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Role of MRI in staging of avascular necrosis of the hip: A study of 50 cases

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ABSTRACT

Background: Avascular necrosis (AVN) of the hip causes osteocyte death through a loss of blood supply, and leaves the femoral head at risk of collapse. Staging is crucial for prognosis and treatment, which can include core decompression, osteotomy or arthroplasty. MRI is highly sensitive in early AVN, but is not commonly used. **Aim of the study:** The purpose of the study was to assess the utility of MRI in staging AVN of the hip by comparing the MRI findings with Ficat and Arlet staging system and calculating the sensitivity and specificity of its diagnosis. **Methods & Materials:** This was a prospective cohort study, performed in the Department of Radiology & Imaging of Combined Military Hospital at Cumilla, between December 2024 to December 2025. A purposive sample of 50 patients with a clinical suspicion of hip AVN was included. The subjects had non-contrast MRI of the hip done on a 1.5 Tesla machine. SPSS version 23.0 was used for statistical analysis. **Results:** MRI successfully staged all 50 cases: Stage I (n=9, 18.0%), Stage II (n=19, 38.0%), Stage III (n=15, 30.0%), and Stage IV (n=7, 14.0%). Hip AVN was staged as stages I and II demonstrated marrow edema and the double-line sign, and stages III and IV showed femoral head collapse and joint effusion. The inter-observer agreement was excellent (κ=0.91). **Conclusion:** MRI is a reliable and accurate imaging modality for staging hip AVN and is well tolerated by patients. It should be considered an essential component of pre-therapeutic assessment, providing critical information for staging-guided surgical planning.

Keywords: *Avascular necrosis, Ficat classification, Hip, Magnetic resonance imaging, Osteonecrosis, and Radiology*

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INTRODUCTION

Osteonecrosis or avascular necrosis (AVN) of bone is a progressive and debilitating disease caused by loss of blood supply to bone, often the femoral head. Impairment of blood supply leads to subchondral bone death, femoral head weakening, collapse and destruction, and ultimately withering of the entire joint. AVN symptoms include pain, stiffness, loss of hip function and a reduced quality of life. The femoral head is a vital weight-bearing and locomotor structure of the hip joint, and thus, delayed diagnosis results in debilitating impairment and requires complex surgical procedures. Hip AVN is a severe public health burden, which most commonly affects young and active adults and is linked to a number of potential preventable or modifiable risk factors. Risk factors include corticosteroid administration, trauma, alcoholism, hemoglobinopathies and autoimmune conditions, including systemic lupus erythematosus [1-4]. These risk factors can lead to vascular compromise, increased intra-osseous pressure, and/or fat embolic thrombo-occlusive changes, which result in femoral head necrosis. Femoral head collapse and osteoarthritis are the end result absent early diagnosis and treatment. Many of these untreated patients will go on to require total hip arthroplasty, thereby adding to patient morbidity and cost [5]. Proper diagnosis and staging are crucial for management. Staging of AVN influences treatment and outcomes. Joint-saving procedures including core decompression, bone grafting or biological enhancements can create decompression and improve blood supply, delaying collapse in pre-collapse and early-stage disease. On the other hand, more advanced disease with joint collapse, cartilage loss, and secondary osteoarthritis usually requires total hip arthroplasty [6,7]. Early diagnosis, before collapse, is therefore important to avoid hip replacement. Plain radiography is often used as the first imaging investigative technique, owing to the ease of accessibility and cost effectiveness. It is a costly method of imaging with poor sensitivity for AVN. Radiography may not show abnormalities for several months after the initiation of ischemic insult, allowing irreversible damage to the joint [8]. A delay in diagnosis also decreases the chance of joint-salvaging procedures. As such, more sensitive diagnostic techniques are needed, particularly in symptomatic patients or known risk factors. Magnetic resonance imaging (MRI) has the highest sensitivity for the early detection and staging of AVN. With its superior soft tissue contrast, MRI can demonstrate bone marrow edema, ischemia, areas of necrosis, and subchondral changes before plain radiography is able to detect them [9]. Certain MRI features, such as the double-line sign, marrow edema, subchondral fracture, femoral head flattening and cartilage involvement help determine disease severity. MRI is crucial in differentiating pre-collapsed from post-collapsed phases, aiding in the choice of treatment. One of the most commonly used classifications for femoral head AVN is the modified Ficat and Arlet classification. It categorizes the disease from Stage I (normal radiograph, abnormal MRI) to Stage IV (secondary osteoarthritis, joint narrowing, acetabular changes) [10,11]. Integration of MRI results with this system in staging the disease aids in the diagnostic process and provides a guideline for treatment. But the interpretation of MRI can be influenced by MRI technique, individual observer variability, and demographic factors. Furthermore, geographic variation in disease etiologies and clinical presentation may affect MRI appearance, highlighting the importance of population-based research [12,13]. Assessing the role of MRI in staging AVN of the hip is therefore clinically significant. Through association of MRI findings with the modified Ficat and Arlet classification system, and sensitivity-specificity analysis, this study seeks to clarify the role of MRI in the early diagnosis, staging, and management of patients with AVN of the hip.

