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Radiological evaluation of avascular necrosis of bone with clinical correlation

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Abstract
Osteonecrosis of bone is a progressive disease affecting the areas with precarious blood supply like head of the femur, head of the humerus, Scaphoid, Talus, Navicular, Condyles of long bones etc. Causes are mostly unknown and few are related to Corticosteroids, Trauma, Alcoholism, and hematological disorders. In the present study, 45 symptomatic patients were evaluated for osteonecrosis using X Ray, CT Scan and MRI in a tertiary care hospital. The age of incidence, gender variability, laterality, involvement of the different bones were studied. The sensitivity of various imaging modalities according to the disease stages was also noted. In majority of the cases the cause was unknown and the head of the femur came out to be the most involved site. MRI was found to be the most sensitive imaging modality followed by CT and X ray. The common findings detected by X ray and CT were Sclerosis, Subchondral lucency, Altered morphology and associated degenerative changes. Bone marrow edema was the most common finding detected by MRI in very early stage. Joint effusion, Double line sign, subchondral collapse, degenerative changes of the joint were other significant findings. T1 hyposensitivity was the main finding in the osteonecrosis of Scaphoid, Navicular and Talus with no enhancement post contrast.

Keywords: Osteonecrosis, avascular necrosis, femoral head, scaphoid, T1 hypo intensity, marrow edema, double line sign, subchondral collapse

Introduction
Osteonecrosis of bone is defined as death of some particular areas of bone and marrow elements secondary to limited or loss of blood supply. Also known as Aseptic necrosis, Ischaemic necrosis, Bone Infarct etc, this condition affects the areas with precarious blood supply like Head of Femur, Talus, Scaphoid, Lunate, Humeral head, Femoral condyles. Avascular necrosis of femoral head tops the list since its first description by Franz Konig in 1888 [1]. Most of them are Idiopathic, while other common causes are Post-traumatic, Alcoholism, Corticosteroid ingestion, haematological disorders. Post-traumatic osteonecrosis is typically unilateral, whereas non-traumatic osteonecrosis are commonly bilateral in up to 70-80% of cases [2, 3]. Progressive increase has been noted in the prevalence of osteonecrosis of hip over past decades. This increase may be attributed to widespread use of Corticosteroid therapy for various diseases, increase in consumption of alcohol and higher incidence of trauma [4].
Radiological manifestations of avascular necrosis are distinctive in location and appearance. Plain Radiography, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Skeletal Scintigraphy and Single Photon Emission Computed Tomography (SPECT) are the main modalities for detection of this condition. At present, MRI is the most sensitive, specific and most widely used diagnostic tool for diagnosis. Plain Radiography shows only 41% sensitivity, while CT shows 55%, in detecting the osteonecrosis. There is a delay of 1-5 years between the onset of symptoms and the appearance of radiographic abnormalities [5].
MRI being very sensitive plays an important role in detecting osteonecrosis at an early stage before the radiological features are apparent and thus paves way for early intervention. Bone marrow edema, joint effusion etc have been well correlated with progression of the condition [6]. The most characteristic finding of osteonecrosis in MRI is the Double line sign in the Subchondral region as well as in the metaphyses and diaphysis.

We are presenting here a study of imaging appearance of avascular necrosis of bone on various imaging modalities and to determine the extent of the disease thereby, provide the staging as well as evaluate the complications. The study was conducted in a tertiary care teaching hospital. The written consent from the patients was taken for participation in the study and the clearance from the Hospital Ethical Committee was obtained.

Materials and Methods

A total of 45 symptomatic patients were studied in a period of one year who came for treatment to Orthopaedics, Medicine, Surgery and Paediatrics Departments and routed to Radio-diagnosis Department for imaging evaluation. In all cases thorough history taking and physical examination were done and clinically suspected cases for avascular necrosis were included. All patients having MRI incompatible cardiac pacemakers, prosthetic heart valves, cochlear implants or any metallic implants were excluded. Claustrophobic patients as well as the unwilling patients were also excluded from the study.

