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RETROSPECTIVE EVALUATION OF AVASCULAR NECROSIS OF FEMORAL HEAD: A MAGNETIC RESONANCE IMAGING ANALYSIS

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Abstract

Avascular necrosis (AVN) of the femoral head is a serious disease that causes bone loss and collapse due to a disturbance in blood flow. AVN must be identified early in order to undertake head-preserving core decompression and avoid more invasive head replacement. **Aim:** This retrospective study was conducted to analyze the role of MRI in the evaluation of AVN of the femoral head. **Materials & methods:** The current study was an observational retrospective study conducted in the Radiology department of the IMS &SUM hospital, Bhubaneswar. **Results:** Fifty-five individuals with avascular necrosis of the femoral head were included in this study; 46 men and 9 women. Patients had a mean age of 40.25 ± 9.46 years old, with the vast majority falling in the 20s and 30s. Thirty-four patients had bilateral AVN of the femoral head (68 femoral heads), whereas twenty-one patients had only one side affected (21 femoral heads). The most common risk factor for avascular necrosis of the femoral head (n = 30) was alcohol drinking. The majority of patients (n = 34) were diagnosed with AVN in Stage II. The double line sign was the most common MRI finding in 75 of 89 femoral heads. Stages II and III AVN were more common in the 21-30 age range, while stage IV AVN was more common in the 41-50 age range. Effusion was found in 59 out of 89 hip joints. Seventy of the 89 femoral heads examined showed signs of bone marrow edema. According to MRI, the anterior-superior compartment (n = 45) is the most frequently afflicted. Using Steinberg Staging, researchers found that 30 percent of femoral heads were classified as Stage IIIC. Thirty percent of 89 femoral heads were classified as Stage IIIC in the final Steinberg Staging research, followed by 23 percent classified as Stage IIC. Stage VI femoral heads were found in 22% of patients, while Stage IIB femoral heads were found in 12%. **Conclusion:** Musculoskeletal problems are increasingly associated to femoral head AVN. Early diagnosis leads to better outcomes. Due to its high sensitivity and specificity, MRI is the gold standard for confirming AVN in clinical suspects. MRI is better in early lesion detection and classification, according to this research.

Keywords: Avascular Necrosis; Femoral Head; MRI; Arlet Ficat Staging; Steinberg Staging; Mitchell's Classification.

INTRODUCTION

Avascular necrosis (AVN) of the femoral head is a debilitating condition that occurs when there is a disruption of the blood supply to the bone, leading to bone death and collapse [1-4]. Early diagnosis of AVN is crucial to implement head-preserving procedures such as core decompression and to avoid or postpone more invasive procedures such as head replacement [1]. AVN primarily affects the epiphyseal ends of major bones, such as the femur and humeral heads. However, smaller bones like the scaphoid and talus are also frequently impacted by this condition [2].

The ailment is characterized by non-specific symptoms and typically affects young males in their third or fourth decade of life [3]. The clinical manifestations of AVN exhibit variability depending on the specific bone involved. Nevertheless, pain emerges as the predominant symptom observed in AVN cases affecting any bone.

The etiology of avascular AVN remains incompletely elucidated, despite the existence of multiple processes that contribute to the development of AVN, all of which ultimately lead to compromised blood supply to the affected bone or a specific segment thereof [1-5]. Various risk factors have been identified in the development of AVN. These include trauma, the use of corticosteroids, pancreatitis, alcohol consumption, sickle cell disease, infiltrative illnesses, radiation exposure, kidney transplantation, Gaucher's disease, gout, and Caisson's disease. The femoral head is a frequently observed site for AVN [1-4].

Avascular necrosis of the femoral head can be detected early using magnetic resonance imaging (MRI). According to research [5-9], conventional radiography can overlook early avascular necrosis. Conventional radiography cannot detect stage-I avascular necrosis of the femoral head. As a result, MRI is the primary imaging modality for evaluation.

