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Radio-diagnosis

Osteonecrosis of the Femoral Head: Correlation of Radiographic Staging and Magnetic Resonance Imaging

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Abstract **Original Research Article**

Osteonecrosis of the femoral head (ONFH) is a pathologic condition primarily affecting younger and active population that usually leads to destruction of the hip joint and hence demanding hip arthroplasty. Of several diagnostic modalities, magnetic resonance imaging (MRI) is considered highly accurate method both for early diagnosis and for staging of the disease, the latter being useful for a positive outcome. The purpose of the present study was to correlate the plain radiographs with MRI in staging of ONFH. Total 104 patients (152 hips) of different age groups with ONFH were evaluated and classified according to the Association Research Circulation Osseous (ARCO) classification criteria with the use of plain radiographs and MRI. Sensitivity (SN), specificity (SP), positive predictive value (PPV), negative predictive value (NPV) and accuracy (AC) of plain radiographs were calculated. According to MRI, 22 hips were classified as stage I, 45 as stage II, 58 as stage III and 27 as stage IV. The SN, SP, PPV, NPV and AC of plain radiographs were for stage II 86.67%, 88.79%, 76.47%, 94.06% and 88.16% ; for stage III 79.31%, 93.62%, 88.46%, 88.00% and 88.16%; for stage IV 88.89%, 100.00%, 100.00%, 97.66% and 98.03% respectively. The results of the present study suggest that MRI should be incorporated in the classification of osteonecrosis to add accuracy and prognostic value.

Keywords: Radiographs; MRI; Osteonecrosis of femoral head; avascular necrosis; ARCO classification.

INTRODUCTION

Avascular necrosis (AVN), also referred to as aseptic necrosis, ischemic necrosis or ONFH is a devastating disease caused by an ischemic injury toward the epiphyseal and sub-articular bone with sparing of the adjacent hyaline cartilage; that eventually results in the collapse of femur head and end-stage secondary osteoarthritis [1]. It is usually idiopathic and often bilateral - affecting both children (Legg-Calvè-Perthes disease) and adults (Chandler disease). It has also been called "the coronary disease of the hip" by Chandler as the disease simulates the ischemic condition in the heart [2].

The skeletal regions most frequently affected are femoral head, humeral head, knee (distal femur and proximal tibia) carpals, talus, metatarsals, and the mandible of patients in the second to fifth decades of life. The typical patient is a male, in his mid-30s. The clinical picture is nonspecific and involves the hip pain, dysfunction, and claudication. Apyrexia and negative inflammatory markers differentiate AVN from acute arthritis (e.g. rheumatoid and septic arthritis) [3].

Osteonecrosis can be idiopathic (primary) or secondary. Pathogenesis of ONFH is multifactorial (Table 1); certain etiologic factors are able to cause the disease by virtue of their action alone, whereas others may have synergistic action with endogenous or exogenous agents [4].

Non-invasive diagnostic tests used in detecting AVN include plain radiography, MRI, computed tomography (CT), skeletal scintigraphy, and single photon emission computed tomography (SPECT). Location of the affected hip by AVN can be determined by antero-posterior radiographs. Nevertheless, abnormalities in the subchondral area might be missed due to the fact that the former and posterior acetabular margins overlap the exceptional part of the femoral head. Hence, it's crucial to order a very good quality side radiograph of the femoral head. Consequently, a cross table lateral radiograph is not as adequate as a frog leg side to represent the architectural details of the femoral head [5, 6].

Table-1: Diseases or pathological conditions associated with ONFH

Trauma Femoral neck fracture Hip dislocation Extensive burns Vessel trauma	Metabolic disease Cushing disease Gaucher's disease Gout Hyperparathyroidism
Hematologic diseases Sickle cell disease Thalassemia Polycythemia	Corticosteroid use Solid organ transplantation Bone marrow transplantation Acute lymphoblastic leukemia
Alcohol consumption	Systemic lupus erythematosus
Alimentary system diseases Pancreatis Ulcerative colitis Crohn's disease	Human immunodeficiency virus infection
Coagulation disorders Antithrombin III deficiency Protein C deficiency Protein S deficiency Thrombocytosis Disseminated intravascular coagulation	Miscellaneous factors Smoking Pregnancy Chemotherapy Radiation Decompression disease

The "double-line" sign introduced by Mitchell et al. was considered pathognomonic for ONFH consists of an inner bright T2 line representing granulation tissue and an outer dark line representing sclerotic bone. It is best seen on T2 weighted sequences and reported in up to 80% of cases [7].

