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Original Research Article

MRI Evaluation of Legg Calve' Perthes Disease – A Preliminary Study

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Abstract: Legg-Calvé-Perthes disease is a common cause of hip pain in preadolescent children that may be initially clinically and radiographically difficult to diagnose and stage. Till recently, diagnosis and treatment decisions were based on X-rays. At present, MR Imaging plays a crucial role in the management of Perthes disease. The purpose of this article is to analyze the femoral head pathology in Perthes Disease at tissue level by different MR sequences. A total of 20 MRI of hips with Perthes disease were analyzed in 18 children aged 3 to 13 yrs. Nine patients had unilateral Perthes disease with normal contralateral hip, 2 children had bilateral Perthes disease and the remaining 7 patients had unilateral Perthes disease with the other hip showing varied changes in epiphysis and synovium. Five hips (25%) showed air pockets in the epiphyses, fluid intense areas were appreciated in 50% of the affected epiphysis and fat was the most frequent component (70%) noted. Migration index of LCPD hips had a wide range (14.52 - 53.15). Statistically significant correlation was documented for MI and Catterall group ($P < 0.01$). Fifteen hips (75%) showed physeal bars and sixteen hips (80%) had metaphyseal cysts. Metaphyseal cysts were heterogenous with fat, cartilage, fluid and air as contents. Air was detected in metaphyseal cysts in three hips (18.75%). All the 20 hips showed synovial effusion. Seventeen hips showed synovial enhancement (85%), 6 hips showed synovial thickening and 1 patient had marked, irregular synovial thickening. In conclusion, MR images could show most of the pathological changes in Perthes disease, even upto the level of tissue characterization. Secondary changes due to weight-bearing influence the MRI findings in Perthes disease and hence optimization of MRI technique and timing is essential for further improvement in imaging. Using MR perfusion for demonstration of avascularity and diffusion imaging for detection of early ischemia can help in timely interventions in the avascular phase and thereby prevent further progression and complications.
Keywords: MRI, Perthes disease

INTRODUCTION

Legg Calve Perthes disease (LCPD) is a disease of pediatric hip first described by Arthur Legg (USA), Jaques Calve (France) and Georg Perthes (Germany) during 1909-1910 [1]. Even after a century of intense research, its etiology is unknown, pathogenesis is unclear and the treatment is controversial. Perthes disease is characterized by ischemic osteonecrosis of the femoral capital epiphysis. Three stages have been described in this self-limiting condition; the stage of ischemic necrosis followed by stage of revascularization and repair and then the healed phase [2]. Resorption of old infarcted bone and formation of new woven bone occur simultaneously. This transition takes some time and the epiphyses in this phase show mixed intensities suggesting granulation tissue, fibrocartilagenous tissue, unossified bone and mature bone. Articular cartilage gets hypertrophied. The increased pressure in epiphysis causes extension of necrosis downwards (into the metaphysis) or laterally, leading to deformed femoral head. (Packed capsule model) [3]. Healing occurs in the altered shape which can lead on to joint incongruency and early osteoarthritis. Management of LCPD is directed to avoid this mishap. Till recently most of the interpretations regarding diagnosis, staging and treatment decisions were based on X-rays. However with the advent of Magnetic resonance imaging (MRI),

more light has been thrown into the pathology of this disease. At present, MRI plays a crucial role in the management of LCPD patients, from initial diagnosis to post-operative follow up. In addition to the usual advantages like lack of radiation, multiplanar capability and better soft tissue resolution, MRI can also evaluate the changes in the cartilage in LCPD. The present article is based on a pilot study conducted in a tertiary care center in South Kerala, where prevalence of LCPD is reported to be high [4]. A total of 20 MRI of hips with LCPD were analyzed in 18 Children aged 3 to 13 yrs. The purpose of this article is to analyze the femoral head pathology in Perthes Disease at tissue level by different MR sequences.

MATERIALS AND METHODS

Study cohort included 18 patients (20 hips) with X-ray positive Perthes disease. Children of either sex, with age before skeletal maturity and normal mental and physical development presenting with hip pain or limping were included. Patients with history of joint disease or previous corrective osteotomy and known cases of hypothyroidism, sickle cell disease and skeletal dysplasia were excluded. The patients underwent MRI evaluation of both hips using a body coil (1.5 T Magnetom Avanto, Siemens). The MRI sequences included were TSE T1, TSE T2 (space), T2 FLAIR (fluid suppressed), STIR (fat suppressed), DWI and ADC mapping, Gradient echo (Medic), and Post contrast dynamic study using fat suppressed T1 images (VIBE).

