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Research Article

Correlation of Plain Radiographic Findings with Magnetic Resonance Imaging in the Evaluation of Avascular Necrosis of the Femoral Head

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Abstract: ***Introduction:*** Avascular necrosis (AVN) of the femoral head is a debilitating condition caused by ischemic osteocyte death, often progressing to subchondral collapse and requiring hip arthroplasty in young patients. Plain radiography has poor sensitivity for early-stage disease, whereas MRI offers superior detection with the characteristic "double-line sign" and can identify disease before radiographic changes appear. This study correlates plain radiographic and MRI findings in clinically suspected AVN cases across different disease stages, emphasizing the importance of early detection for successful joint-preserving treatment.**Objective:** Avascular necrosis (AVN) of the femoral head is a common cause of musculoskeletal disability in which delayed diagnosis leads to joint collapse. Plain radiographs are insensitive in early disease, whereas magnetic resonance imaging (MRI) detects lesions before radiographic change. This study aimed to analyse clinically suspected AVN with subtle radiographic findings using MRI and to correlate plain radiographic with MRI findings across the stages of AVN. **Methods:** This cross-sectional study was conducted in the Department of Radiodiagnosis, Victoria Hospital, Bangalore Medical College and Research Institute, between August 2022 and January 2024. Thirty-five consecutively sampled patients aged over 18 years with non-traumatic clinically suspected AVN underwent plain radiography (anteroposterior and frog-leg lateral) and MRI on a 1.5 Tesla scanner. Findings from both modalities were staged using the Ficat and Arlet system. Data were analysed with Epi Info using descriptive statistics, the chi-square test, diagnostic performance metrics and Pearson correlation, with $p < 0.05$ considered significant. **Results:** Patients were predominantly male (57.1%) with a mean age of 45.3 years. Groin pain (71.4%) was the commonest presentation. Radiography classified 14.3% as Stage I, whereas MRI classified 22.9% as Stage I, reflecting the superior early detection by MRI. Radiographic and MRI stages were concordant in 60.0% of patients and discordant in 40.0%, chiefly in early disease. Compared with MRI, radiography showed a sensitivity of 68.6%, specificity of 85.7%, positive predictive value of 82.1%, negative predictive value of 74.3% and overall accuracy of 77.1%. Radiographic and MRI stages were strongly correlated (Pearson $r = 0.78$; $p < 0.001$).**Conclusion:** MRI is essential for accurate early diagnosis and staging of femoral head AVN, while radiography remains a valuable complementary tool in advanced disease.

Keywords: Avascular necrosis; Femoral head; Magnetic resonance imaging; Plain radiography; Ficat and Arlet classification.

INTRODUCTION

Avascular necrosis (AVN) of the femoral head is increasingly recognised as a significant cause of musculoskeletal disability that poses considerable challenges in diagnosis and treatment. Although patients are frequently asymptomatic at onset, the disease commonly progresses to subchondral collapse and joint destruction, often necessitating total hip arthroplasty before the fifth decade of life [1]. The condition represents ischaemic death of osteocytes and marrow within the epiphyseal or subarticular femoral head; the term “bone infarct” is conventionally reserved for metaphyseal and diaphyseal involvement, whereas “avascular (ischaemic) necrosis” describes epiphyseal or subarticular disease, with osseous cell death due to vascular impairment being the defining feature [1,2,3].

An estimated 10,000 to 20,000 new cases are diagnosed annually in the United States, and AVN accounts for approximately 10% of the 250,000 hip arthroplasties performed each year [1,4]. The reported prevalence is around 0.01% in German-speaking countries and 1.9 per 100,000 in Japan [5]. Men are affected three to five times more often than women, and treatment is typically undertaken in the fourth decade [6]. The femoral head is the most commonly affected site, with patients presenting with hip and groin pain and referred knee discomfort [1]. Causes are traumatic or atraumatic: femoral neck fracture and hip dislocation account for osteonecrosis in approximately 15–50% and 10–25% of cases respectively, while more than 80% of non-traumatic cases are attributable to chronic corticosteroid therapy and excessive alcohol use [2,7]. Additional associations include sickle cell disease, systemic lupus erythematosus and other autoimmune disorders, pancreatitis, radiation exposure, and infiltrative conditions such as Gaucher’s disease and Caisson disease [1,2]. The femoral head derives most of its blood supply from the medial and lateral circumflex femoral

branches of the profunda femoris, with limited collateral flow through the cruciate and trochanteric anastomoses; interruption of this supply produces osteocyte death, articular surface collapse and secondary degenerative arthritis [2,3].