Plain radiographs of the respective bones were obtained and then placed for CT and MRI within a week. The presence or absence of avascular necrosis of the particular bone and the grade and the extent of the disease were analysed. The grades of those in the hip were graded according to the staging system proposed by Ficat and Arlet.

Plain radiographs were obtained by Siemens 500 mA (Model- Klinoskop H/ Fluoro- Vision) machine. CT evaluations were done using Siemens Syngo Somaris/ 5VA47C Spiral CT Scanner.

MR Imaging was carried out on Siemens TIM Avanto 1.5 T Scanner. For the hip, MRI images were acquired in Coronal, Sagittal, and Axial planes in T1, T2, STIR and PDFS sequences with slide thickness of 3 -4 mm. whenever required, contrast study was performed using intravenous Gadolinium DTPA - dimeglumine solution.

Results and Observations

The study included a total of 45 patients. Avascular necrosis of hip was the most common with 40 patients; out of which 22 with unilateral involvement and 18 with bilateral involvement totaling 58 hips. There were 3 patients of Post-traumatic osteonecrosis of Scaphoid, one case of Navicular and one case of Post-fixation Talus.

Osteonecrosis of Femoral Head

Most were in the age group of 20-29 years (n=8, 20%). Next higher incidences were in 30-39 years and 40-49 years age group each having 17.5% (n=7). From 3rd to 5th decades there were 55% of total cases. Less than 9 years and 10-19 years group had 15% (n=6) of cases each and 12.5% (n=5) cases were in 50-59 years age group while only one case was there in 60-69 years age group.

There was an increase tendency of osteonecrosis of femoral head for male totaling 26 patients (65%) in contrast to females of 14 patients (35%). Male to Female ratio thus was 1.86:1.

Pain was the most common presenting symptoms in all the 40 cases. Associated restriction of hip movements was found in 32 cases (80%) and limping was observed in 8 cases (20%). In this study, the most number of hip osteonecrosis was found to be Idiopathic (42.5%), followed by Corticosteroid intake (25%); both of them caused bilateral involvement. There was 20% cases were Post-traumatic which were unilateral. There were 3 cases (7.5%) with Chronic Pancreatitis and 2 cases (5%) were Chronic Alcoholics. Most numbers of femoral head osteonecrosis were found to be in Stage III (46.5%), followed by Stage IV (27.6%). The least were in Stage I (10.3%) and the Stage II amounted to 15.5% of the cases. Antero-superior segment of the femoral head was found to be the most common site of involvement in 58.6% of the affected hips while the remaining 41.4% showed multi-segmental involvement.

In this study, 82.7% of the cases were detected by X ray; 86.2% by CT and 100% were detected by MRI. X ray and CT could not detect any of the cases of Stage I (0% Sensitivity), whereas MRI could detect all the 6 cases of Stage I (100% Sensitivity). The sensitivity of detecting Stage II cases were 55.5% by X ray, 77.7% by CT and 100% by MRI. The sensitivity of detecting Stage III and IV cases were 100% by all the three modalities.

The most common finding observed on X rays was Sclerosis (70.7%), followed by Subchondral lucency (58.6%). Altered morphology was noted in 36.2% of the cases. The most common CT finding was Sclerosis (86.2%). Altered morphology (43.1%) and Degenerative changes (27.6%) were seen in the advanced stages of the disease. Cresent sign indicating collapse of subchondral bone were detected in 46.5% of the cases. The most common finding picked up by MRI was Bone marrow edema (86.2%). This was the only finding associated with early stage (Stage I) of disease. The next common was Joint effusion (65.5%), which was mostly associated with Stage III and IV. Cresent sign indicating subchondral fracture was noted in 37.9% of the cases. Flattening and Altered morphology including subchondral collapse were noted in 43.1% of the cases. T1 band and T2 double line sign were noted in 7 out of 9 cases in Stage II amounting to 12.06% of overall cases. Degenerative changes like reduction of the joint space, marked collapse of subchondral bone and marginal osteophytes were noted in advanced stage (Stage IV) of the disease.