MRI can accurately determine femoral head involvement and percentage, which is critical for treatment planning [6,7]. MRI can detect avascular necrosis in non-trauma instances where the initial ischemia duration is unknown [8]. It is an essential tool in the evaluation of this condition because of its capacity to detect early lesions and reliably measure femoral head involvement [1–9]. This retrospective study was conducted to analyze the role of MRI in the evaluation of avascular necrosis of the femoral head.

MATERIALS & METHODS

The current study was an observational retrospective study conducted in the Radiology department of the IMS &SUM hospital, Bhubaneswar. Fifty-five individuals with avascular necrosis of the femoral head were included in this study: 46 men and 9 women. All patients who met the inclusion and exclusion criteria for this study and were sent to our imaging department for evaluation of a clinical suspicion of AVN of the femoral head were included. The inclusion criteria were patients who provided informed consent to participate in the research.

Included patients with varying stages and severity of AVN to provide a comprehensive analysis which included early and advanced stages of AVN. Included the AVN patients from immediate imaging after diagnosis to several years of follow-up. Included AVN patients with medical histories, such as corticosteroid use, alcohol abuse, trauma, or underlying conditions like sickle cell disease or systemic lupus erythematosus. We ensured the consistency in the MRI protocol to include patients to minimize variability in imaging quality and interpretation.

Patients who denied consent constituted exclusionary criteria. Did not include the patients who have received specific treatments for AVN prior to the MRI evaluation. Contraindications for MRI included patients with ferromagnetic implants, cardiac pacemakers, claustrophobia, etc. were excluded.

Every patient's demographic and anthropometric details were recorded. Risk factors for AVN are being sought out, hence a thorough historical account is being compiled. There was an enquiry into the prevalence of smoking and drinking in the past. It was also asked whether or whether there had been any prior history of trauma, steroid use, or radiotherapy. Inquiries about cardiac pacemakers, cochlear implants, and claustrophobia in pregnancy helped eliminate those conditions as potential MRI contraindications.

Relevant clinical records and laboratory values were evaluated for all patients undergoing MRI for AVN. Classifications were made using variants of Ficat and Arlet, Sterling, and Mitchells. Bone marrow edema, joint effusion, loss of shape, reduced joint space, and the existence of the double line sign were all analyzed using MRI in every case.

Written informed consent was obtained after the MRI Examination process was explained to the patient or legal guardian. All of the patient's current symptoms, medical history, lifestyle choices, and ferromagnetic implant contraindications were recorded. The proper MRI sequences were used for multiplanar imaging in each case.

Statistical analysis:

The statistical examination was conducted using version 16.0 of the statistical software SPSS. The Office suite from Microsoft was used to create diagrams and charts.

RESULTS

Among the study population of 55 patients who were subjected to analysis for avascular necrosis of the femoral head, it was observed that there were 46 male individuals and 9 female individuals. Out of these, analysis of the age groups of the cases revealed that most patients in their 30s were between the ages of 20 and 40. Fourteen of the patients were in their forties or fifties.

There were four patients younger than 20, and seven patients older than 50. Patients had an average age of 40.25 ± 9.46 years. Overall female patients were diagnosed at a younger age than male patients, and this difference was statistically significant ($P < 0.05$). A total of 34 individuals exhibited bilateral manifestation of the AVN, while 21 individuals displayed unilateral manifestation (total 89 femoral heads).

The investigation of risk variables impacting patients reveals that AVN of the femoral head is primarily linked to alcohol consumption (n=30), followed by idiopathic AVN (n=11). The study identified two additional risk factors associated with impacted instances, namely steroid usage (n=8) and trauma (n=9). Two cases of Stage I AVN were identified in the femoral heads, while 34 cases of Stage II AVN were observed in the same anatomical region.

A combined total of 29 femoral heads and 21 femoral necks exhibited indications of advanced stage III and IV of AVN, respectively (Fig.1). The examination of the association between age and the stage of AVN demonstrated that among the femoral heads analyzed, 10 out of 21 cases with Stage IV AVN occurred in individuals aged 41-50 years, whereas 11 out of 29 cases with Stage III AVN occurred in individuals aged 21-30 years.