Normal femoral capital epiphysis appears hyperintense on T1, T2 and hypointense on Gradient Echo (Bony). Epiphyses with LCPD appear hypointense on T1 and T2 (Fig 1). When epiphyses appeared heterogeneous, FLAIR and STIR sequences were applied to identify fluid and fat respectively. Focal hypo intensities, which were hypo on all sequences were due to air {Presence of fat, fluid and air were again confirmed using computerized tomography (CT) scan} (Fig 2) .Whenever differentiation of hypertrophied articular cartilage from affected epiphyses was difficult (both being hypointense on T1 and T2), gradient echo sequence (Medic) was found useful (Fig 3). Post-contrast dynamic images were mandatory to assess extent of revascularization of epiphysis and differentiation of thickened synovium from hypertrophied cartilage (Fig 4)

The epiphyseal changes, especially those involving the articular surface were better appreciated on coronal images. Sagittal sections were reconstructed from space sequence whenever necessary and these sections were useful in knowing the extent of femoral head involvement and degree of flattening. Axial sections were of limited use as the superior portion of the femoral head was inadequately visualized because of partial volume averaging. Fourteen children underwent CT scan because MRI of these children showed signal intensities suspicious of air or signal intensities which could not be resolved by the different sequences in MRI. Radiation dose was kept to the minimum by special software ("care dose for you" by Siemens) and gonadal protection. CT sections and different MR sequences were analyzed by the same radiologist.

Epiphyseal involvement by Perthes disease was categorized on MRI using the Catterall classification (1971) for X-rays [5]. It was based on the extent of epiphyseal involvement

Group 1 - 25% involvement with clear demarcation between involved and uninvolved areas
Group 2 - 50% involvement with clear demarcation between involved and uninvolved areas
Group 3 - 75% (Subtotal) involvement
Group 4 - 100% (Total) involvement

The affected epiphyses were further categorized based on the major signal intensity as either bone or cartilage (100% bone, >50% bone, < 50% bone or 0% bone). The heterogeneous signals were identified and noted as fluid/ fat/ air. Assessment of epiphyseal flattening was done by measuring the height of epiphysis on coronal MRI and /or CT with coronal reconstruction. CT showed only bony component whereas cartilage was also seen on MRI. Mid coronal or near mid coronal sections were selected and maximum height was measured. Epiphyseal fragmentation was assessed by visual impression and was better appreciated on X-ray and CT than MRI. Uneven articular surface of epiphyses with joint incongruency was taken as epiphyseal deformity. We used the migration index to measure the lateral displacement of the ischemic femoral epiphysis in LCPD. Reimers Migration index was used to assess the risk of hip subluxation in children with cerebral palsy [6]. The fraction of femoral head projecting out of the lateral acetabular margin was calculated in frontal hip X rays [7]. The measurement was taken on mid-coronal T2 images (with maximum neck included), where the three points were clearly appreciated (Fig 5). Line A is the vertical tangent through the lateral most point of epiphysis, and line C is through the medial most point. Line B is the vertical tangent through the lateral most point on acetabular margin. Migration index was calculated in both normal and abnormal hips. Physeal

bars were appreciated as interruptions of the hypointense physis by focal altered signals (Fig 6). Metaphyseal cysts appeared as focal, well circumscribed areas of altered signal intensity in the metaphysis just beneath the physis. The signal intensity varied according to their contents. Synovial thickening, enhancement and effusion were also noted.

OBSERVATION AND RESULTS

Study included 18 patients (16 males and 2 females) with a mean age of 7.4 years (range 3-13 years). Nine out of 18 patients (50%) had unilateral Perthes disease with normal contralateral hip. Right and left hip involvement was 45.55% and 55.45% respectively. Among the 9 patients who had bilateral abnormal hips, 2 children had bilateral Perthes disease (11.11%) and the remaining 7 patients had unilateral Perthes disease with the other hip showing varied changes in epiphysis and synovium. A total of 20 hips (16 unilateral + 2 bilateral) with Perthes disease were analyzed by MRI in this study.

Thirteen hips were in Catterall 4 group and only 2 patients were in Catterall 1group. Further categorization of signal intensity as bone or cartilage revealed 65% had mixed intensities, suggesting non-ossified or cartilagenous category. Five hips (25%) showed air pockets in the epiphyses and among these 5 hips, all of them had Catterall 4 disease and three had extension of air pockets to the metaphyseal cyst. Fluid intense areas were appreciated in 50% of the affected epiphysis and fat was the most frequent component (70%) noted. Fourteen epiphyses (70%) were flattened and deformed. Epiphyseal fragmentation was noted in 55% of hips, and all had associated lateral migration. Subchondral fissuring/ sclerosis were noted in 2 epiphyses (Fig 7). Approximately half of the epiphyses (55%) enhanced on post contrast images. Patterns of enhancement included peripheral ring like, peripheral dotted, central dotted and double ring enhancement. Epiphyseal enhancement was always associated with synovial as well as metaphyseal cyst wall enhancement.

Migration index (MI) was measured in all subjects. Migration index of LCPD hips had a wide range (14.52 - 53.15) (Fig 8), whereas in normal hips, it ranged from 7.51 to 32.61. The hip with maximum lateral migration belonged to Catterall 4 (Fig 9) and least was in Catterall 3. The only healed Perthes hip had MI of 14.52. There was significant difference between the MI of 2 patients in Catterall 1 (25.16 & 35.54). Mann Whitney test of significance was applied and correlation of MI with Catterall group was done for all 36 hips. The P value was 0.0001, indicating high statistically significant variables.

Fifteen hips (75%) showed physeal bars. Other physeal changes noted include undulations of the physeal line and physeal enhancement. Physeal enhancement was the only physeal change noted in one patient. The most common and the only metaphyseal change noted was presence of metaphyseal cyst. Sixteen out of the 20 hips (80%) had metaphyseal cysts. Among the four cases without metaphyseal cysts, one was Catterall 3 (metaphysis showed focal fat intensity) and two cases were Catterall 1 and 3 (no involvement of physis or metaphysis). The fourth case was healed perthes disease with bony physeal bars and no MR evidence of cyst in the metaphysis.

