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Research Paper

Avascular Necrosis of the Femoral Head Imaging Evaluation by Magnetic Resonance Imaging (A Retrospective Study)

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ABSTRACT:

BACKGROUND:

Avascular necrosis of the femoral head is a frequent cause of musculoskeletal disability. Its preoperative staging is of utmost importance in determining the appropriate treatment option.

OBJECTIVE:

Magnetic Resonance evaluation of the distribution and staging of avascular necrosis of the femoral head among a sample in Duhok City, Kurdistan region of Iraq.

PATIENTS AND METHODS:

In this retrospective cross-sectional study, data were collected from one hundred patients of various ages ,conducted from May 2022 to November 2023 to those patients who were referred and diagnosed with avascular necrosis from specialized orthopedics at specialized hospitals in Duhok city, magnetic resonance imaging study with different sequences suitable to the hip region has been undergone .Data included information about the demographic and imaging distribution of the patients with avascular necrosis of the femoral heads in addition to their imaging evaluation following the Ficat - Arlet and Mitchell classifications.

RESULTS:

The age group most affected by the disease is between twenties and forties, accounting for 56% of the cases. Males show statistically significant higher percentages than females, making up 86% of the total number. Bilateral involvement is more common than unilateral involvement, accounting for 62% compared to 38%. Trauma shows significant correlation as the most common risk factor for the disease, accounting for 51% of cases. Bone marrow edema shows statistically significant values as the most commonly found in aging character, accounting for 91% of cases. Stage II is the most common stage among individuals under the age of 20. Stage III is the most common among individuals aged 21-40. Stage IV is the most evaluated in the age group of 41-60 (Ficat and Arlet). Class D shows the most common values, accounting for 37% of cases, followed by Class C at 34% (Mitchell).

CONCLUSION:

MRI is indispensable for the early and accurate detection and staging of AVN, which facilitates a better response to treatment.

KEYWORDS: Avascular necrosis, Femoral head, Magnetic Resonance Imaging, Staging

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INTRODUCTION:

Avascular necrosis of the femoral head (AVN) is an ischemic injury that occurs when the blood flow to the epiphyseal or subarticular regions of the femoral head is compromised, resulting in osteoid tissue death. AVN can be idiopathic or caused by trauma. It can also be non-traumatic and associated with various diseases, such as sickle cell disease, Gaucher disease, Caisson disease, pancreatitis, or the use of corticosteroids. Radiation exposure can also contribute to AVN. It can be unilateral or bilateral [(1)], affects mostly patients between the third and fifth decades of life with a male predominance. Owing to these factors early detection with imaging characterization are essential for proper management [(2)].

Magnetic resonance imaging (MRI) plays a crucial role in establishing various imaging criteria, including staging,

severity, lesion characterization and surrounding regional reactionary changes. Variable imaging criteria can provide valuable information from the MRI regarding tissue composition and the progression of the disease process. Many imaging staging systems have been applied for its proper classification. Ficat and Arlet (modified Steinberg classification) [3] has been regarded as the most commonly used classification system based on MRI imaging findings. It is divided into stages. Stage I represents the early resorptive stage observed on MRI as diffuse zones of low signal intensity within the fatty marrow on T1-weighted image. These changes begin in the anterosuperior aspect of the femoral head without extension to the neck. Stage II (figure 1) is a reparative stage in which focal necrosis observed as low signal intensity on both T1 and T2-weighted sequences surrounded by a thick sclerotic band and accompanied by another inner thin band of high signal intensity on the T2-weighted sequence, known as the "double-line sign" that represents the reactive interface which separates the normal marrow from the necrotic marrow. It can extend to the femoral neck and is specific for diagnosing AVL [3].

During the prolonged ischemia, stage III begins (Figure 2), as the necrotic bone will exhibit a fluid signal (low signal intensity on T1 and high signal intensity on T2-weighted sequences). In the final stage IV (Figure 3), fibrosis and sclerosis of the affected bone are observed, resulting in low signal intensity on both T1- and T2-weighted sequences. Secondary signs and sequelae of AVN can be visualized on MRI imaging, such as joint effusion, cartilage loss, fragmentation, femoral head collapse and synovial inflammatory signal changes [4].

