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Review Article

Utility of MR Imaging in Developmental Dysplasia of Hip

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Abstract

Developmental dysplasia of the hip is the most common cause of an unstable hip in paediatric population. It can be assessed using various radiological modalities. However due to excellent soft tissue characterization and with no radiation hazards, Magnetic Resonance Imaging (MRI) plays an important role in the early detection as well as in the evaluation of various soft tissue obstacles that can cause hindrance in reduction. Preoperative MR imaging also helps in determining the acetabular labral coverage which further guides the orthopaedic surgeon in planning the management. In postoperative cases, apart from the assessment of adequacy of reduction, immediate and delayed post operative complications like ischemic necrosis can be detected earlier than with other imaging modalities thus helping in appropriate and timely management. Here we present a pictorial assay of the MR imaging techniques and the findings with a focus on various important anatomical structures required to be evaluated while performing and reporting MRI of these cases.

Keywords: Acetabulum; Complications; Computed tomography (CT); Developmental dysplasia of hip (DDH); Magnetic resonance imaging (MRI); Radiography

Introduction

Developmental Dysplasia of Hip (DDH), also termed as infantile hip dysplasia is the most important cause of unstable hip in children [1]. Left hip is more commonly involved (40 to 60% of cases) with bilateral involvement in 20% [2]. It includes spectrum of developmental disorders in which mild dysplasia refers to stable and aligned hip while in severe cases the hip is unstable and dislocated [3]. DDH occurs either due to the acetabular dysplasia or due to the laxity of the supporting structures. The hip joint develops from the cartilaginous anlage at around 4 to 6 weeks gestational age. The femoral head gets completely encircled by the acetabular cartilage. Due to disproportionate growth of the femoral head and the surrounding cartilage, less than 50% coverage of the femoral head occurs at birth. However weeks after the birth, the acetabular cartilage develops more rapidly than the femoral head which results in progressively increased coverage [4]. Therefore minimal structural support of the femoral head is during late gestation and few months after birth so there are more chances of hip dislocation or subluxation in this period. Intrauterine factors like oligohydrominos and post natal positioning such as wrapping the legs in extended position affect the acetabular development [5]. The Risk factors include positive family history, breech presentation, torticollis, scoliosis and structural abnormalities which include underdevelopment of anterior capsule, ligament of Bigelow or rectus muscle [6]. Early diagnosis and treatment are important as the acetabulum is susceptible for remodeling in the first 6 weeks.

Clinical tests play a major role in the early detection of DDH. Imaging studies which include plain films, Ultrasound, CT and MRI supplement the clinical tests both for diagnosis as well as for follow up. Plain films are valuable in children >6 months after the femoral head and acetabular ossification occurs. Ultrasound plays an important role in the evaluation of acetabular morphology before the appearance of ossific nucleus and also in the dynamic examination. CT has a limited role and is only done in postoperative cases for assessment of adequacy of reduction when the patient is in spica cast and ultrasound cannot be done [7]. To minimize the radiation, low dose CT technique should be employed [8]. Due to better soft tissue characterisation and no risks of ionising radiation, MRI is the excellent modality to show the relationship of femoral head and the acetabulum even when they are not ossified. It is preferred to look for- the femoral ossific nucleus, the acetabulum, and the soft tissue obstacles in the reduction in non reducible cases and also to look for the immediate and delayed post operative complications like ischemia which can be detected earliest on MRI.

Overview

MRI can be used in early detection and evaluation of DDH. The femoral capital epiphysis displays intermediate signal on T1W and hyperintense signal on T2W. Due to its multiplanar imaging capability ,the position of the capital epiphysis can be demonstrated on coronal imaging especially when it is uncertain on conventional radiograph and the ossific nucleus is not visible on plain radiograph. Axial and coronal MR images are most useful and small surface coils with high spatial resolution are necessary to evaluate DDH. Essential sequences include T1W for portraying the ossified elements with good anatomical detail, T2W for effusion, PDFS to see for cartilage a s well as labrum and dynamic Post contrast T1W FS for the early detection of ischemia in post operative cases.MR imaging has numerous advantages over radiography particularly in looking for the ossified femoral nucleus as well as in better demonstration of morphology of the acetabular dysplasia in single examination with lack of ionising radiation. Also with the proper use of sequences arthrogram like image can be produced [9]. MR is also used to evaluate the causes of non reducibility in the preoperative imaging and also to detect the immediate and delayed post operative complications. Aditi et al.