Metaphyseal cysts were heterogenous with fat, cartilage, fluid and air as contents. Air was detected in metaphyseal cysts in three hips (18.75%). All these patients had air within their epiphyses and metaphyseal involvement was noted in continuity (Fig 10). Thirteen metaphyseal cysts showed (81%) enhancement of their lining with associated enhancement of the synovium, indicating presence of synovial lining for the cysts also. None of the cysts showed enhancement of their contents. Bone is not a usual content of metaphyseal cyst, however in our series; bone was noted in one case of healed Perthes.

All the 20 hips showed synovial effusion. Seventeen hips showed synovial enhancement (85%), 6 hips showed synovial thickening and 1 patient had marked, irregular synovial thickening which amounted to proliferation with associated severe effusion (Fig 11). However, synovial thickening and enhancement was also noted in contralateral hips without Perthes disease (18.7%). Labral elevation was correlating with the degree of lateral migration of epiphysis (Fig 12). Fourteen out of the 20 hips showed elevated labrum. Labral tears were inconstant finding.

Table 1 - Relation between physeal –metaphyseal changes and Migration index

Catterall Group	Physeal Changes	Metaphyseal Changes	Migration Index
1 (<25%)	+	+	25.16
1 (<25%)	Nil	Nil	35.54
3 (75%)	Nil	Nil	17.46
3 (75%)	Nil	Nil	30.52
3 (75%)	+	+	44.53
4 (100%)	+	+	47.50
4 (100%)	+	+	32.20
4 (100%)	+	+	53.15

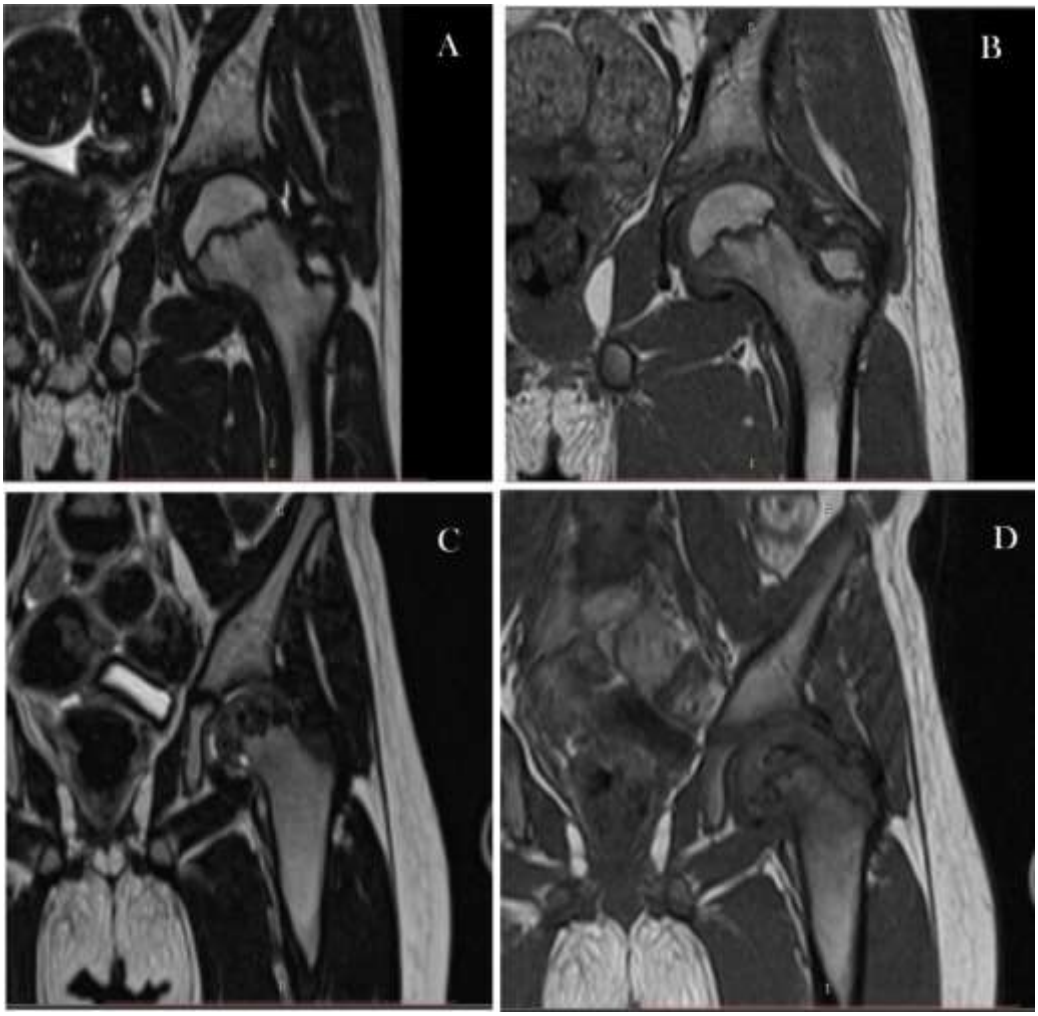

Fig 1: Normal epiphysis is hyper on T2 (A) and T1 (B). Perthes disease causes hypointensity on T2 (D) and T1 (E)