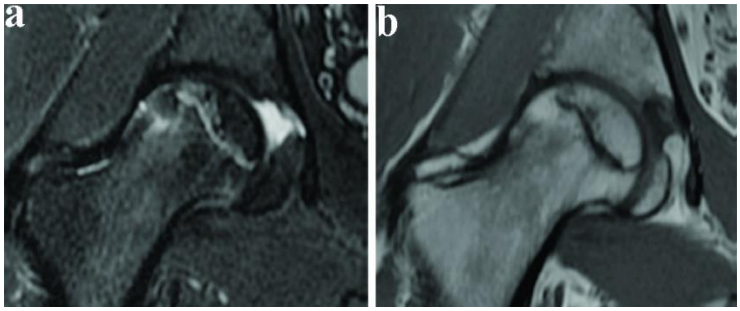

Figure 1: AVN Stage-II Coronal STIR (a) and T1W (b) sequences of the right hip joint ,a wedge-shaped area of hypointensity seen on the T1W sequence with regional loss of femoral head fatty signal and marrow edema [5].

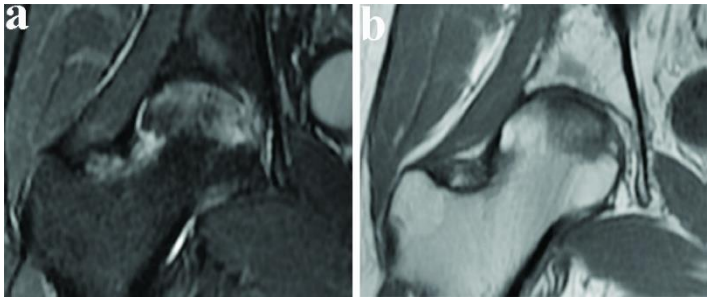

Figure 2: AVN Stage-III Coronal STIR (a) and T1W (b) sequences of the right hip joint , subchondral collapse, fragmentation , flattening and sclerosis of the femoral head in addition to reduced joint space [4].

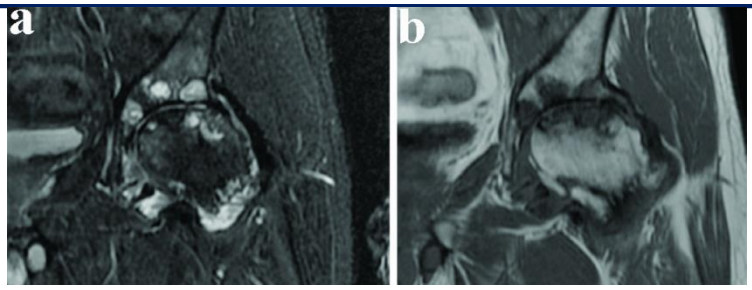

Figure 3: AVN Stage-IV Coronal STIR (a) and T1W (b) sequences of the left hip joint , altered shape of the femoral head, with collapse, fragmentation, and flattening of the femoral head, loss of joint space with absent cartilage [5].

Another widely used classification is the Mitchell classification. It is based on the characterization of necrotic tissue imaging using MRI and is divided into four classes: Class A indicates an early stage of edema, while both Classes B and Class C represent an intermittent heterogeneous pathological changes including inflammation, hyperemia, hemorrhage in addition to variable fatty and fibrous components. Class D indicates the late stage of advanced fibrosis and sclerosis [5, 6].

PATIENT AND METHODS:

This cross sectional retrospective observational study was conducted over a period of 18 months, from May 2022 to November 2023, in two large specialized hospitals in Duhok City. Approved by the ethical committee of the Ministry of Higher Education and the College of Medicine at the University of Duhok in which valid written consent was obtained from one hundred patients who were included in this study after explaining, pre-tested questionnaire was prepared for data collection. Including age, sex, history of pelvic bony trauma, corticosteroid usage, any associated chronic or congenital disease. Various etiological factors were evaluated; clinical diagnosis to the included patients was made by the specialists. All MRI examinations were performed using 1.5 Tesla MRI scanners (Optima and Signa, General Electric Medical Systems, Milwaukee, Wisconsin, USA) with dedicated coils and routine avascular necrosis protocol including coronal T1- and ShortTau Inversion Recovery (STIR) or T2-weigthed fat-saturated, axial T1,T2-weighted fat-saturated, sagittal T1-weighted sequences and Gradient echo sequence (GRE sequences), contrast enhanced images were included when the possibility of inflammation or synovial pathology found. Collected images were studied and evaluated by more than two consultant specialized radiologists in addition to the researcher.

