenerative changes of hip joint.

In our study, Stage IIIC was the most common seen comprising 50 femoral heads (37.8%) followed by Stage VI (29 femoral heads, 21.9%). Four patients showed acetabular involvement. It was also observed that if the lesion is seen involving <30% of femoral head then there is low risk of collapse, if lesion is seen involving between 30% and 50% then there is moderate risk of collapse, and if >50% involvement is seen then there is high risk of collapse of femoral head. Thus, collapse is directly proportional to

femoral head involvement; similar findings were also seen in the studies done by Beltran *et al*.[17]

CONCLUSION

MRI has distinct advantage over other modalities in being radiation free, non-invasive, excellent soft tissue contrast, multiplanar imaging capability, and high sensitivity in detecting osteonecrosis of femoral head. We diagnosed a large number of patients with early AVN where radiographs were normal and also detected AVN on contralateral hip in patients with advanced stage. Thus, MRI is the modality of choice for staging of AVN which helps in early and accurate treatment of the patients.

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How to cite this article: Choudhary J, Dubepuria A, Kaushal L, Rajput P. Magnetic Resonance Imaging in Evaluation of Avascular Necrosis of Femoral Head. Int J Sci Stud 2019;7(7):50-55.

Source of Support: Nil, **Conflict of Interest:** None declared.