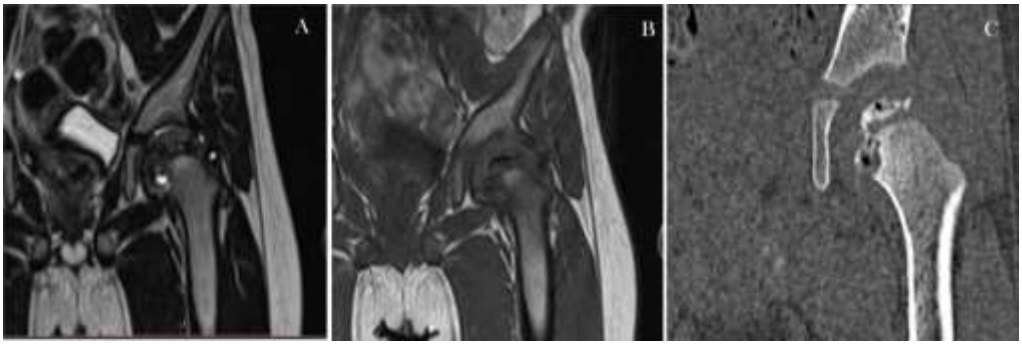

Fig 2: Air appears hypointense on T2 (A) and T1 (B). Corresponding CT image shows air density (C)

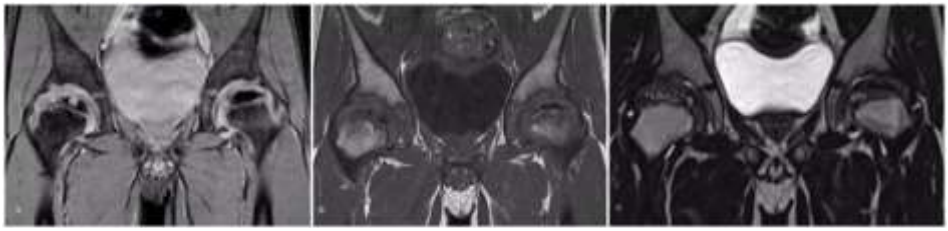

Fig 3: When T1 /T2 images (B & C) cannot show Epiphysis separate from hypertrophied articular cartilage, MEDIC is useful (A)

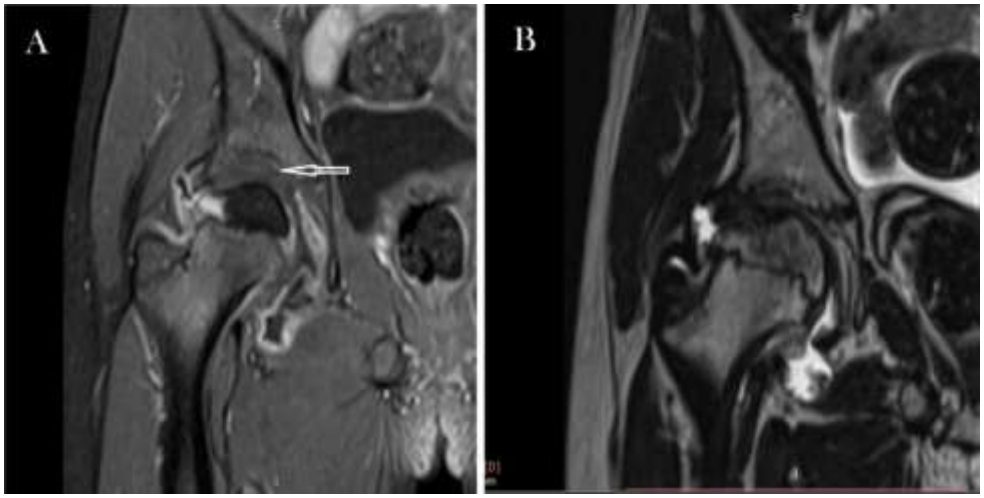

Fig 4 (A) - Post contrast T1 FS - enhancing synovium seen separate from non-enhancing cartilage (white arrow-cartilage). (B) - T2 -Synovium is not seen distinctly from the cartilage

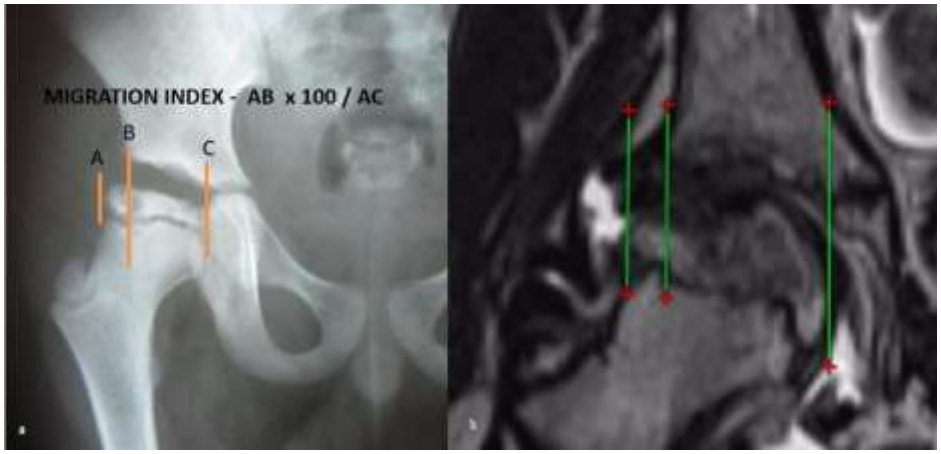

Fig 5: (a) Antero-Posterior X ray of right Hip showing the 3 vertical lines. (b) Mid coronal MR image illustrating the same.