Diagnostic imaging aims to tailor treatment to the stage of disease. Initial evaluation typically employs plain radiography of the hip in two planes, but its sensitivity for early (stage 0 and stage 1) disease is as low as 41%, and a one- to five-year interval may separate the onset of symptoms from radiographic change; a normal radiograph therefore does not exclude disease [3]. Ficat and Arlet devised a widely used staging system that integrates radiographic, MRI and clinical features [8], and the Steinberg system additionally incorporates scintigraphic and MRI findings [7]. MRI has emerged as the most sensitive available modality, detecting very early lesions with greater than 90% sensitivity and specificity based on histological correlation [9]. Characteristic MRI features include a low-signal reactive band demarcating necrotic from viable marrow and the highly specific "double-line sign" on T2-weighted images, as well as class A to D signal patterns that correlate with the stage of disease [10,11]. Single photon emission computed tomography (sensitivity approximately 85%) and computed tomography (sensitivity approximately 55%) provide complementary information but are less sensitive than MRI for early disease [12,13].

Because early detection of femoral head AVN materially improves the success of conservative treatment and joint preservation, and because plain radiographs may remain normal despite established disease, accurate correlation of the two modalities is clinically important. This study was therefore undertaken to analyse clinically suspected AVN cases with subtle plain radiographic findings using MRI, and to correlate plain radiographic with MRI findings across the different stages of AVN of the femoral head.

MATERIALS AND METHODS

Study design and setting

This was a cross-sectional study conducted in the Department of Radiodiagnosis, Victoria Hospital, Bangalore Medical College and Research Institute, Bengaluru, over an 18-month period from August 2022 to January 2024. Patients presenting to the outpatient and inpatient departments of the attached hospitals with signs and symptoms suggestive of AVN of the femoral head formed the source population. Institutional Ethics Committee approval was obtained before commencement, and the study conformed to the Declaration of Helsinki.

Participants

Consecutive sampling was used. All patients referred to the department with a clinical suspicion of AVN of the hip who satisfied the eligibility criteria were enrolled.

Inclusion criteria were: (1) patients more than 18 years of age; (2) non-traumatic, clinically suspected cases of AVN with unilateral or bilateral groin, buttock, thigh or knee pain, deformity or limitation of the range of hip movement; and (3) patients giving consent for MR imaging.

Exclusion criteria were: (1) patients with non-AVN causes of hip, thigh or knee pain; (2) patients with claustrophobia; and (3) patients with pre-existing hip pathology.

Written informed consent was obtained from every eligible patient after the procedure had been explained, and demographic and clinical information was recorded on a structured study proforma.

Sample size

The sample size was estimated for the comparison of two population proportions. Using a two-tailed level of significance with $Z_{1-\alpha/2} = 1.96$ and $Z_{\beta} = -1.28$, and anticipated population proportions of 0.75 and 0.99, the calculated sample size was n = 29. After allowing for a non-response rate of 10% ($29 + 3 = 32 \approx 35$), the final sample size was 35. The study was accordingly undertaken on 35 subjects.

Imaging technique / protocol

No specific patient preparation was required. Suspected cases first underwent plain radiography of the hip in anteroposterior (AP) and frog-leg lateral projections, followed by MR imaging. MR examinations were performed on a Siemens Magnetom Avanto 1.5 Tesla scanner. Technicians positioned patients by palpating the greater trochanter to ensure image acquisition at the correct level. A limited protocol of coronal T1-weighted images was acquired initially using a body coil for radiofrequency transmission and reception, followed by a full examination in axial, coronal and sagittal-oblique planes comprising T1-weighted, T2-weighted, gradient-recalled echo (GRE-T2) and short tau inversion-recovery (STIR) sequences, including coronal T1WI, coronal T2WI, axial T1WI, axial T2WI and oblique sagittal T2WI acquisitions. The findings of plain radiography and MRI were analysed and correlated across all stages of the Ficat and Arlet system.