Osteonecrosis of Scaphoid

We studied 3 cases, two were in the 21-30 years age group while the other was in 31-40 years age group and all were male. Among the three cases 2 cases had fracture at the waist and one had a fracture in the proximal pole. Sclerosis of the proximal fragment was seen in two cases in both X ray and CT. In MRI, T1 hypointensity of the proximal fractured fragment was the most common finding detected in all three cases (100%). No evidence of contrast enhancement in the proximal fragment was seen in any of the patients.

Thus, X ray and CT could detect only 2 out of 3 cases with a sensitivity of 66.6%; however, MRI detected all 3 cases with 100% sensitivity.

Osteonecrosis of Navicular Bone

We had one patient, 46 years man with pain right foot and difficulty in walking for one year. There was a history of motor vehicle accident causing fracture of the Navicular one and half years ago. All three modalities, X ray, CT, and MRI could identify features suggesting osteonecrosis.

Both X ray and CT showed Sclerosis of the Navicular with marginal osteophytes as well as reduction of Talo-navicular joint space.MRI showed fragmentation of the medial aspect

of the Navicular bone and focal T1, T2. And PDFS hypointensity in the medial aspect of the Navicular with no enhancement was noted suggesting osteonecrosis. Marrow edema in the lateral aspect of the Navicular bone and head of Talus as well as Talo-navicular joint space reduction and marginal osteophytes were also noted.

Osteonecrosis of Talus

The only patient of talar osteonecrosis was a 26 years old male with pain and swelling in the right foot for three months. He had a fracture of Talus 5 months back which was treated by open reduction and internal fixation.

X ray and CT, both showed an old fracture in the neck of Talus with internal fixator screws in situ. Sclerosis was noted in the Talar dome. MRI also showed old fracture of Talar neck with Screws in situ. There was T1 and T2 hypointensity in the Talar dome showing no enhancement on post contrast study suggesting osteonecrosis. Thus the case was diagnosed as osteonecrosis of Talus of right foot involving the Talar dome.

Discussion

Osteonecrosis of Femoral head

The diagnosis of avascular necrosis of bone depends on careful clinical evaluation of the patient as well as the relevant imaging methods. The sensitivity and specificity of such imaging modalities are variable. Clinical examination findings are thus always important to aid in the diagnosis.

Majority of the cases of osteonecrosis studied are in their 3rd to 5th decade of life. This is also found in different studies [7, 8]. Similarly, male gender is affected more by this condition. [7, 8, 9]. There are however few studies where female preponderance was found [10]. The geographical variation of causative factors or different criteria of selection of patients may have some role in the gender variations.

Clinically, most of the patients present with pain in the affected hip joint. This is often associated with restriction of motion of the hip joint as well as limping of the affected side [6, 11]. There are some incidences of asymptomatic avascular necrosis of femoral head also [11]. On analyzing the etiology of the osteonecrosis most of the cases did not have any verifiable cause and termed as idiopathic [11, 13]. The relation of the long-term corticosteroid use and the incidence of osteonecrosis are now well established. In this study also there were a fair number of patients who gave the history of steroid intake. Similarly, the intake of alcohol is also associated with the occurrences of osteonecrosis [11, 13, 14]. Post-traumatic hip with surgical intervention also poses as a risk factors for osteonecrosis. Few studies reported that avscular necrosis developed in nearly 20% of all type of femoral neck fractures after surgical management [15]. Idiopathic and corticosteroid induced osteonecrosis were mostly bilateral while those associated with trauma were unilateral [16, 17, 18].

Various earlier studies had shown that the weight bearing antero-superior aspect of the femoral head to be the most commonly involved region in osteonecrosis of the femoral head [19, 20]. In the present study also, isolated antero-superior segment involvement was found to be the most common (58.6%) compared to multi-segmental involvement (41.4%). Multi-segmental involvement was most commonly seen in stage IV cases.

Regarding sensitivity of the imaging modalities, MRI is found to have the highest sensitivity, which is nearly 100% and its ability to detect the osteonecrosis at the early stages [21, 22]. In all the studies X ray was not useful in the detection of the disease at Stage I. The sensitivity of CT however, was better than the X ray. In few studies CT were found to be more useful in diagnosing subchondral fractures and visualization of areas of bony changes than MRI [23, 24]. In the present study also, MRI was found to have a greater sensitivity than X ray and CT scan in detecting early stages. However in the advanced stages all the three modalities were equally capable of detecting the disease.