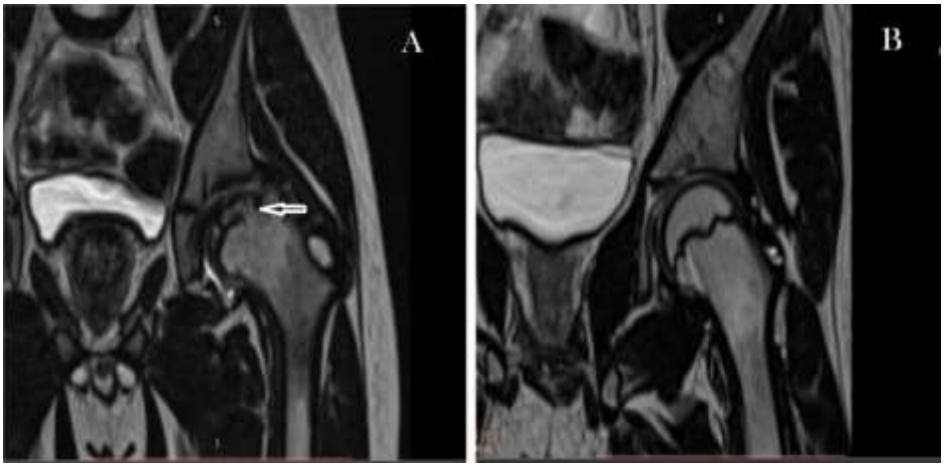

Fig 6: (A) - Physeal bar is seen connecting epiphysis and metaphysis (arrow). (B) - Normal physis is a thin hypointense line between epiphysis and metaphysis

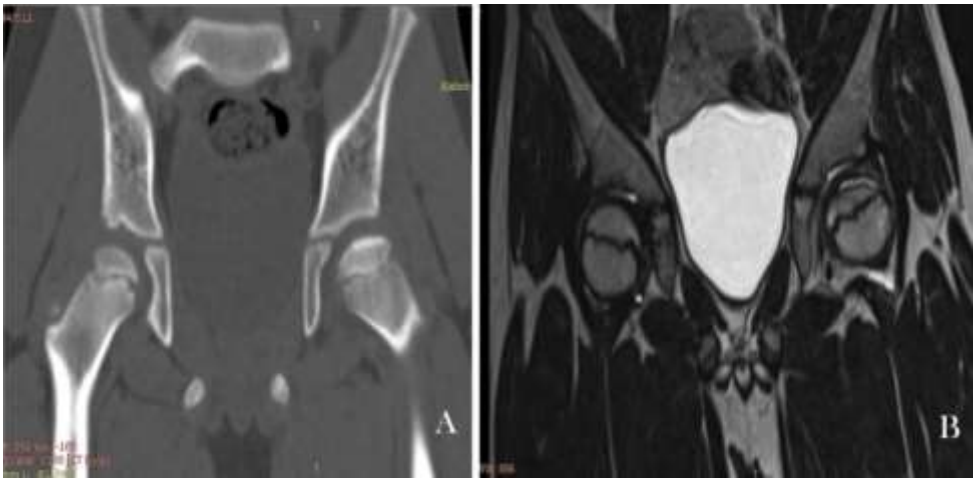

Fig 7: Subchondral sclerosis of Left Femoral epiphysis on CT coronal reconstructed image (A); seen as curvilinear hyperintensity on T2 (B)