All patients of various ages with confirmed clinical and MRI imaging findings of AVL were included in the study. Those with pelvic bony postoperative cases, operative implants, claustrophobia, the use of cardiac pacemakers, or any other medical contraindication to MRI examination were excluded from the study.

Statistical Analysis: Data collected and analyzed using the computerized statistical software, Statistical Package for the Social Sciences (SPSS Version 20). Descriptive statistics were presented as frequencies and percentages, and the results were converted into tables and charts.

Imaging interpretation:

The MRI scans were performed on a 1.5 TGE HDE Scanner using T1 Weighted spin echo (T1W) sequence in the axial and the coronal plane, the T2 weighted fast spine echo sequence in the axial plane, the STIR sequence in the coronal and the axial planes and Gradient echo sequence (GRE) in the sagittal plane. The Ficat and Arlet classification of avascular necrosis was used to stage the patients.

The various well-known manifestations of AVN like bone marrow oedema, joint effusion, flattening of femoral head, narrowing of joint space, marginal irregularity, femoral head collapse, subchondral fracture and double line sign were detected by the protocoled sequences. Imaging appearances of the lesion over the various sequences of MRI were used as the criteria for diagnosing and staging of AVN. Stage I represent the early resorptive stage and observed as diffuse zones of low signal intensity within the fatty marrow. In stage II MRI findings are characteristic with Bone marrow edema, double-line sign, and necrotic lesions; in stage III subchondral fracture, necrotic zones, wider zones of

oedema, joint space changes were looked for; in stage IV secondary osteoarthritic changes with associated femoral head deformity, acetabular changes, and joint destruction were evaluated.

According to Mitchell classification, characterization of necrotic tissue imaging changes was divided into four classes: Class A represents a fat-like signal of the necrotic tissue, Class B represents blood- like signal intensity, Class C represents a fluid-like signal of the involved lesion and Class D represents fibrous tissue.

RESULTS:

According to the gender distribution of the studied sample, males were more common than females, accounting for 86% of the total number, while females accounted for 14%, as clarified in figure (4).

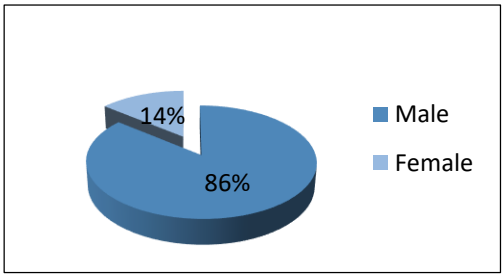

Figure 4: Gender distribution of the studied cases.

According to the age distribution, the most common age group affected was between 20-40 years, accounting for 56% of the total cases. This was followed by the age group of 41-50, which accounted for 26%, as indicated in table (1).

Table 1: Age distribution of the studied sample.

Age	No. of patients (n-100)	Percentage%
< 20	6	6%
21-30	28	28%
31-40	28	28%
41-50	26	26%
51-60	9	9%
61-70	3	3%
Total	100	100%

Bilateral femoral head involvement was more common than unilateral involvement, accounting for 62% compared to 38% for unilateral involvement, as represented in figure (5).

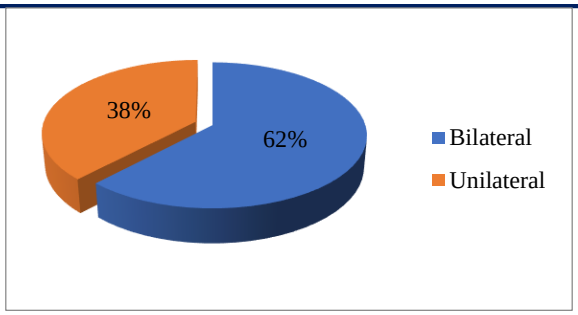

Figure 5: Unilateral vs. Bilateral avascular necrosis in the affected cases.