Statistical analysis

Data were entered into Microsoft Excel and analysed using Epi Info software, and presented through tables and diagrams. Descriptive statistics including mean, proportion and standard deviation were computed. The chi-square test was used as a test of significance. The diagnostic performance of radiography against MRI was expressed as sensitivity, specificity, positive predictive

value (PPV) and negative predictive value (NPV), together with overall diagnostic accuracy, and the agreement between the two staging assignments was assessed using Pearson's correlation coefficient. A p value < 0.05 was considered statistically significant.

All 35 consecutively enrolled patients underwent both plain radiography and MRI and were staged by both modalities; there were no post-enrolment exclusions or missing imaging data, so the entire cohort was included in the analysis.

RESULTS

A total of 35 patients diagnosed with AVN of the femoral head were studied. The cohort was predominantly male, comprising 20 males (57.1%) and 15 females (42.9%) (Table 1). The mean age was 45.3 years with a range of 18 to 70 years; the largest group was the 40–49 year age band, accounting for 28.6% of patients, indicating that AVN predominantly affected middle-aged individuals (Table 2).

Table 1. Gender distribution of the study population (n = 35).

Gender	Number of patients (n = 35)	Percentage (%)
Male	20	57.1
Female	15	42.9

Table 2. Age distribution of the study population (mean age 45.3 years; range 18–70 years).

Age group (years)	Number of patients (n = 35)	Percentage (%)
18–29	5	14.3
30–39	8	22.9
40–49	10	28.6
50–59	7	20.0
60–70	5	14.3

Table 3. Clinical presentation of patients.

Clinical symptom	Number of patients (n = 35)	Percentage (%)
Groin pain	25	71.4
Buttock pain	18	51.4
Thigh pain	12	34.3
Knee pain	10	28.6
Deformity	8	22.9
Limitation of movement	15	42.9

The clinical presentation was dominated by groin pain, reported by 25 patients (71.4%), followed by buttock pain (18 patients, 51.4%), limitation of hip movement (15 patients, 42.9%), thigh pain (12 patients, 34.3%), knee pain (10 patients, 28.6%) and deformity (8 patients, 22.9%) (Table 3; Figure 1). These findings reflect the progressive nature of AVN, in which localised pain from femoral head ischaemia advances to more widespread pain and functional impairment.

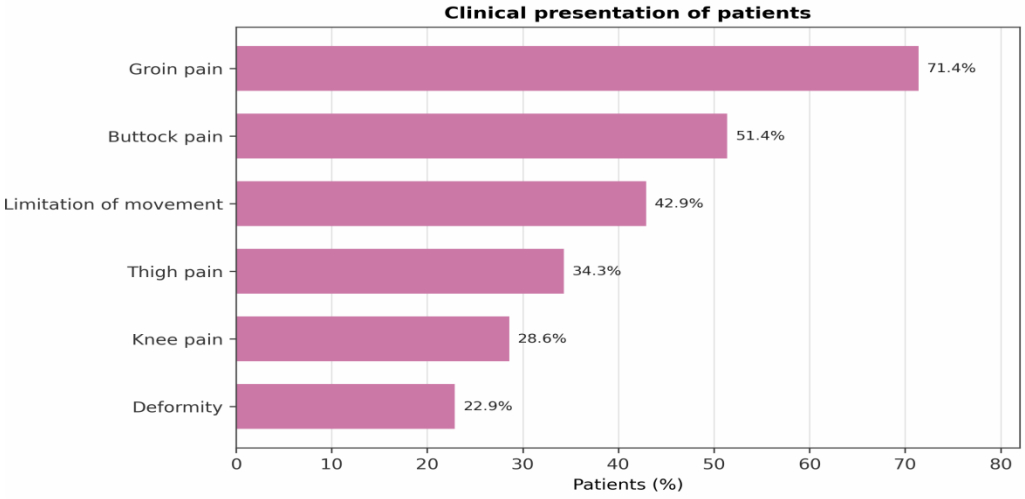

Figure 1. Frequency of presenting clinical symptoms among the 35 patients with avascular necrosis of the femoral head, ranked from most to least common; groin pain was the commonest presentation (71.4%), followed by buttock pain and limitation of hip movement (data from Table 3).