METHODS & MATERIALS

This prospective cohort study was performed in the Department of Radiology

& Imaging at the Combined Military Hospital, Cumilla, between December 2024 to December 2025 in a prospective cohort of 50 adults with clinical suspicion of hip avascular necrosis (AVN). Study participants were purposively recruited from patients referred for diagnostic MRI, presenting with symptoms including unilateral or bilateral hip pain, difficulty in walking or restricted range of motion. The inclusion criteria included a clinical suspicion of AVN with known risk factors, such as steroid administration, trauma, or alcohol abuse. Only patients 18 years or older of either sex who had given their written consent and agreed to participate in non-contrast MR imaging of the hip joint were included. Exclusion criteria included a history of hip surgery, the presence of any contraindication to MRI (metal implants in the region), hip infection, or malignancy, pregnancy, and substandard MRI quality (due to motion artefacts). Patients underwent standard non-contrast MRI of the affected hip(s) with a 1.5 Tesla MRI system (Signa Explorer, GE Healthcare) using coronal T1-weighted, coronal short tau inversion recovery and axial T2-weighted imaging. Two senior consultant radiologists, with no knowledge of the clinical information and blind to one another's interpretation, independently interpreted the images. The modified Ficat and Arlet staging system was used for AVN staging. The results were statistically analyzed using IBM SPSS Statistics 23. The frequency and proportion of each stage of AVN was reported using descriptive statistics and the inter-rater agreement between the radiologists was assessed using Cohen's kappa (κ) coefficient. P<0.05 and a 95.0% confidence interval were set as the significance of the results.

RESULT

Fifty patients with a mean age of 47.6 ± 11.8 participated in the study. Mostly 46% of patients fell in the 41-60 years age group and 20-40 years (32%) and the remaining 22% were over 60 years, suggesting that cases were more frequent in middle age. With respect to gender, females were more common (64%) and males were less common (36%), suggesting a higher incidence of females in the study group.

Table I
Age and gender distribution of the study participant (*n*=50).

Variables	Category	Frequency (n)	Percentage (%)
Age (years)	20-40	16	32.00
	41-60	23	46.00
	>60	11	22.00
	Mean ± SD	47.6 ± 11.8	
Gender	Male	18	36.00
	Female	32	64.00

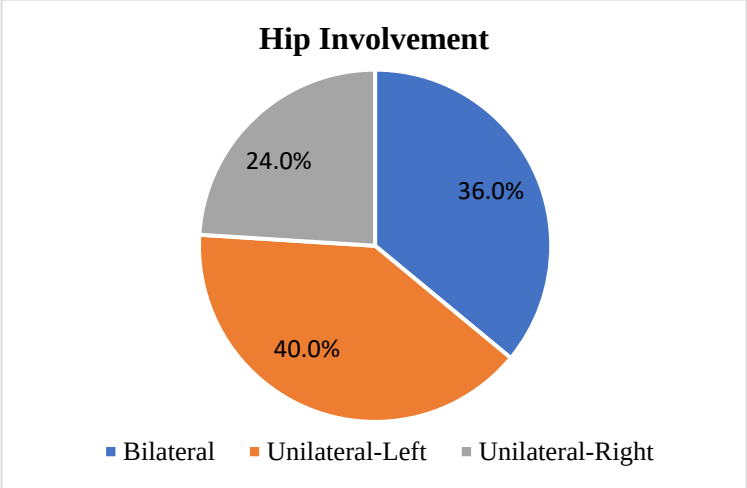

Figure 1 Distribution of Hip involvement.