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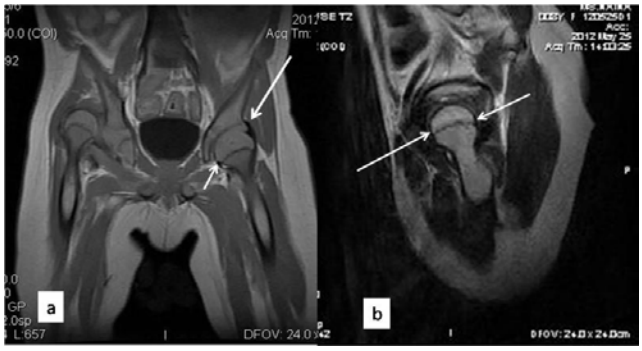

Figure 1 a&b: (a) T1 W coronal image depicts normal superior (large white arrow) and inferior acetabular labrum(small white arrow) (b) T2 W sagittal image of left hip showing anterior (large white arrow)and posterior labrum(small white arrow) which appear hypointense on both and are named according to location.

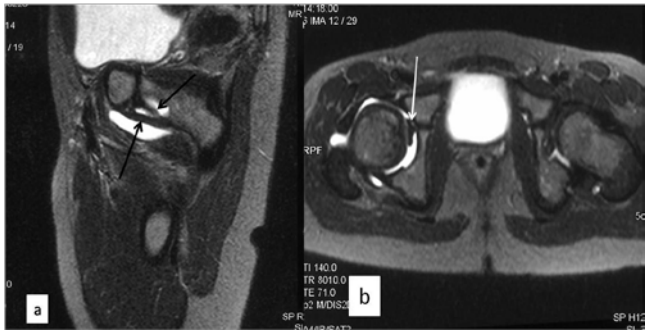

Figure 2 a&b: (a) T2WFS Sagittal image of the left hip depicting normal transverse acetabular ligament (large black arrow) and ligamentum teres (small black arrow). (b) T2W FS axial view depicting the normal ligamentum teres (white arrow).Note is made of right hip joint effusion.

[10] described the use of postoperative MRI after spica cast to look for the successful reduction and also to see for the post reduction complications.

However, limitations of MRI include high cost, need for sedation in children due to long scanning time and lack of dynamic evaluation. Also immediate post operative imaging cannot be done if the non compatible MR implants are used.

In general, MRI is only indicated for complicated or severely dysplastic hips and in post operative unsuccessful reduction and to see for post operative complications [6].

MR Techniques and interpretation

Sedation is given in infants and younger children to optimize the MR imaging technique and to avoid the motion artifacts. Proper sedation guidelines are to be followed and commonly used sedatives include barbiturates and fentanyl. Proper monitoring should be done during and after the sedation.

For imaging and comparison of both the hips large FOV is required for which body coil is used however dedicated Hip coil is used to provide high resolution images. Examination is performed with 512 x 256 or 256 x 256 acquisition matrix using 1 or 2 excitations (NEX). Thin sections (3 or 4 mm) are used with minimal interslice gap. Standard imaging protocols in hip includes coronal T1W Spin echo, coronal short tau inversion recovery, axial T2 W Fast Spin Echo (FSE), fat saturated oblique sagittal FSE, Proton Density (PD) FS and axial FSE PD images. Additional protocols include coronal three-dimensional spoiled gradient recall echo with fat suppression and post contrast FS T1W.

Anatomy with normal MR appearance

Important anatomical structures to be evaluated and to be reported in hip in DDH with their typical appearance on MRI are:

1. **Acetabular Labrum:** It is the fibro cartilaginous rim which deepens the acetabular cavity. On routine MR imaging, the normal labrum is seen as dark signal triangle covering the articular cartilage at the peripheral margin of the acetabulum and are named according to the location as anterior superior, superior and posterior superior labrum (Figure1a and b).

2. **Transverse acetabular ligament:** The inferior aspect of the acetabulum is not covered with the labrum and the transverse ligament spans the inferior acetabulum (Figure 2a). It shows homogeneous low signal on spin echo and gradient echo images.

3. **Ligamentum teres:** It is the ligament which extends from the acetabular fossa to the fovea capitis, a small depression on the medial femoral head (Figure 2b).

4. **Cartilage:** The acetabulum is entirely covered by the articular cartilage except for the acetabular fossa. Fovea capitis is the only aspect of femoral head deficient in cartilage.It is thicker along the superior margin of the femoral head and thinnest along the posterior margin. It shows intermediate signal intensity on spin echo and gradient echo images (Figure 3).

5. **Capsule:** Fibrous capsule attaches proximally to the acetabular labrum, transverse ligament and extends to the most of the femoral neck with attachment to the base of trochanter. Capsule is reinforced by ischiofemoral, iliofemoral and pubofemoral ligaments which are the thickening of the capsule. On routine MRI, capsule appears hypointense on T1W and T2W images (Figure 4a).