On plain radiography, staging by the Ficat and Arlet classification distributed patients as Stage I in 14.3%, Stage II in 28.6%, Stage III in 34.3% and Stage IV in 22.9% (Table 4). A substantial proportion of patients therefore presented in advanced radiographic stages (Stages III and IV), in which subchondral fracture, joint space narrowing and femoral head collapse are more evident. On MRI, again staged by the Ficat and Arlet system, patients were classified as Stage I in 22.9%, Stage II in 34.3%, Stage III in 28.6% and Stage IV in 14.3% (Table 5). The higher proportion of early-stage disease (Stages I and II) identified by MRI compared with radiography reflects the superior sensitivity of MRI for detecting bone marrow oedema and early necrosis (Figure 2).

Table 4. Radiographic findings according to the Ficat and Arlet classification.

Ficat and Arlet stage	Number of patients (n = 35)	Percentage (%)
Stage I	5	14.3
Stage II	10	28.6
Stage III	12	34.3
Stage IV	8	22.9

Table 5. MRI findings according to the Ficat and Arlet classification.

Ficat and Arlet stage	Number of patients (n = 35)	Percentage (%)
Stage I	8	22.9
Stage II	12	34.3
Stage III	10	28.6
Stage IV	5	14.3

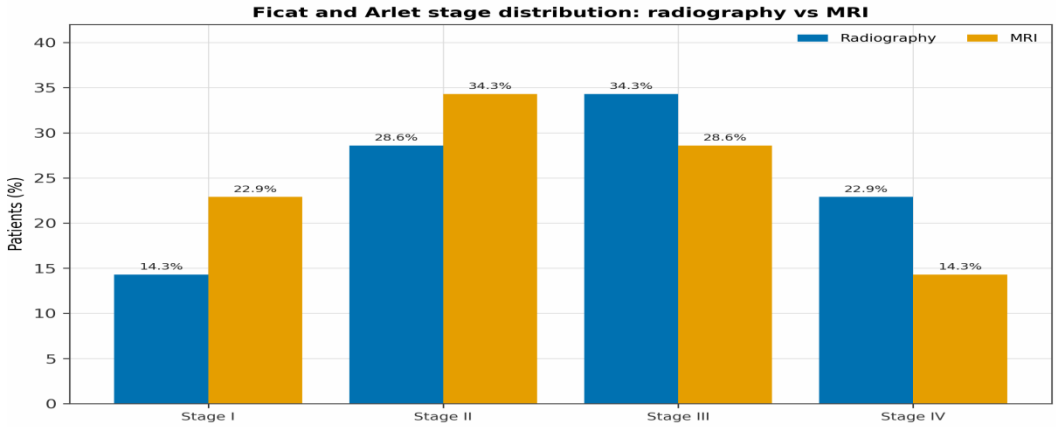

Figure 2. Distribution of patients across Ficat and Arlet stages by imaging modality; radiography assigned a greater proportion of patients to advanced stages (III and IV), whereas MRI identified more early-stage (I and II) disease (data from Tables 4 and 5).

Table 6. Accordance and discordance between radiographic and MRI findings.

Category	Number of patients (n = 35)	Percentage (%)
Accordance	21	60.0
Discordance	14	40.0

Comparison of the two modalities showed accordance in 21 patients (60.0%), in whom the radiographic and MRI stages matched, and discordance in 14 patients (40.0%), in whom the stages differed (Table 6; Figure 3). The patient-level comparison of radiographic and MRI staging is presented in Table 7; discordance occurred predominantly in early-stage disease, where radiography under-staged relative to MRI.