Trauma was the most common risk factor for the occurrence of the disease, accounting for 51% of cases, followed by idiopathic changes at 29% and corticosteroid usage at 17%, as stated in table (2).

Table 2: Distribution of the patients according to the risk factors

Risk factor	Number of patients(100)	Percentage%
Trauma	51	51
Idiopathic	29	29
Corticosteroid	17	17
Others	3	3

According to the MRI, the main characteristic findings were bone marrow edema, which was the most commonly found, accounting for 91% of the total cases. This was followed by the double line sign at 88%, joint effusion at 79%, reduced joint space at 66%, and contour loss at 57%, as it can be seen in table (3).

Table 3: MRI characterization of the involved femoral heads. Note: each femoral head has more than one characteristic.

MRI findings	No. of femoral heads	Percentage%
Bone marrow edema	91	91
Double line sign	88	88
Fluid effusion	79	79
Contour loss	57	57
Reduced joint space	66	66
Synovial pathology	12	12

According to Ficat and Arlet's staging, Stage II was the most common in the age group under 20 years. Stage III was the most frequent among the (21-40) age group, while stage IV was the most common in the (41-60) age group, as indicated in table (4).

Table 4: Association between age group and staging of AVN (according to Ficat and Arlet staging).

Age	Stage I	Stage II	Stage III	Stage IV	Total
< 20	1	4	1		6
21-30	2	4	16	6	28
31-40		2	17	9	28
41-50		1	7	18	26
51-60			3	6	9
61-70			1	2	3

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Among the total of the studied sample, Stage III was the most commonly observed at 49%, followed by Stage IV at 37%. Stage II accounted for 11%, and Stage I accounted for 3%, as demonstrated in figure (6).

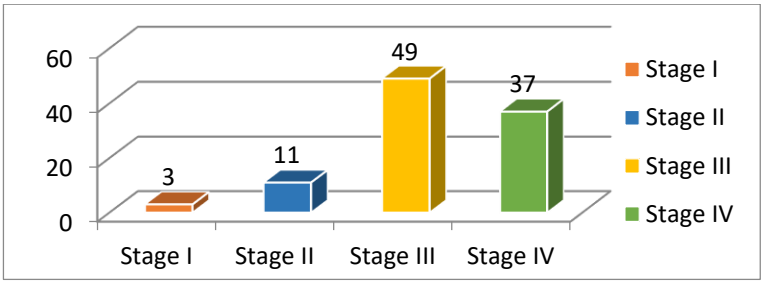

Figure 6: Ficat and Arlet staging of AVL among the studies sample.

According to the MRI signal intensity characterization of the femoral head lesion (Mitchell's classification), Class D was the most common, accounting for 37% of the total cases. This was followed by Class C at 34%, Class B at 24% and Class A at 5%, as illustrated in table (5).

Table 5: Distribution according to (Mitchells classification.

Class	No of involved femoral heads	Percentage%
A	5	5
B	24	24
C	34	34
D	37	37
Total	100	100

DISCUSSION:

Avascular necrosis of the hip (AVN) is one of the common causes of hip joint pain in young adults. The disease progresses rapidly, starting with mild epiphyseal ischemia and leading to fibrosis, sclerosis, collapsed bone, and eventually osteoarthritic changes. Early detection and follow-up are crucial in managing this condition. MRI shows high sensitivity in staging and characterizing pathological changes and progression [7].

In the present study, males exhibited a significantly higher prevalence than females. The age group most affected was between 20 and 40 years. Similar findings were also observed in

another study conducted by Choudhary in 2019, the male-to-female ratio was 2.2:1 in their study and the average age was 38.35 years [7]. Comparable findings were also observed in other similar studies [8,9, 10].

Bilateral involvement of the femoral head was more common than unilateral involvement in this study, accounting for 62% compared to 38% for unilateral involvement. Similar results were also observed in a study conducted by Khaladkar, where bilateral hip involvement was reported in 61% of all cases [9]. in another study conducted by Gehlot, bilateral hip involvement was observed in 74% of the participants. Similar results were also observed in another study conducted by Rangareddy S et al [11].

However, in a study conducted by Choudhary the findings contradict the current findings. They found that unilateral involvement was twice as common as bilateral hip involvement in their study sample, which consisted of 132 femoral heads [7].