Eleven out of the thirty-four patients who received a diagnosis of stage II AVN were classified as young adults. A male individual, aged 36, was diagnosed with stage I AVN, which is distinguished by the presence of solely two femoral heads.

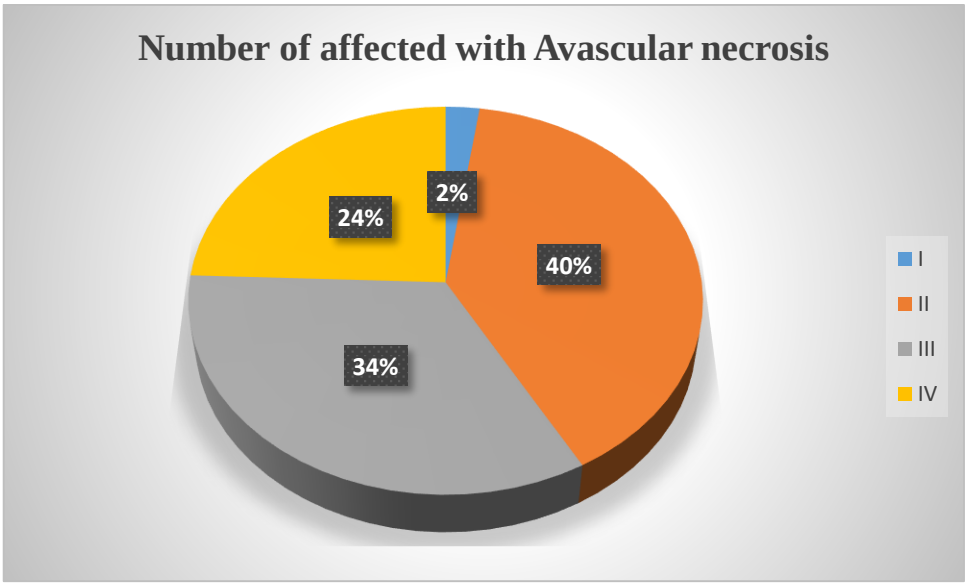

Figure 1: Arlet and Ficat Femoral head avascular necrosis staging.

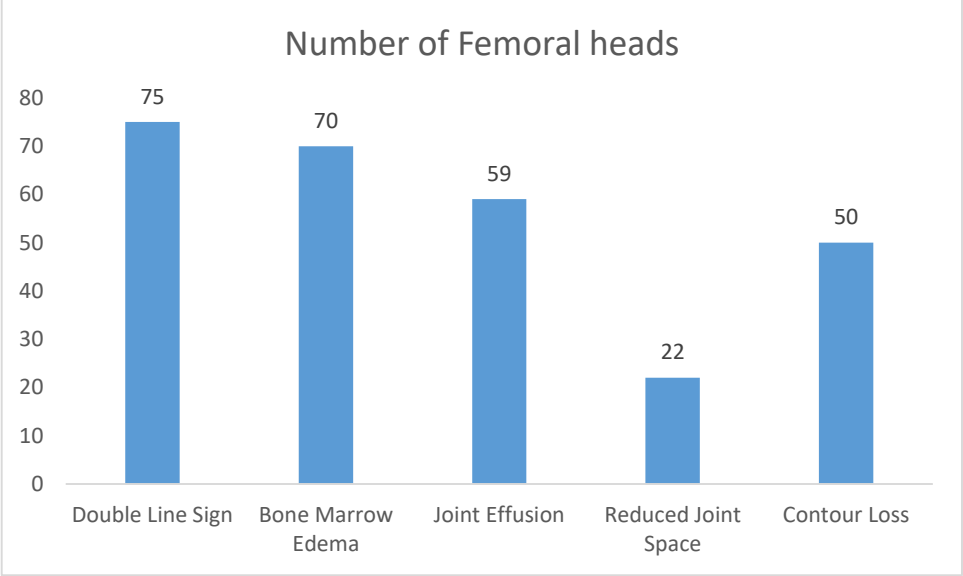

Figure 2: MRI results of AVN pertaining to the femoral head.