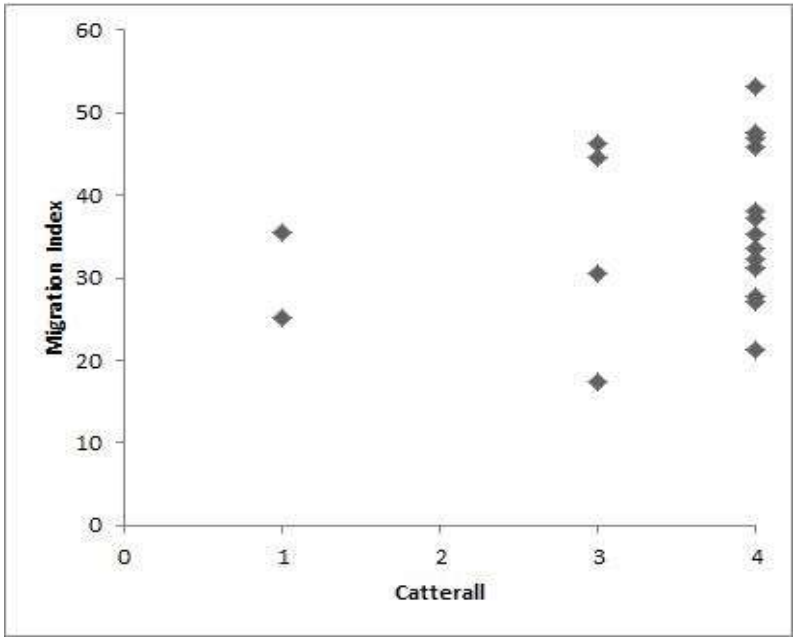

Fig 8: Migration index of children according to Caterall group

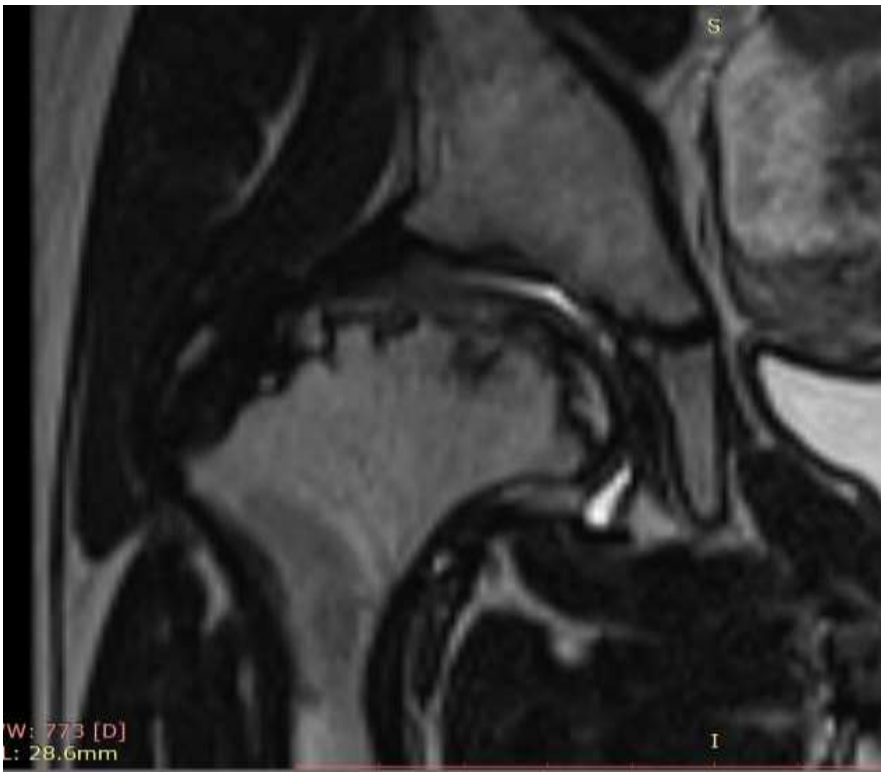

Fig 9: The hip with maximum lateral migration (53.15) belonged to Catterall 4. Note the horizontally oriented labrum

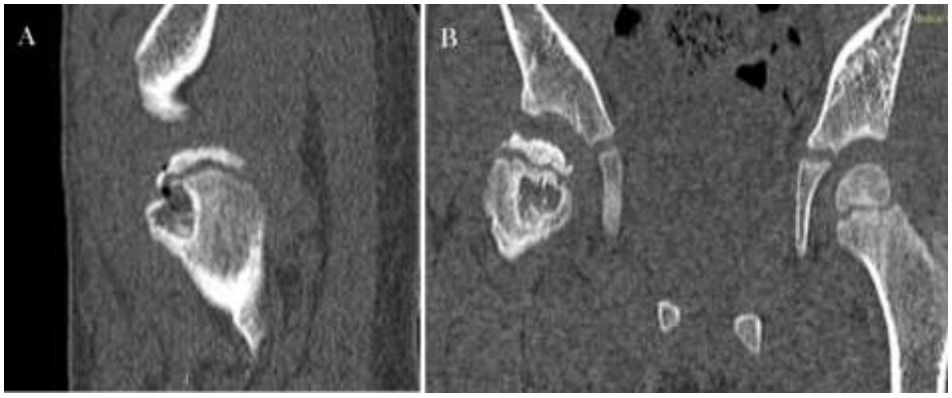

Fig 10: CT sagittal and coronal reconstruction- Catterall 4 disease - Air pockets in epiphysis, extending to metaphysis through physis (A). Large size of the metaphyseal cyst is seen (B)