Regarding the risk factors for disease occurrence, trauma was found to be the most common factor, accounting for 51% of cases. This was followed by idiopathic changes at 29% and corticosteroid usage at 17% in the present study. Comparable findings were observed in another study conducted by Saleem [12] in 2019. They found that alcohol consumption was the most common risk factor, accounting for 56% of all cases. This was followed by idiopathic causes, trauma, and corticosteroid use (20%, 16%, and 14%, respectively).

In our society, alcohol consumption is relatively low compared to the mentioned study location in India. Another study conducted by Kamal [13] found that smoking was the most common risk factor, followed by idiopathic causes, alcohol consumption and trauma. In a study conducted by Turamari [14], idiopathic causes were found to be the most prevalent risk factor, followed by excessive alcohol consumption and trauma.

In the present study, the most frequently observed MRI imaging characteristic was bone marrow edema, which accounted for 91% of the total cases. This was followed by the double line sign at 88%, joint effusion at 79%, reduced joint space at 66%, and contour loss at 57%. Similar findings were also observed in another similar study conducted by Choudhary [7].

Synovial fluid effusion followed by femoral head collapse was the most commonly observed imaging criteria in a study conducted by Khaladkar [9]. The study conducted by Nevalainen in 2021 found that the double line sign, joint effusion, and bone marrow edema were commonly observed imaging findings, accounting for 87.5%, 50%, and 37.5% respectively [15].

In another study conducted by Saleem [12] the most prevalent MRI characteristics observed were the double line sign, followed by bone marrow edema and joint effusion. In yet another study conducted by Turamari, the most common findings were hip joint effusion, followed by bone marrow edema and decreased joint space, accounting for 57.8%, 47.3%, and 39.4% respectively. The double line sign was found in 34.2% of all cases [14].

According to the Ficat and Arlet staging system, stage III was the most commonly observed (49%) among the total sample studied, followed by stage IV (37%). Stage II accounted for 11%, while stage I accounted for 3%. Stage II was the most common stage among individuals under 20 years of age. Stage III was the most frequent among the 21-40 age groups, while Stage IV was the most common in the age group of 41-60.

Similar findings were observed in several other studies, including those conducted by Gehlot [10], Saleem [12], Khaladkar [9], Choudhary [7] and Kamal [13]. Comparable results were observed in two other studies conducted by Rangareddy [11] and Gakhar. [16] In these studies, stage II was the most commonly observed stage, followed by stage III and then stage I. In two studies conducted by Turamari [14] and Sarker [17] they found that stage IV followed by stage III and then stage II were the most prevalent stages.

According to the MRI signal intensity characterization of the femoral head lesion (Mitchell's classification), Class D was the most common, accounting for 37% of the total cases. This was followed by Class C at 34%, Class B at 24%, and Class A at 5%. Similar findings were observed in another comparable study conducted by Vaghamashi [18].

In a study conducted by Saleem [12], it was found that Class B, followed by Class D and then Class C, were the most prevalent according to Mitchell's classification. In another study conducted by Choudhary [7], Class C was the most prevalent, accounting for 47% of their study sample, followed by Class D at 25.7%, and then Class B at 19%. Class B, followed by class C, class A, and then class D, was the sequence of findings observed in a similar study conducted by Rangareddi [11].

Lastly, a recent study conducted by Goyal [19] examined the correlation between Ficat-Arlet and Mitchell staging. In their sample study, the researchers observed that the majority of Ficat-Arlet stage I and stage II joints exhibited a Class A signal on MRI, whereas most of the Ficat-Arlet stage III and stage IV joints displayed a Class B, Class C, or Class D signal on MRI.

CONCLUSION:

Magnetic Resonance Imaging is of vital importance in the evaluation, staging of the pathological changes involving the pelvis and femoral heads, successfully improving imaging superiority in displaying detailed subsequences, delicately identifying joint effusions, synovial changes, bone marrow signal alterations, articular cartilage abnormalities, muscle pathologies, subchondral bone changes and juxta-articular soft tissues, allowing more detailed information to be provided to orthopedic surgeons and physicians who are concerned about avascular necrotic changes.

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Conflict of interest: None

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