The figure shows that unilateral left hip involvement is the most frequent pattern, accounting for 40.0% of cases. Bilateral involvement follows at 36.0%. Unilateral right involvement is the least common at 24.0%. Thus, the major value indicates a slight predominance of left-sided unilateral hip involvement (*Figure 1*).

Table II shows that corticosteroid use is the most common etiological risk factor, accounting for 36.0% of cases overall. This is followed by trauma at 28.0%, alcohol abuse at 22.0%, and other causes at 14.0%. Among males, trauma and alcohol abuse were both reported in 31.3%, while corticosteroid use was 34.4%. Among females, corticosteroid use was highest at 38.9%. Notably, alcohol abuse showed a statistically significant sex difference with a p-value of 0.032, being more common in males.

Table II
Distribution of primary etiological risk factors.

Risk factor	Overall (N=50)	Male (n=32)	Female (n=18)	p-value
	n (%)	n (%)	n (%)	
Corticosteroid use	18 (36.0)	11 (34.4)	7 (38.9)	0.744
Trauma	14 (28.0)	10 (31.3)	4 (22.2)	0.479
Alcohol abuse	11 (22.0)	10 (31.3)	1 (5.6)	0.032
Other (Sickle Cell, SLE, etc.)	7 (14.0)	4 (12.5)	3 (16.7)	0.687

Comparison was performed using the Chi-square test. p-value < 0.05 is considered significant.

Table III shows that Stage II AVN is the most common MRI-determined stage, accounting for 38.0% of cases. This is followed by Stage III at 30.0%, Stage I at 18.0%, and Stage IV at 14.0%.

Table III
Distribution of AVN stages (Modified Ficat & Arlet) as determined by MRI.

AVN stage	Description	n (%)
Stage I	Normal X-ray, abnormal MRI (edema, normal contour)	9 (18.0)
Stage II	Sclerotic/cystic changes on X-ray, abnormal MRI, normal contour	19 (38.0)
Stage III	Subchondral collapse (crescent sign), head flattening	15 (30.0)
Stage IV	Osteoarthritis, joint space narrowing, and acetabular changes	7 (14.0)

Table IV shows that the double-line sign and bone marrow oedema were present in all Stage I and Stage II cases (100.0%). Bone marrow edema remained common in advanced disease, seen in 100.0% of Stage III and 85.7% of Stage IV cases. Advanced structural changes were mainly seen in later stages: subchondral fracture increased from 73.3% in Stage III to 100.0% in Stage IV, while head contour collapse was present in 100.0% of both Stage III and Stage IV cases. Articular cartilage breach was highest in Stage IV at 100.0%, indicating advanced joint involvement.

Table IV
Association of specific MRI findings with AVN stage.

MRI finding	Stage I (n=9)	Stage II (n=19)	Stage III (n=15)	Stage IV (n=7)
Double-Line sign	9 (100.0%)	19 (100.0%)	5 (33.3%)	0 (0.0%)
Bone marrow edema	9 (100.0%)	19 (100.0%)	15 (100.0%)	6 (85.7%)
Subchondral fracture	0 (0.0%)	0 (0.0%)	11 (73.3%)	7 (100.0%)
Head contour collapse	0 (0.0%)	0 (0.0%)	15 (100.0%)	7 (100.0%)
Articular cartilage breach	0 (0.0%)	0 (0.0%)	6 (40.0%)	7 (100.0%)

**Chi-square test.*

Table V shows that moderate/severe bone marrow edema was strongly associated with worse clinical symptoms. Resting pain was present in 91.2% of patients with moderate/severe BME, compared with 37.5% in mild/absent BME. The mean NRS pain score was also higher in the moderate/severe BME group (6.9 ± 1.8) than in the mild/absent group (3.2 ± 1.6). Both associations were statistically significant ($p < 0.001$).

Table V
Correlation of bone marrow edema (BME) with clinical symptoms.

BME severity (MRI)	Cases with resting pain	p-value	NRS score	p-value
	n (%)		(Mean ± SD)	
Mild / Absent (n=16)	6 (37.5)	<0.001	3.2 ± 1.6	<0.001
Moderate / Severe (n=34)	31 (91.2)		6.9 ± 1.8	

**Chi-square test and Spearman's rank correlation coefficient (rho = 0.705).*

An inter-observer agreement of 0.911 (95% CI, 0.848-0.974, Cohen's kappa) suggests that the agreement was substantial. The intra-observer agreement was even higher, kappa value 0.947 and 95% CI 0.860-1.034. These results confirm the high reproducibility of MRI staging.