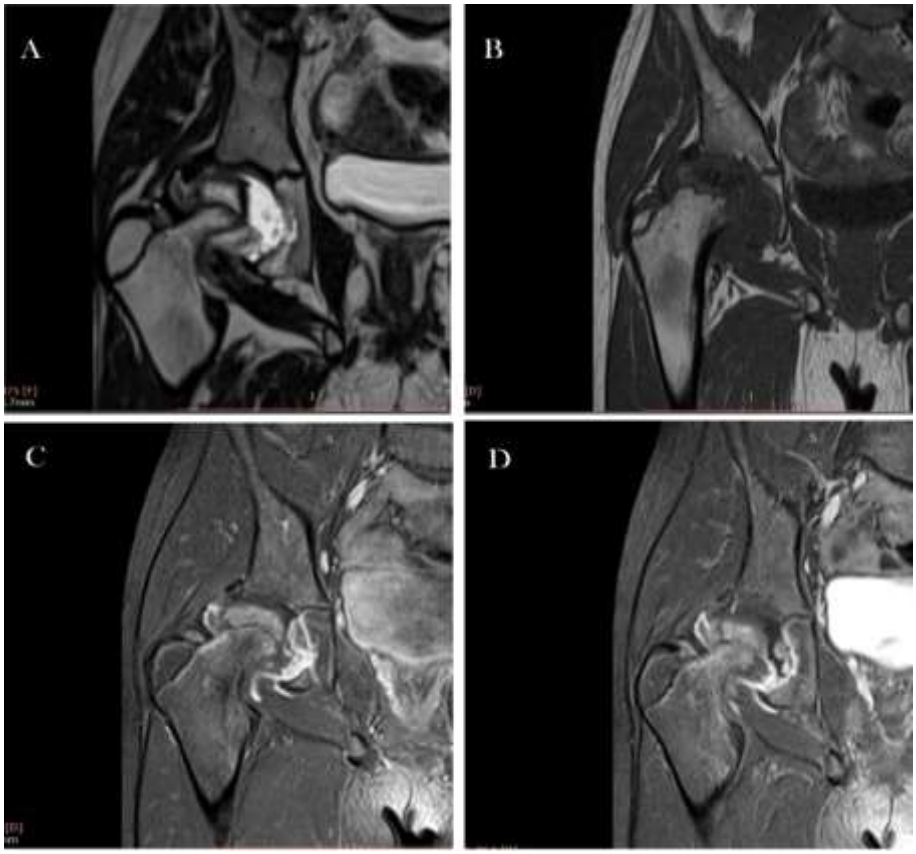

Fig 11: T2 (A), T1 (B) and post contrast images (C, D) showing thickened, enhancing synovium with proliferation

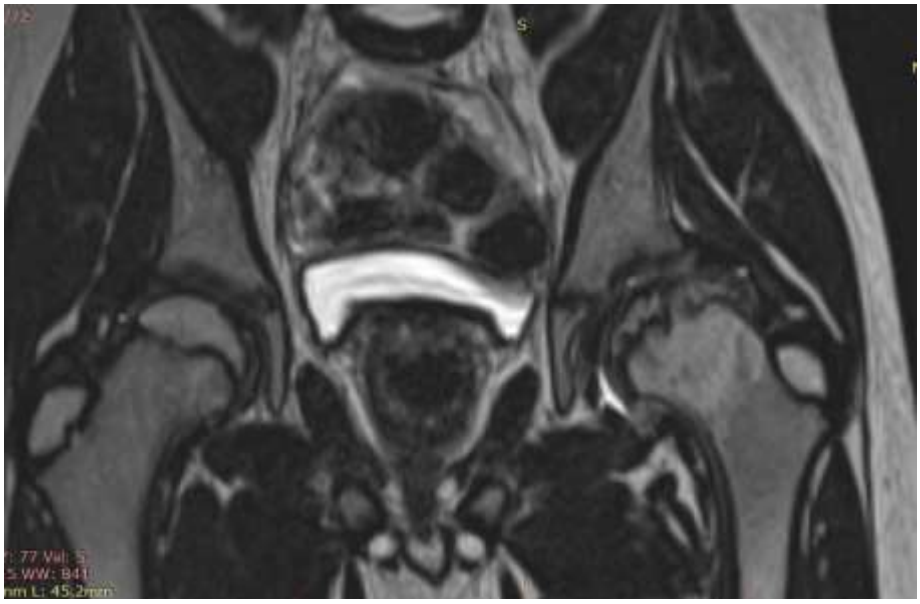

Fig 12: Horizontal labrum of left hip due to elevation by the enlarged, migrated epiphysis

DISCUSSION

Most of our observations were correlating with similar findings in studies published. Unilateral hip involvement was the rule in our study also, as described in other studies. The two cases with bilateral Perthes had initial single hip involvement with asymmetric disease. The 7 patients with unilateral perthes having abnormal contralateral hips showed changes like cartilage hypertrophy (growth of epiphyseal cartilage is halted while the surface cartilage gets nourished by synovial fluid and continues to grow) [8], and epiphyseal irregularity. An additional finding of altered signal intensity was noted in the epiphysis of one asymptomatic hip. Neither physeal nor metaphyseal changes were noted in these 7 hips. These changes in the opposite hips in unilateral perthes disease have also been described in earlier studies and may represent early evidence of Perthes disease or response of the unaffected epiphysis to additional stress [9]. Long-term follow up of these cases by clinical and radiological means is needed for confirmation.

Based on the MRI findings, an attempt was made to group patients into different stages as described by Jonathan R Dillman as vascular phase, revascularization and reparative phase and healing phase, considering the different parameters like extent of epiphyseal involvement, extent of lateral migration, physeal and metaphyseal changes [10, 11]. However, there was considerable overlap while attempting to stage patients in this study. The role of MRI in detecting the different pathological changes is well described [10]. In our study, these changes were further analyzed and interpreted by the different sequences to identify the tissues. The bone necrosis and different stages of its regeneration – granulation tissue, cartilage and non-ossified bone have different appearances on MRI. Epiphyses showed fat, fluid and air in the areas of repair. All the epiphysis, which showed air were in the Catterall 4 category, suggesting presence of air as an indicator of severe ischemia. Air in Perthes disease has not been reported so far.