The most common X ray finding in the present study were sclerosis of the femoral head and subchondral lucency, noted in 70.7% and 58.6% of the total hips respectively. Sclerosis was also the most common finding noted on CT scan (86.2% of the total hips). Altered morphology of the femoral head and resulting degenerative changes of the hip joint in the advanced stages were also equally picked up by CT scan.

On MRI, the most common finding detected in the present study was bone marrow edema (86.2% of the hips studied). This was the only finding in early stage (Stage I) of disease. Other studies also indicated that the bone marrow edema is the earliest finding in non-traumatic osteonecrosis of hip [12, 25, 26]. The next common finding in our study on MRI was joint effusion, which was mostly associated with Stage III and IV. The effusion was also a common finding noted on CT scan. Effusion was more common in the advanced stage of the disease. They opined that cartilage destruction and collapse of the articular surface of the femoral head result in synovial irritation leading to joint effusion [11, 21].

Marrow conversion i.e. change of normal haematopoietic marrow to fatty marrow was also noted in the present study (63.7% of total hips affected). Similar findings were also noted by other studies [21, 22, 27]. The 'T2 double line sign' is considered to be pathognomonic for avascular necrosis since mentioned by Mitchell *et al*. in 1987 [28]. This is more commonly found in Stage II disease and in the present study it amounted 77.8% of the cases in Stage II. These are similar to previous studies [29]. Another sign observed in Stage III diseases was 'Cresent sign' which indicates subchondral fracture. This was similar to the findings of other previous investigators [30]. CT scan was also able to detect this sign comparable to MRI.

Flattening and altered morphology of the femoral head including subchondral collapse were noted in 43.1% of the cases in the present study. Degenerative changes with reduction of the joint space, marked collapse of subchondral bone and marginal osteophytes were noted in the advanced stages like other studies [30]. Widening of the femoral neck was mostly associated with advanced stages [31].

Osteonecrosis of Scaphoid

In the present study, Plain radiography and CT were able to diagnose 2 of the 3 cases (Sensitivity 66.6%) of osteonecrosis of the proximal fragment. Sclerosis of the proximal fragment was the common finding along with an old fracture line. These findings were similar to other studies [32, 33].

MRI had the sensitivity of 100%, where the main finding was T1 hypointensity of the proximal fragment showing no enhancement on post contrast study. Few studies like Michael G Fox et. al. [34] and Cerezal *et al.* [35] however, found the sensitivity of unenhanced MRI to be 55% and 78% respectively.

Osteonecrosis of Navicular

The osteonecrosis of Navicular is not a common occurrence. Few of the reported literature supported the role of trauma with it [36, 37]. Usually there is sclerosis of the bone along with marginal osteophyte formation and reduction of talonavicular joint space reduction on X ray and CT scan. MRI showed fragmentation and hypointensity of T1, T2 and PDFS sequences. On T2W images there is high signal intensity on the talonavicular joint suggesting degenerative changes.

Arandes and Viladot 1956, stated that for Kohler disease (osteonecrosis of Navicular in children) "Clinical findings are nothing, radiology is everything". Regarding Muller Weiss disease (Osteonecrosis of navicular in adults) they emphasized that clinical findings may be helpful but plain weight bearing radiographs of the feet are the basic tools for diagnosis. This condition mostly affects the women and often bilateral [38]. There is loss of bone on lateral aspect and the bone appears comma shaped.

Osteonecrosis of Talus

Osteonecrosis of talus is mostly associated with fractures of the neck and body. Canale ST *et al.* evaluated 71 cases of talar neck fractures where they found osteonecrosis in 52% of the cases [39]. Inokuchi *et al.* in their study found that fractures involving the body of talus had higher prevalence of osteonecrosis and worse prognosis [40]. In cases of atraumatic osteonecrosis of talus the most commonly associated risk factor is Systemic Lupus Erythrematosus. Most common site affected was found to be postero-lateral aspect of talar dome. Other associated factors could be corticosteroid use, alcohol abuse, tobacco use and hypertension [41].