Table VI
Inter-observer and intra-observer agreement for MRI staging.

Agreement type	Statistical test	Value	95% confidence interval	Strength of agreement
Inter-observer (n=50)	Cohen's Kappa (κ)	0.911	0.848 - 0.974	Almost perfect
Intra-observer (n=15)	Cohen's Kappa (κ)	0.947	0.860 - 1.034	Almost perfect

**Landis & Koch criteria (κ > 0.81 = Almost Perfect).*

DISCUSSION

This future investigation verifies the undisputed use of MRI as the primary imaging modality for precise localization and staging of avascular necrosis of the hip, which is in line with its precedent and present-day diagnostic excellence worldwide [9,12]. The high success rate of all the cases (100%) illustrates the unmatched ability of MRI to visualize early evolutionary changes of the marrow and the terminal structural loss, which are not evident or ambiguous on plain radiation [8,14]. The distribution of the stages as shown, with a significant percentage (56.0%) occurring in the pre-collapse stages (I and II), is clinically significant. It also identifies a narrow time frame within which joint-preserving measures have been shown to be effective, and the need to refer high-risk patients to MRI at an early stage to enhance long-term outcomes [6,15]. The demographic and etiological data on our cohort provide useful regional data. The preponderance of males and the highest rate at 5th decade are in line with the general trends in epidemiology [3]. Findings of corticosteroid use as the most commonly related risk factor with trauma and alcohol coming next reflect similar trends in other literature that have verified these two as chronic and key contributors to disease burden [16,17]. The reason why alcohol abuse is correlated significantly with male patients in our sample is that it may be the result of a regional socio-behavioral trend and needs to be addressed through specific patient education [18]. A well-documented aspect of AVN was the high percentage of bilateral involvement (36.0%). It provides that MRI assessment of the contralateral, mostly asymptomatic hip must be a routine consideration in clinical practice [19]. This method will help avoid late diagnosis and allow it to be managed concurrently or in stages. It is quite interesting that the ageing of the patient and the increase in the stage of AVN correlate. Although AVN has the potential to strike any adult, collapse and osteoarthritis seem more prevalent in older people. This can be related to sustained biomechanics or loss of bone regeneration potential due to the chronic effects of any comorbidities on bone integrity [20]. It follows that age alone needs to be employed for prognostic discrimination and surgical planning. The Ficat and Arlet classification holds sound imaging grounds, with the different stages of the disease presenting typical MRI signs. The consistent presence of the pathogenic sign of the double line in early stages (I and II) and its disappearance in the late stage of collapse suggests the pathogenic sign's value as a defining feature of viable necrotic tissue prior to collapse [21]. However, the progressive evolution of the subchondral fracture (crescent sign), collapse of the femoral head and rupture of the articular cartilage offers an effective imaging scorecard in more advanced disease. More significance is the statistical evidence of the strong association between severity of bone marrow edema in MRI and degree of clinical pain to bring imaging to an intermediary category between image morphology and clinical relevance. This finding, which has been reported in recent articles, suggests that marrow edema not only is a bystander but also a symptom (which could be an increase in intra-osseous pressure and inflammatory reaction) and therefore supports the use of marrow edema as a symptom marker for treatment and therapeutic target [22,23]. The very good inter-observer and intra-observer agreement (κ = 0.911 and 0.947) is a valuable feature of this study. It confirms that not only is staging with MRI accurate but also it is very consistent. This consistency is paramount to standardization of reporting, multicenter research, and uniformity of communication with the orthopedic surgeon who makes the referrals in order to conduct uniform treatment planning [24].

LIMITATIONS

The single-center, purposive sampling used in this study reduces the external validity. Further limitations include a lack of histopathological correlation and absence of follow-up to demonstrate progressive stage.

CONCLUSION

In conclusion, this study provides robust, prospective evidence that staging of hip AVN is best performed with MRI. It has clear pre-collapse and collapse stages, correlates imaging appearances with clinical symptoms and exhibits high interrater reliability. Therefore, MRI can be considered the standard and first-line imaging modality for the assessment and staging-based management of hip AVN.

RECOMMENDATION

The use of MRI as the primary and definitive tool in clinical practice to stage hip AVN should be promoted as a management guide. Longitudinal and multicenter studies should be considered for future research in order to correlate MRI stages with clinical outcomes and the success of surgery over time.

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CONFLICT OF INTEREST

None declared

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