Furthermore, Technetium 99m diphosphonate imaging serves as a helpful technique for spotting osteonecrosis [8]. This was backed up by many researches that have confirmed that MRI is one of the most precise of all imaging methods [9].

The high spatial resolution and contrast resolution of CT allow analysis of morphologic features. The sensitivity of CT in detecting early AVN is 55%, which is similar to the sensitivity of planar nuclear medicine imaging. CT is more appropriate in evaluating the extent of involvement, such as subchondral lucencies and sclerosis during the reparative stage, before the onset of femoral head collapse and superimposed degenerative disease [10].

The choice of treatment for the ONFH remains one of the more complex problems for an orthopaedic surgeon. Without definite treatment approximately 70% to 80% of clinically diagnosed cases will progress and most will require some form of hip replacement within 3 to 4 years of diagnosis [11]. There are two main categories of treatment; the first targets the joint-preserving procedures and the second the joint-replacing procedures. The treatment is determined in large part by the stage of the disease [12]. It is important therefore to use a reliable and effective method of classification and staging.

Over the years, numerous different classification systems (Table 2) have been developed to evaluate patients with femoral head osteonecrosis [13]. However, for the purpose of this study, we use the stages of ARCO classification [14].

The purpose of the present study was to correlate plain radiographs and MRI findings for ARCO staging (Table 3) and to assess the sensitivity of plain radiograph in staging of ONFH.

Table-2: Evolution of different classification and staging systems for ONFH

	Marcus and Enneking	Ficat and Arlet	Modified Ficat and Arlet	Steinberg	ARCO
Year of introduction	1973	1977	1985	1984	1993
Contribution	Initial staging system	Acknowledged the need for a biopsy to confirm functional changes in bone	Acknowledged presence of ONFH with negative XR	Added MRI criteria and lesion size and category for subchondral fracture with no collapse	Added location of lesion

Table-3: ARCO classification system

Stage	Radiological findings	Sub-classification
0	Histology + ; Radiograph/CT/MRI/scintigraphy -	-
I	MRI and/or bone scintigraphy + ; radiograph/ CT -	+ [(a)] + [(b)]
II	Sclerosis, osteolysis	+ [(a)] + [(b)]
III	Crescent sign, +/- flattening of articular surface	+ [(a)] + [(b)] + [(c)]
IV	Osteoarthritis, acetabular changes, joint destruction	-

[(a)] Location of femoral head necrosis: 1) medial third, 2) median third, 3) lateral third.
[(b)] Size of femoral head necrosis: A) minimal <15%, B) moderate 15–30%, C) extensive >30%
[(c)] Intrusion degree of femoral head contour: A) <2 mm, B) 2–4 mm, C) >4 mm

MATERIALS AND METHODS

This retrospective study was carried out at radiology department of tertiary care rural hospital using electronic data of radiography and MRI done from May 2015 to Jan 2019.

Total 104 patients (152 hips) of different age groups with ONFH were evaluated. The imaging study of these patients was performed with plain radiographs (anteroposterior and frog-lateral views) and MRI (1.5T Magnetom Avanto - Siemens Medical Systems). All patients underwent the same imaging protocol (Table 4).

Table-4: Technical parameters and sequences used

Sequences	Orientation	TR (ms)	TE (ms)	Slice thickness	FOV
STIR	Coronal	3500	53	4	256×256
T2 FSE	Coronal	3600	89	4	256×256
T1 FSE	Coronal	380	11	4	256×256
T2 FSE	Axial	4320	89	5	512×256
T1 FSE	Axial	427	11	5	512×256

TE: echo time, TI: time of inversion, TR: repetition time, FOV: field of view, NEX: number of excitations

Statistical analysis was carried out using SPSS software ver.21 after collecting patient data in a master chart. MRI was considered as the modality of choice for making final diagnosis of AVN and radiographs were compared with the MRI findings using standard formulae to arrive at the test characteristics.