In MRI, the avascular area appears as a well-demarcated area of subchondral talar bone ischaemia with hypointense signals and also bone marrow edema. In early stages, a small hypointense focus is noted in the superior talar dome [42]. A sclerotic line adjacent to subchondral plate or diffuse osteonecrosis with a serpiginous bone infarct pattern may be seen. Double line sign on FS PD FSE images are also appreciated. In the osteonecrosis of talar dome, the Hawkins sign is a reliable sign for vitality of the talus after fracture, which was mentioned by many investigators [43]. Positive Hawkins sign cases usually had less possibility of osteonecrosis.

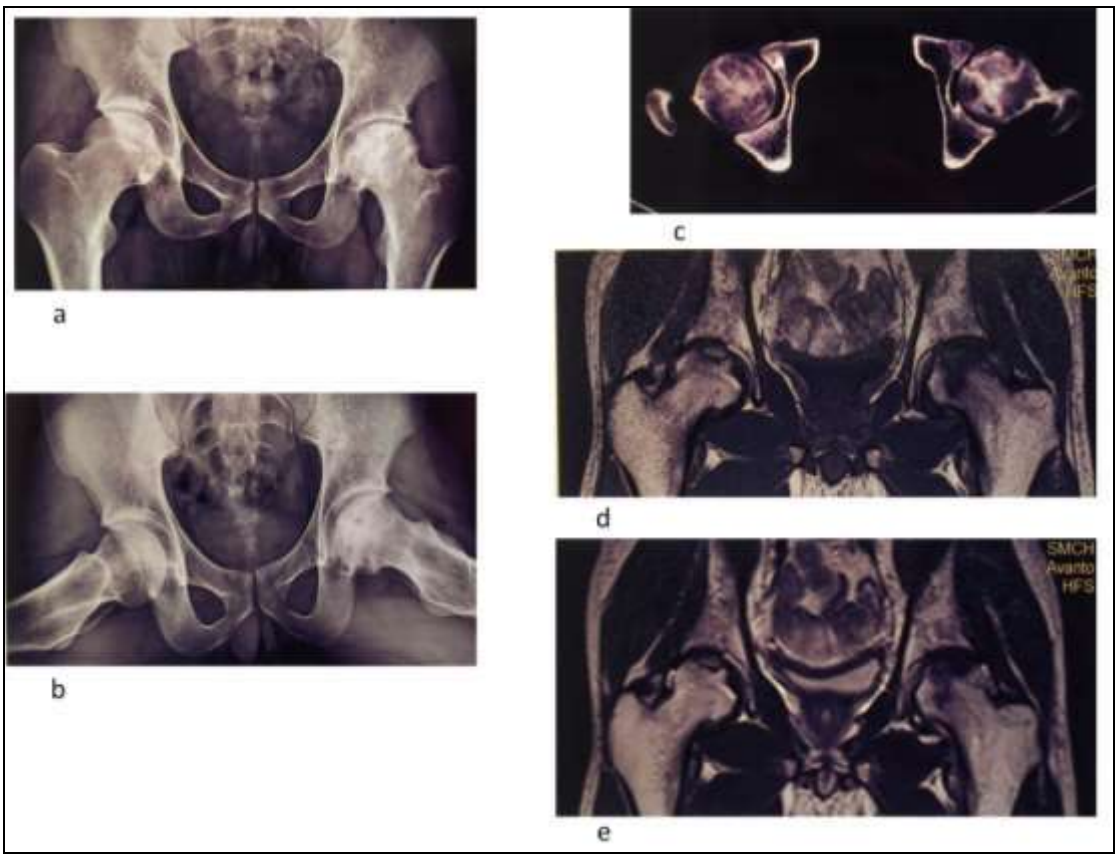

Fig 1: Osteonecrosis of hip. X Ray (a and b), CT(c) MRI T1 Coronal (d), T2 Coronal (e).