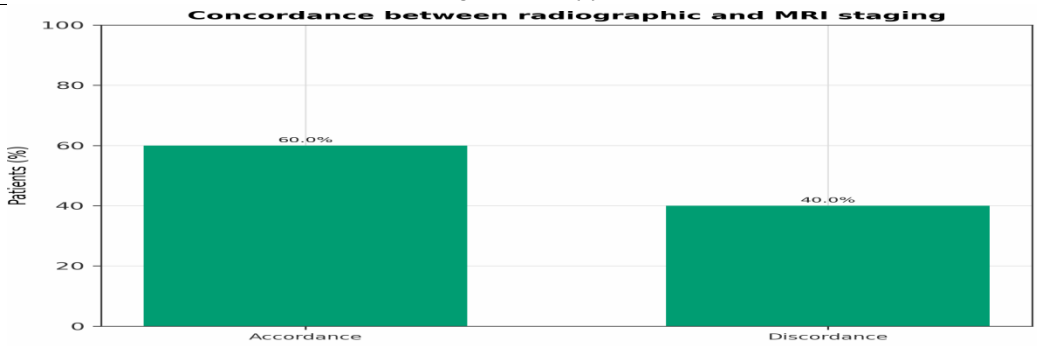

Figure 3. Overall agreement between radiographic and MRI Ficat and Arlet staging; the two modalities were concordant in 60.0% of patients and discordant in 40.0%, with discordance concentrated in early-stage disease (data from Table 6).

The diagnostic performance of plain radiography against MRI is summarised in Table 8. Radiography demonstrated a sensitivity of 68.6%, specificity of 85.7%, PPV of 82.1% and NPV of 74.3%, with an overall diagnostic accuracy of 77.1% (Figure 4). The stages identified by radiography and MRI were strongly and positively correlated, with a Pearson correlation coefficient of 0.78 ($p < 0.001$), indicating that although radiography is less sensitive in early disease, it aligns closely with MRI in more advanced stages.

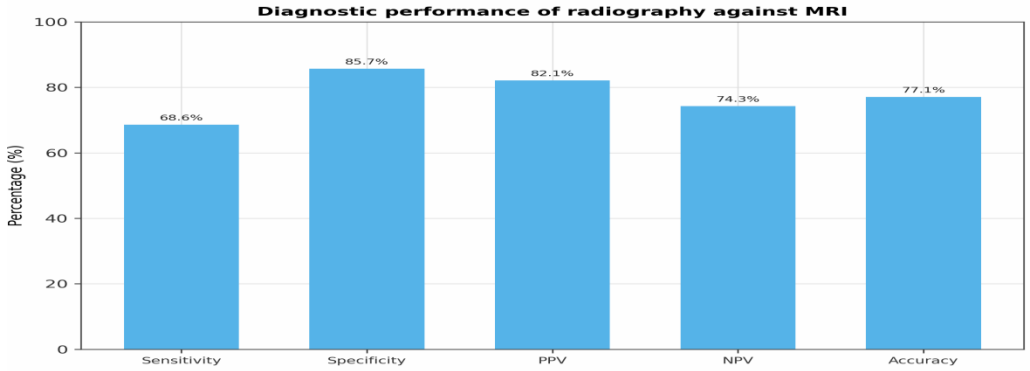

Figure 4. Diagnostic performance of plain radiography against MRI as the reference standard, showing sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy; specificity (85.7%) exceeded sensitivity (68.6%), reflecting radiography's limited detection of early disease (data from Table 8).

Table 7. Patient-level comparison of radiographic and MRI staging.

Patient ID	Radiographic stage (Ficat and Arlet)	MRI stage (Ficat and Arlet)	Accordance (Yes/No)
1	Stage I	Stage I	Yes
2	Stage II	Stage II	Yes
3	Stage III	Stage III	Yes
4	Stage IV	Stage IV	Yes
5	Stage II	Stage III	No
6	Stage III	Stage IV	No
7	Stage I	Stage II	No
8	Stage III	Stage III	Yes
9	Stage IV	Stage IV	Yes
10	Stage II	Stage II	Yes
11	Stage III	Stage III	Yes
12	Stage I	Stage II	No
13	Stage II	Stage III	No
14	Stage III	Stage IV	No
15	Stage I	Stage I	Yes
16	Stage IV	Stage IV	Yes
17	Stage II	Stage II	Yes
18	Stage III	Stage III	Yes
19	Stage II	Stage III	No
20	Stage III	Stage IV	No
21	Stage I	Stage I	Yes
22	Stage II	Stage II	Yes
23	Stage III	Stage III	Yes

24	Stage IV	Stage IV	Yes
25	Stage II	Stage II	Yes
26	Stage III	Stage IV	No
27	Stage I	Stage II	No
28	Stage II	Stage III	No
29	Stage III	Stage IV	No
30	Stage I	Stage I	Yes
31	Stage II	Stage II	Yes
32	Stage III	Stage III	Yes
33	Stage IV	Stage IV	Yes
34	Stage II	Stage III	No
35	Stage III	Stage IV	No

Table 8. Diagnostic performance and correlation of plain radiography against MRI.