OBSERVATIONS AND RESULTS

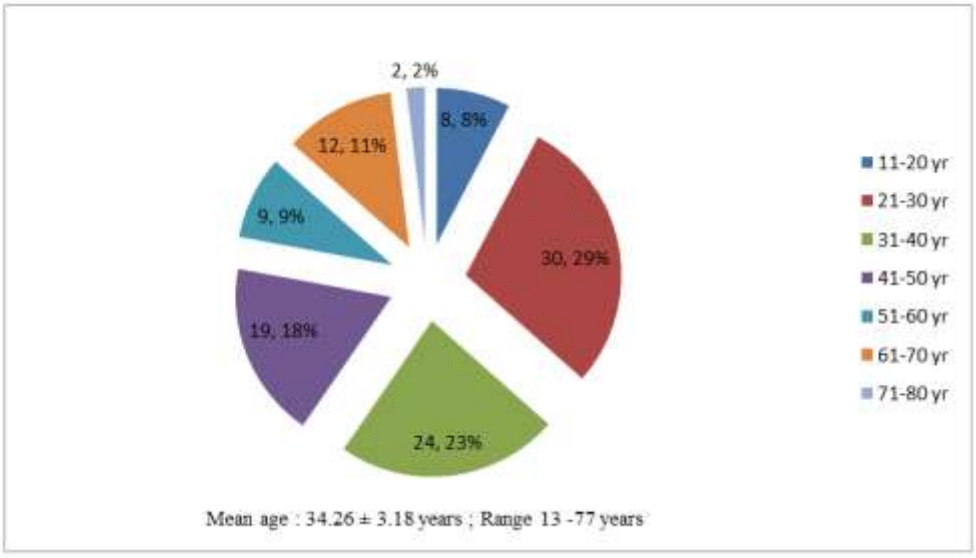

Fig-1: Distribution of patients according to age

Table-5: Distribution of the patients according to gender

Gender	Number	Percentage (%)
Male	71	68.2
Female	33	31.7
Male to female ratio was 2.1:1		

Table-6: Distribution of the patients according to side of hip affected

Hip	Number	Percentage (%)
Right	31	30
Left	25	24
Bilateral	48	46

Table-7: Evaluation of the osteonecrotic lesion with MRI and radiographs

STAGE	MRI	Radiographs	COMMENTS
ARCO I	22	Normal	Radiographs are negative in Stage I
• Location ○ Medial ○ Median ○ Lateral • Area involved ○ >15% ○ 15-30% ○ >30%	 8 6 8 5 6 11		
ARCO II	45	39	Overestimation n = 6 as stage III
• Location ○ Medial ○ Median ○ Lateral • Area involved ○ >15% ○ 15-30% ○ >30%	 2 17 26 4 19 22		
ARCO III	58	46	Underestimation n = 12 as stage II
• Location ○ Medial ○ Median ○ Lateral • Area involved ○ >15% ○ 15-30% ○ >30% • Surface collapse/ depression ○ >15% / <2 mm ○ 15-30% / 2-4 mm ○ >30% / >4 mm	 1 13 44 3 10 45 12 35 11		
ARCO IV	27	24	Underestimation n = 3 as stage III

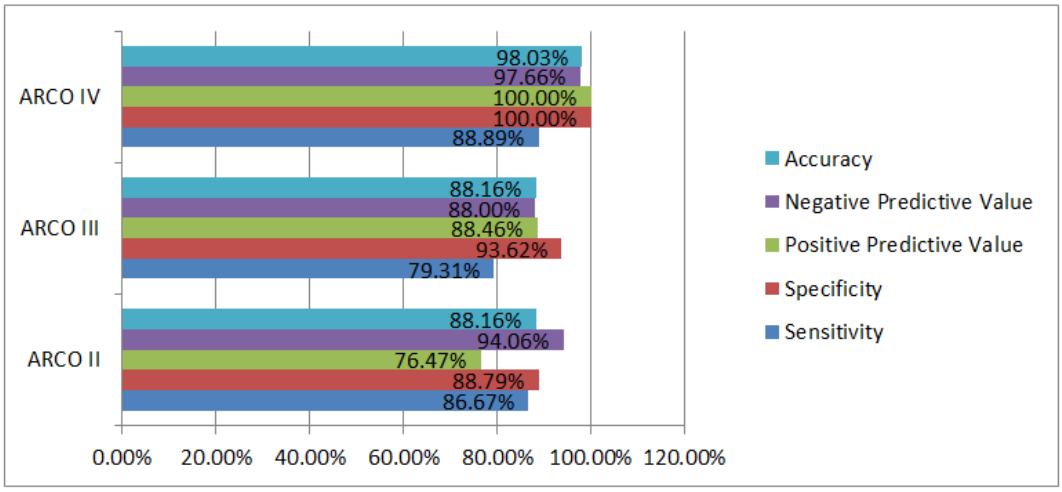

Fig-2: Sensitivity, specificity, PPV, NPV and accuracy of radiographic staging of ONFH