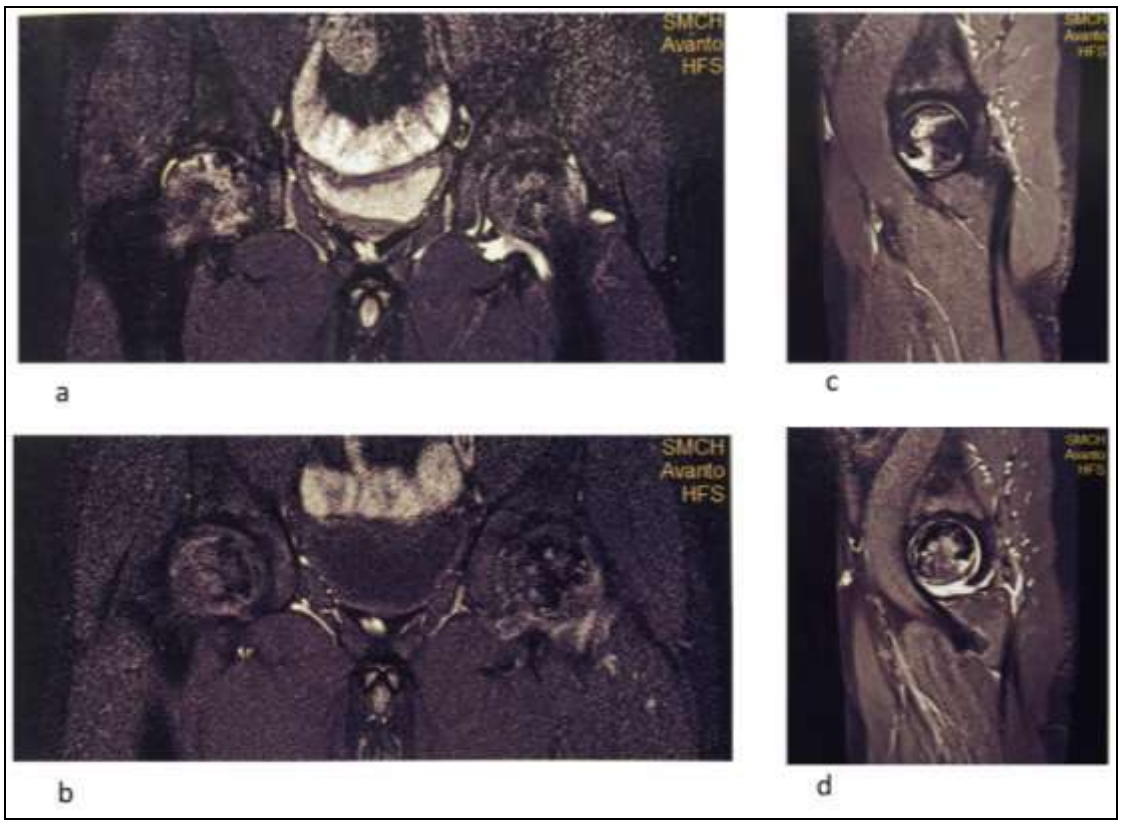

Fig 2: Osteonecrosis of hip. MRI PDFS Coronal (a), Post-contrast Coronal (b), STIR right hip(c), Left hip (d).