Metric	Value
Sensitivity	68.6%
Specificity	85.7%
Positive predictive value	82.1%
Negative predictive value	74.3%
Overall diagnostic accuracy	77.1%
Correlation of radiographic vs MRI stage (Pearson r)	0.78
p-value	< 0.001

Table 9. Distribution of AVN in bilateral versus unilateral cases.

AVN distribution	Number of patients (n = 35)	Percentage (%)
Bilateral	18	51.4
Unilateral	17	48.6

Table 10. Duration of symptoms before diagnosis.

Duration (months)	Number of patients (n = 35)	Percentage (%)
< 3	8	22.9
3–6	12	34.3
6–12	10	28.6
> 12	5	14.3

AVN was almost equally distributed between bilateral and unilateral involvement, with 18 patients (51.4%) having bilateral disease and 17 patients (48.6%) having unilateral disease (Table 9). The duration of symptoms before diagnosis varied: 22.9% of patients reported symptoms for less than 3 months, 34.3% for 3–6 months, 28.6% for 6–12 months and 14.3% for more than 12 months (Table 10), indicating that a substantial proportion of patients experienced symptoms for several months before diagnosis.

DISCUSSION

Avascular necrosis of the femoral head is a serious and progressive condition that may culminate in hip joint collapse and considerable disability if not diagnosed and managed promptly. This study evaluated and correlated the diagnostic performance of plain radiography and MRI in identifying and staging AVN, a comparison that is important because early detection and accurate staging are decisive in preventing further joint deterioration and improving outcomes. Previous work has emphasised the limited sensitivity of plain radiographs in early disease; Mitchell et al. reported a radiographic sensitivity of only 45% for early AVN compared with 99% for MRI [14]. By quantifying the correlation between the two modalities in a single cohort, the present study offers practical guidance for selecting the most appropriate imaging strategy in suspected AVN.

The cohort of 35 patients showed a male predominance (57.1%) and a mean age of 45.3 years, with the highest prevalence in the 40–49 year group. These demographics closely mirror those of Mont et al., who reported a similar male predominance (60%) and a mean age of 42 years [15]. The higher prevalence in men is plausibly related to lifestyle factors such as higher rates of alcohol consumption and corticosteroid exposure, both established risk factors for AVN, and reinforces the need for heightened clinical vigilance in middle-aged patients presenting with hip pain.

The clinical presentation was dominated by groin pain (71.4%), followed by buttock pain, limitation of movement, thigh pain, knee pain and deformity, a pattern consistent with the progressive ischaemic pathophysiology of the disease. Agarwal et al. similarly reported groin pain as the commonest symptom, in approximately 70% of their patients [16]. Recognition of this typical symptom complex is important for prompting timely diagnostic imaging and intervention before irreversible joint damage occurs.

Radiographic staging revealed that a majority of patients presented in advanced stages, with 34.3% in Stage III and 22.9% in Stage IV. This is comparable to Shah et al., who found that around 60% of their patients presented with Stage III or IV disease on radiographs [17]. The predominance of advanced radiographic stages at first presentation indicates that many patients seek medical attention only after substantial joint damage has developed, and underscores the limitations of radiography for early detection. In contrast, MRI classified a greater proportion of patients in early stages (22.9% in Stage I and 34.3% in Stage II), reflecting its capacity to detect bone marrow oedema, early necrotic change and subtle structural alteration that are invisible on radiographs. Hauzeur et al. similarly demonstrated that MRI could detect AVN in 94% of early-stage cases compared with 56% for radiography [18].

The finding that radiographic and MRI stages were concordant in only 60% of patients, with 40% discordance concentrated in early disease, is a central result of this study. Tripathy et al. reported a comparable discordance of approximately 35% between radiographic and MRI findings in early-stage AVN [19]. The discordance arose chiefly where radiography appeared normal or showed only subtle change while MRI identified established pathology, demonstrating that reliance on radiography alone risks under-diagnosis or misclassification and consequent delay in treatment. Integrating MRI into the diagnostic pathway therefore ensures a more complete evaluation, particularly for patients with early symptoms.