MRI results of the AVN pertaining to femoral head were shown in figure 2. The most common MRI sign was the double line sign, seen in 84.2 % (number=75) of AVN femoral heads, according to the study of MRI findings in the cases under consideration. Joint effusion 66.2% (n=59), loss of shape (n=50), and edema of the bone marrow (n=70) were also commonly observed during MRI examinations. Reduced joint space was seen in 22 of the femoral heads. Seventy out of 89 femoral heads impacted by bone marrow showed signs of edema. Among the stages of AVN of the femoral head, it was observed that stage III had the highest prevalence of joint effusion, with a sample size of 27.

This was followed by stage IV AVN, which had a sample size of 22. The occurrence of effusion was observed in 17 out of 34 joints exhibiting stage II AVN, whereas just one joint with stage I AVN displayed effusion. Twenty-three out of 32 femoral heads were swollen in stage II illness. Stage III illness was characterized by edema reaching

the neck region in 28 of 30 femoral heads. In Stage IV, the bone marrow in the neck and sub trochanteric area of certain affected femoral heads was swollen.

The MRI examination revealed among the 89 femoral heads scanned, AVN was found in 31.4% (n=28) of the anteromedial area and 50.5% (n=45) of the anterosuperior area. The femoral head was afflicted in 16.8 % (n=17) of instances, while the anterolateral compartment was affected in 2.3% (n=2) of cases.

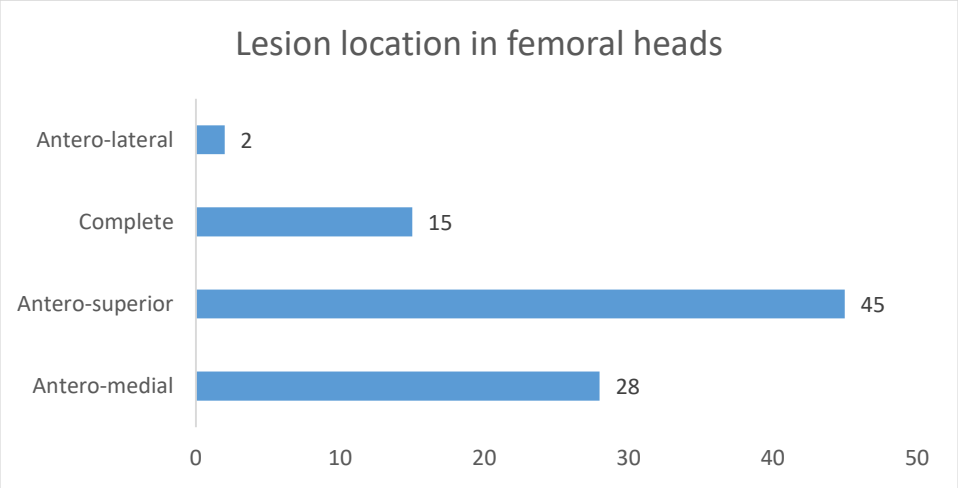

Figure 3: Dispersion based on femoral head lesion site.

The predominant signal intensity lesions identified in our study were categorized as Type B (n = 35) or Type D (n = 31) based on Mitchell's Classification of Signal Intensity. Out of the observed femoral heads, 14 exhibited Class C signals, while 6 exhibited Class A signals.