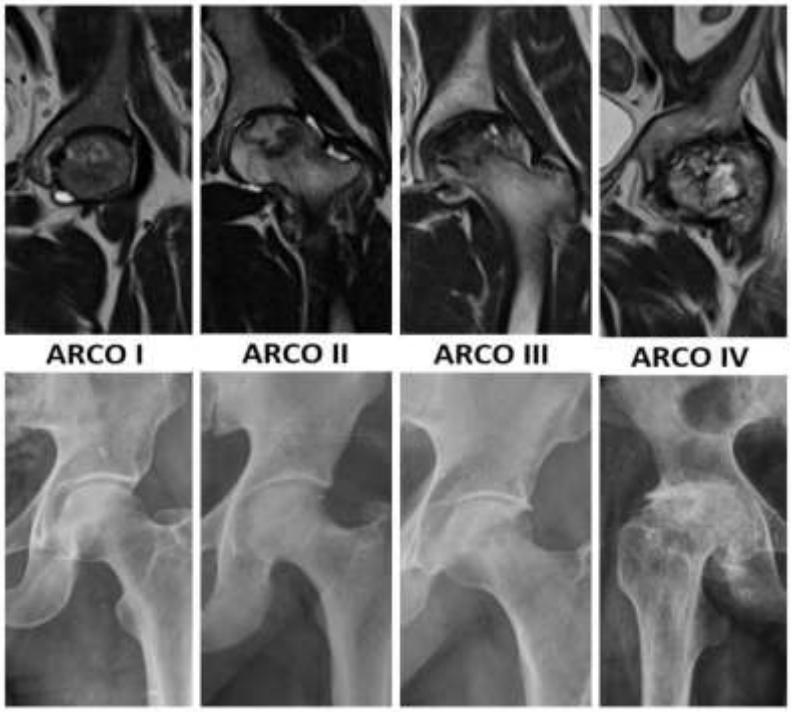

Fig-3: Various stages of ONFH on MRI and radiographs

DISCUSSION

Early diagnosis of ONFH is crucial for the therapeutic management and outcome. The ideal classification system should correspond accurately to the pathologic and radiographic changes of osteonecrosis, and should clearly and distinctly characterize each stage in a reproducible manner.

The comparison of the plain radiographs and MRI showed that the evaluation with plain radiographs for the staging of the osteonecrotic lesion is overestimated or underestimated. As a general rule, the radiographs overestimate stage II lesions and underestimate stage III lesions. This confirms the earlier reports of others who have described MRI as being more sensitive than plain radiography like the work done by A.H. Zibis *et al*. [15]; David J. Sartoris *et al*. [16]; Beverly G. Coleman *et al*. [17] and William G. Totty *et al*. [18] in addition to above finding Donald G. Mitchell *et al*. [19] also stated that MRI is a promising modality for characterizing the extent and severity of the necrotic process and its complication.

The results of the present study show that the additional information provided by MRI, may modify the classification of the hip osteonecrosis in any stage of the disease. A limitation of the present study is the absence of any histological confirmation.

Table-8: Comparison of sensitivity, specificity, PPV, NPV of radiographic staging of ONFH

	ARCO II		ARCO III		ARCO IV	
	A.H. Zibis *et al*.	Our study	A.H. Zibis *et al*.	Our study	A.H. Zibis *et al*.	Our study
Sensitivity	88%	86.67%	79.2%	79.31%	76%	88.89%
Specificity	90.5%	88.79%	82%	93.62%	100%	100%
PPV	78.6%	76.47%	80.8%	88.46%	100%	100%
NPV	95%	94.06%	87.2%	88%	90.9%	97.66%

CONCLUSION

The evaluation of an osteonecrotic lesion based only on plain radiographs could miss important information. The use of MRI findings could considerably improve the accuracy and prognostic value on staging, allowing thus the surgeons to achieve a better choice of treatment and a better outcome in patients with hip osteonecrosis.

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