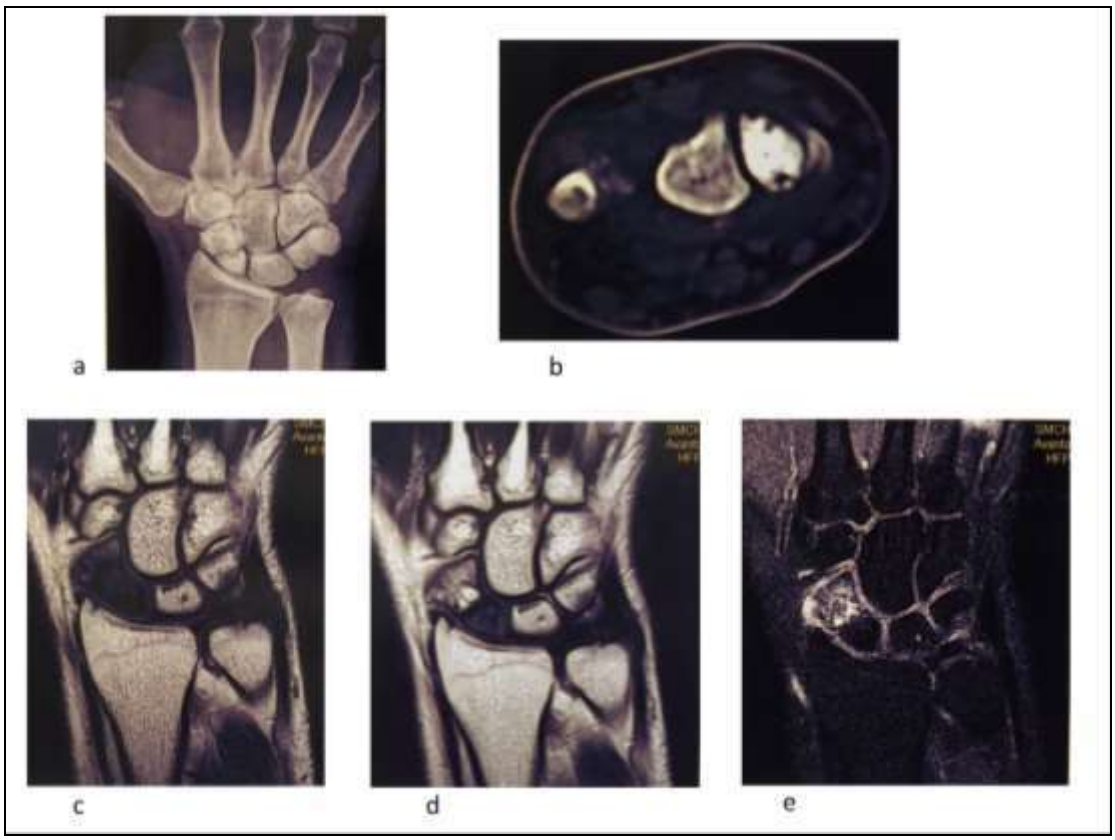

Fig 3: Osteonecrosis of Scaphoid. X ray (a), CT (b), MRI T1 Coronal (c), T2 Coronal (d) and Post-contrast Coronal (e).