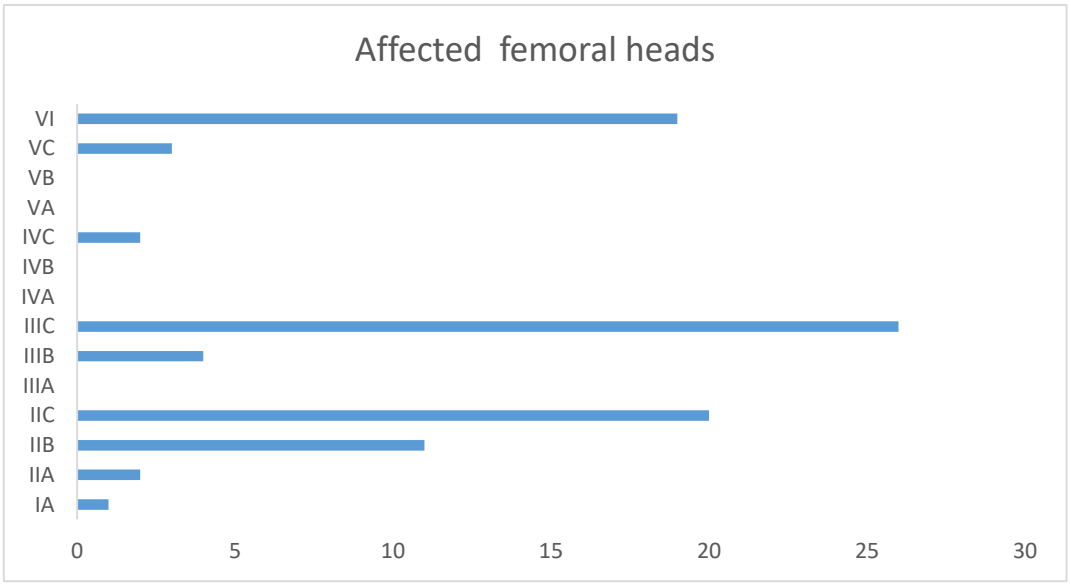

Figure 4: Steinberg staging the avascular necrosis of femoral heads.

According to the final Steinberg Staging study, it was observed that among a sample of 88 femoral heads, 30% exhibited Stage IIIC, whereas 23% had Stage IIC. The occurrence rates of Stage VI and Stage IIB femoral heads were found to be 22% and 12% correspondingly.

DISCUSSION

Out of the cohort size of 55 participants, 46 individuals were identified as male, while the remaining 9 participants were identified as female. The prevalence of AVN in males is significantly greater in comparison to females. The study conducted by Tan et al. in the year 2021 [10} examined the occurrence of Femoral Head AVN in the Chinese population. The findings revealed a male to female ratio of 2.40 [10]. Additionally, the aforementioned study provided evidence that the occurrence of AVN was notably more prevalent among males compared to females [10].

The study revealed that individuals within the age range of 15 to 70 exhibited AVN. The age range of 21 to 40 exhibited the highest population density. The average age of males was 40, while girls had an average age of 25. The study conducted by Tan et al. [10] observed a diverse age range among the patients, spanning from 18 to 95 years. The findings of the study indicated that men had a lower median age compared to women, with men having a median age of 50 years and a standard deviation of 12.56, while women had a median age of 55.56 years and a standard deviation of 14.94.

The study had a sample of 30 participants, and the findings indicated that alcohol was the predominant factor contributing to their AVN. In the study, it was observed that 83.3% of the sample, specifically 25 out of 30 patients, had heavy drinking behavior within the age range of 31 to 40. In our investigation, a total of nine patients with a documented history of trauma were seen, and among them, three individuals experienced fractures specifically in the femoral neck region.

A total of eleven patients exhibited symptoms that could not be readily explained. Corticosteroids were identified in a sample of eight people. Alcohol emerged as the predominant risk factor in 39% of the cases, as supported by the research conducted by Cheng et al. [11]. In their study, Mont et al. [12] discovered that smoking accounted for the predominant risk factor in 36.9% of the patients under investigation.

According to our analysis, it was observed that Type B lesions (n = 35) and Type D lesions (n = 31) had a higher prevalence in terms of signal strength, as per Mitchell's Classification of Signal Strength. All 14 femoral heads observed exhibited Class C signals, but just 6 femoral heads displayed Class A signals.

Our study revealed that within the cohort of patients diagnosed with Stage II sickness, many cases were classified as B class femoral heads (35 instances), followed by D class (31 cases), and C class (14 cases). Patients at Stage III typically exhibit femoral head involvement above 30%.