The diagnostic performance of radiography against MRI—sensitivity 68.6%, specificity 85.7%, PPV 82.1% and NPV 74.3%—indicates that radiography is fairly reliable for advanced disease but insufficiently sensitive for early detection. These values are closely aligned with those of Marcus et al., who reported a radiographic sensitivity of 65% and specificity of 88% for early AVN [20]. The high specificity means that radiographic changes, when present, are likely to represent true AVN, but the moderate sensitivity and NPV highlight the risk of false-negative studies in early disease. The strong positive correlation between radiographic and MRI stages (Pearson $r = 0.78$; $p < 0.001$) is consistent with the correlation coefficient of 0.80 reported by Jones et al. [21], and supports the use of radiography as a complementary tool—especially for follow-up and where MRI is unavailable—while affirming that it should not be relied upon alone for early diagnosis. The overall diagnostic accuracy of radiography relative to MRI was 77.1%, comparable to the 75% accuracy reported by Zaltz et al. against 95% for MRI [22].

AVN was almost equally distributed between bilateral (51.4%) and unilateral (48.6%) involvement. Powell et al. similarly reported bilateral involvement in about 50% of their cohort [23]. Bilateral disease suggests a systemic aetiology, frequently associated with corticosteroid use, alcohol consumption and systemic disorders, and warrants comprehensive assessment and monitoring of both hips. The duration of symptoms before diagnosis was frequently prolonged, with more than 40% of patients symptomatic for six months or longer; Kelly et al. likewise observed an average symptom duration of around seven months before diagnosis [24]. This insidious course argues for greater awareness among patients and clinicians and a lower threshold for cross-sectional imaging so that AVN is identified and treated before joint collapse.

Taken together, these findings carry clear implications for clinical practice. The pronounced discordance between radiography and MRI in early disease supports incorporating MRI into the diagnostic protocol for all suspected cases, given its superior sensitivity and specificity for early diagnosis and accurate staging, which in turn guides appropriate therapeutic intervention. Understanding the demographic and clinical profile of AVN aids identification of at-risk populations, and accurate staging enables individualised, stage-appropriate management. These conclusions are in keeping with Hartley et al., who emphasised the role of MRI in early diagnosis and individualised treatment of hip osteonecrosis [25]. Future work should pursue larger, multicentre and longitudinal cohorts and investigate the genetic and molecular mechanisms underlying AVN, as advocated by Sugano et al., to inform preventive strategies and novel therapies [26].

STRENGTHS AND LIMITATIONS

The main strength of this study is the direct, patient-level correlation of plain radiographic and MRI staging within a single prospectively enrolled cohort assessed by a uniform imaging protocol on a 1.5 Tesla scanner, which allowed diagnostic performance and correlation to be quantified against MRI as the reference standard. Several limitations should nonetheless be acknowledged. The relatively small sample size of 35 patients may limit the generalisability of the findings. The cross-sectional design precludes assessment of disease progression and long-term outcomes. The study was conducted at a single tertiary care centre, which may introduce selection bias. As noted by Berghs et al., larger and more diverse studies with longitudinal follow-up are needed to validate these observations and to provide a more comprehensive understanding of AVN [27].

CONCLUSION

This study highlights the critical role of MRI in the accurate diagnosis and staging of AVN of the femoral head. While plain radiographs are valuable for initial assessment and monitoring, their limited sensitivity in early-stage disease underscores the necessity of MRI for comprehensive evaluation. The strong correlation between radiographic and MRI findings in advanced stages supports the complementary use of both modalities. Early diagnosis and timely intervention are essential for preventing disease progression and improving patient outcomes, and the findings reinforce the importance of integrating MRI into the diagnostic pathway and tailoring treatment strategies to accurate staging and patient-specific factors. Future research should focus on deepening the understanding of AVN, exploring preventive strategies and optimising treatment, consistent with the emphasis of Glimcher and Kenzora on early MRI diagnosis in improving outcomes [28].

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