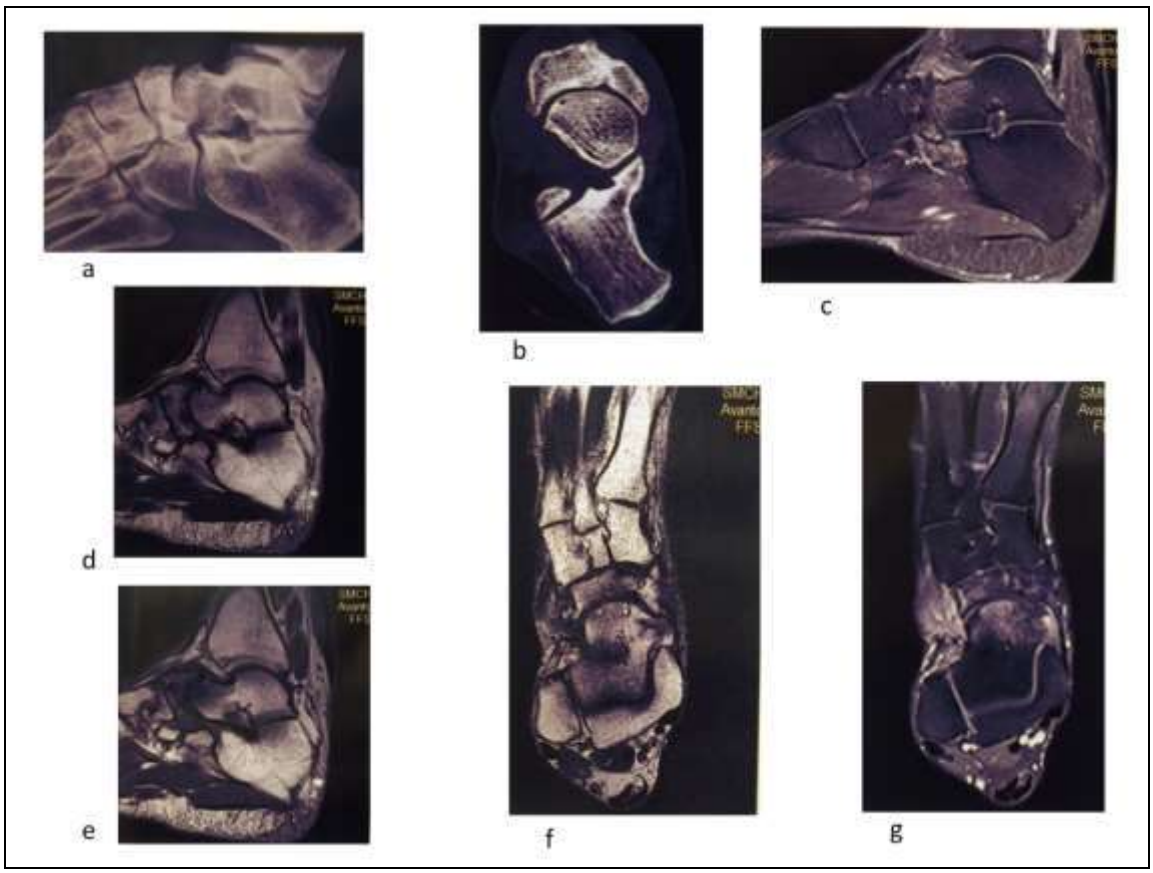

Fig 4: Osteonecrosis of Navicular. X ray (a), CT (b), MRI T1 Sagittal (d), T2 Sagittal (e), T2 axial (f), Post contrast Sagittal (c) and Axial (g).

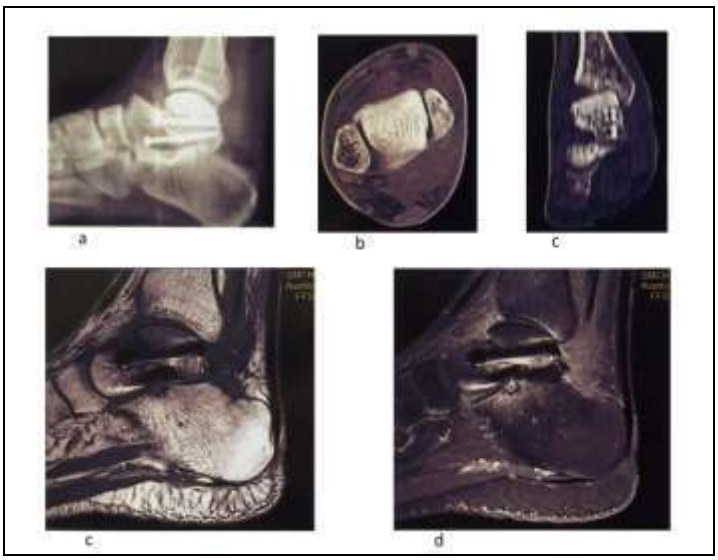

Fig 5: Osteonecrosis of Talus. X ray (a), CT (b and c), MRI T1 Sagittal (c), Post contrast Sagittal (d).

Conclusion

Avascular necrosis of bone poses a major diagnostic and therapeutic challenge. Despite treatment, the condition has been normally seen to follow a progressive course towards a destructive osteoarthropathy. The femoral head is the most common vulnerable site followed by Scaphoid, Lunate, Talus, Humeral head, Femoral or Tibial metadiaphysis. The condition is mostly idiopathic and associated with Corticosteroid, Hematological disorders, and Trauma.

MRI is the most sensitive imaging modality for diagnosis. Its ability to detect the marrow changes giving it a superior sensitivity in the early stages. CT scan however, depicts bony changes like subchondral fractures more clearly than MRI.

Early diagnosis of avascular necrosis is of very much importance in order to obtain optimal results when performing conservative treatment and to prevent advanced disease process, lifelong disabilities or complex surgical intervention.

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