Thirteen out of the twenty-one patients at Stage IV were found to be impacted by advanced degenerative disease and osteoarthritis. In our investigation, the involvement of the femoral head was observed in less than 30% of the hips, whereas it was present in 41% and 35% or more of the hips. Patients with femoral head involvement ranging from 30% to 50% demonstrate a modest reduction in contour, whilst those with involvement over 50% experience a degree of femoral collapse ranging from partial to complete.

All hips with Stage IV illness exhibit partial collapse, with three hips showing acetabular involvement and thirteen hips displaying secondary degenerative changes. Ito et al. [13] conducted an assessment of the prognosis of asymptomatic AVN, with a particular emphasis on the extent of the lesion in their research.

The presence of a lesion affecting less than 30% of the femoral head is correlated with a minimal likelihood of femoral head collapse. Conversely, a lesion affecting between 30% and 50% of the femoral head is associated with a moderate risk of collapse. Lastly, a lesion affecting more than 50% of the femoral head is linked to a high risk of collapse [13]. This conclusion aligns with the findings of Zhao et al., [14] as they demonstrated a positive correlation between the extent of femoral head involvement and the incidence of hip collapse. Specifically, their study revealed that a larger region of femoral head involvement is associated with a higher likelihood of collapse [14].

The anterior-superior area was the most common site of involvement across all levels. In half of all cases, it can be found. Around a third of all instances were located in the anterior-medial part of the body. Specificity of MRI findings along the anterior superior portion of the femur was shown in one investigation [15]. Large necrotic lesions are more likely to impact the anterior-superior femoral head region, as shown by another study [16], which also found that lesion size and position are prognostic predictors of collapse.

Current research shows that secondary osteoarthritis (OA) alterations are common in advanced stages of the illness. Secondary OA alterations are present in the majority of patients at Stage IV. In this analysis, Class B hips were shown to be the most common kind (42%), followed by Class D (38%). Stages II and III of a disease are typically connected with classes B and C. Class D patterns manifest in terminally ill patients. Similarly, a study [17] found that Class A signals in necrotic nuclei are commonly linked to early AVN alterations, whereas Class B and C signals were associated with more advanced Stages.

Our investigation found that the double-line indication was present in 75 of 89 hips with the condition. It occurs in 97% of Stage II cases and 87% of Stage III cases, making it the most common symptom in these stages of the disease. A study with consistent results was considered diagnostic of AVN [18].

Our research revealed that in 70 of 89 afflicted femoral heads, bone marrow edema was the most prominent symptom. Marrow edema is seen in a greater percentage of femoral heads as the stage progresses. Edema was localized to the area of necrosis in 23 femoral heads with stage II osteonecrosis. The edema on 28 femoral caps in stage III illness progressed to the neck. The neck and trochanteric region edematous in every femoral head with Grade IV illness. According to research [19], marrow edema is most common in femoral heads at stage III of the illness, and the pattern of marrow edema is unique and is not seen in AVN of the femoral head at earlier stages.

Our study's objective was to determine whether joint effusion is linked to edema in the bone marrow. Joint effusion was present in 57 out of 71 (80.2%) femoral caps that also exhibited bone marrow edema. In individuals where there was no edema in the bone marrow, 4/10 nevertheless had effusion. Joint effusion is more common in those with AVN who also have bone marrow edema, with a correlation of a 20-fold greater risk [20]. Among the 89 femoral heads scanned, AVN was found in 31.4% (n=28) of the anteromedial area and 50.5% (n=45) of the anterosuperior area. The femoral head was afflicted in 16.8 % (n=17) of instances, while the anterolateral compartment was affected in 2.3% (n=2) of cases.

CONCLUSION:

Musculoskeletal impairments are increasingly being linked to AVN of the femoral head. There is a strong correlation between early diagnosis and a better prognosis. MRI is the gold standard for verifying the diagnosis of AVN in patients with clinical suspicion because of its excellent sensitivity and specificity. This research shows that MRI is superior to other diagnostic methods for identifying and classifying lesions at an early stage.

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