The prognostic classification of LCPD by MRI proposed by Nande de Sanctis considered the extent of necrosis (for classification into A and B, <50% necrosis in A and >50% in B) [11]. Two epiphyses (10%) were in group A (both <25% necrosed) and both had physeal involvement and migration index in reciprocal relation. Out of the remaining 18 epiphyses (Group B), 2 showed neither physeal nor metaphyseal changes. The lateral migration was more in both these epiphyses (Table -1) suggesting that the necrotic epiphyses under pressure show tendency to migrate either down into physis or laterally, favoring Packed capsule model [12]. However, physeal changes and Migration index were not so correlating with higher grades. It was also noted that the epiphysis with Catterall 3 (MI - 17.46) and Catterall 1 (MI - 35.54) were devoid of physeal and metaphyseal changes. The only explanation is that the latter (Catterall 1 - MI 35.54) showed articular cartilage hypertrophy which contributed to high MI, suggesting that the extent of epiphyseal necrosis is not the only factor deciding the lateral migration. Other factors like

metaphyseal involvement and synovial proliferation and effusion are important. These associated changes also need grading before we reach a conclusion regarding the feasibility of packed capsule model.

MRI was superior in demonstrating the cartilaginous hypertrophy in epiphyses which showed only flattened bone on X-rays and CT. No reliable conclusions were made regarding the pattern of enhancement or volume of enhancing tissue and its role in predicting prognosis and treatment. Epiphyseal enhancement when present, indicated revascularization and new bone formation. Attempts to stage the disease according to the Jonathan R Dillman [10] pathological classification was not effective and there were considerable overlap between these stages, especially with physeal and Metaphyseal changes. The usefulness of this measurement as an indicator of lateral hip migration in Perthes disease was tested in this study and was found to be highly significant. The lowest value for hip with LCPD was 14.52. The relation of MI with severity of involvement of metaphysis was not statistically significant (p- 0.4273). Small sample size in each catterall group caused the assessment of packed capsule model to be inaccurate.

Physeal cartilage is seen as a distinct hypointense line between the epiphysis and metaphysis, hypointense on all sequences except MEDIC. MRI can pick up physeal changes better than any other modality as the hypointensity is replaced by other signals in the presence of physeal bars. This study substantiated this ability of MRI to detect physeal changes. However two cases had diagnostic difficulties and in these cases, CT was used to solve the issue by demonstrating the bar and its contents, especially because of its capacity to measure the density. Thus, CT was more useful in case of healed perthes. The enhancing physis, as the sole or early finding of physeal involvement, needs further studies for confirmation. The close association of physeal bars and metaphyseal cysts has been well described in literature and proves the "packed capsule model" in LCPD [3, 11]. This association was noted in the present study also. The study does not prove 100% sensitivity of CT or MRI in demonstrating physeal changes (may be due to small sample size and use of CT was restricted). Increased undulations of the physis and deepening or cupping of the physis have been described in previous studies but these findings were not demonstrated in the present study. At present, there is no evidence whether these changes can be taken as earliest evidence of physeal involvement and has to be proven by close follow up.

The most common metaphyseal changes described in LCPD is metaphyseal cysts. Contents of the cysts have been described as extension of physeal cartilage, metaphyseal osseous resorption or fibro vascular (granulation) tissue deposition [2, 13]. Metaphyseal cysts have also been described as increased metaphyseal adipose tissue, disorganized ossification and metaphyseal extension of unossified growth plate [10]. Fat necrosis, vascular proliferation and focal fibrosis were the histopathological findings demonstrated from core biopsy specimens in a study by Eckerwall *et al.;* [2]. The present study attempts to characterize the actual tissue in the metaphyseal cysts as cartilage, fat, fluid and bone. However, there is lack of confirmation by biopsy in this study. The presence of air in metaphyseal cyst has never been reported in literature previously. All 3 metaphyseal cysts with air had associated air in epiphyses also, denoting extension from ischaemic epiphysis. Enhancing cyst lining along with synovial enhancement denotes synovial lining for these cysts. Only 3 cases of Perthes disease had absent metaphyseal cyst (1 patient in Catterall 1 and 2 patients in Catterall 3). All three cases had bony epiphyses without much cartilage. This morphology can explain the lack of physeal and metaphyseal involvement. Synovial thickening and proliferation and effusion were the synovial changes noted in our study. The hip with synovial proliferation had severe effusion. These changes have already been described in LCPD [13, 14].

CONCLUSION

MR images could demonstrate most of the pathological changes in LCPD, even upto the level of tissue characterization. Staging or classification system for purpose of treatment and prognosis is lacking and needs further studies with large sample size and more variables like cartilage hypertrophy, synovial proliferation, and labral changes. Effect of weight bearing and secondary changes influence the MRI findings in Perthes disease. Optimization of MRI technique and timing is essential for further improvement in imaging. Using MR perfusion for demonstration of avascularity and diffusion imaging for detection of early ischemia can help in timely interventions in the avascular phase and thereby prevent further progression and complications.

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