6. **Iliopsoas tendon**: Major hip flexor which is inserted on lesser trochanter and passes anterior to the hip joint (Figure 4b).

7. **Pulvinar fat:** Acetabular fossa is the inferiomedial part of the acetabulum which is occupied by the pulvinar fat pad and the round ligament.

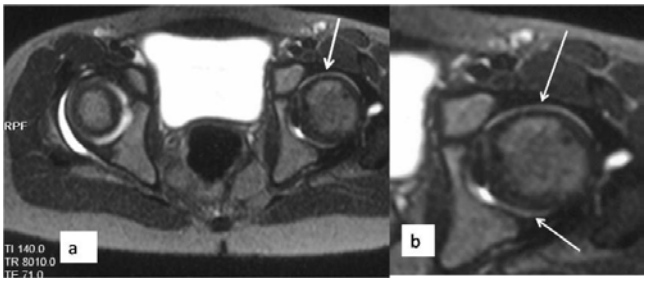

Figure 3a: Axial T2W FS image of the pelvis including bilateral hips depicting normal acetabular cartilage (white arrow) showing intermediate signal which is deficient at the fovea capitis. Joint effusion is seen on right side. (b) Zoomed image of the same better depicts the anterior and posterior articular cartilage (arrow).

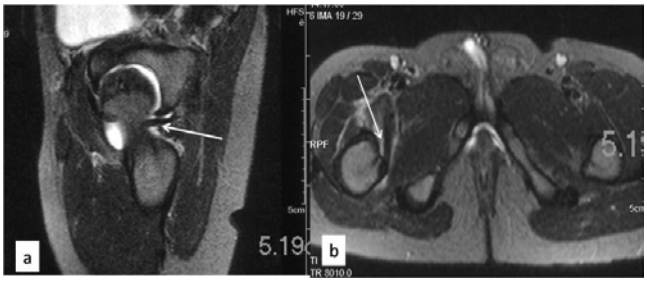

Figure 4a: Sagittal T2W FS image of left hip demonstrates the normal fibrous capsule (arrow) appearing hypointense on all sequences and is reinforced by multiple ligaments. (b) T2W FS axial image shows iliopsoas tendon (arrow) as a low intensity structure which is a major flexor of hip joint and is inserted on the lesser trochanter.

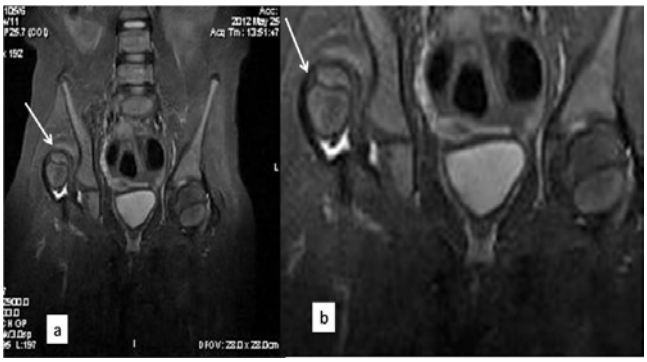

Figure 5 a&b: Right sided DDH STIR Coronal image (a) Head is dislocated superiorly on right side (arrow). (b) Labrum is also thickened and appears hyperintense (arrow).

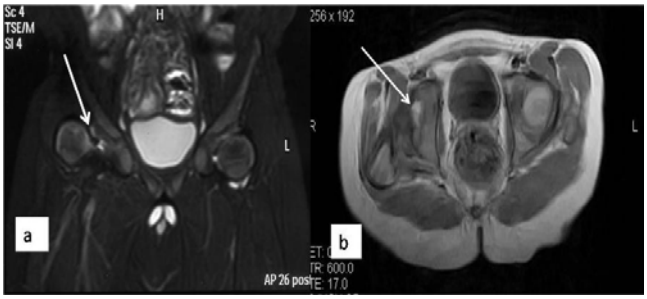

Figure 6 a&b: STIR coronal image with right sided DDH. Femoral head is displaced superiorly. Acetabular labrum is hypertrophied and slipped into the joint (arrow) which blocks the closed reduction. (b) Axial T1W image with DDH on right side shows pulvinar hypertrophy (arrow), another cause of difficult reduction.

Imaging findings in DDH

MR findings in DDH include:

1. Laterally displaced femoral head with superior and posterior dislocation.

2. Changes in labrum which include thickened labrum, altered signal intensity (Figure 5 a&b) or flipped labrum (Figure 6a)

3. Pulvinar hypertrophy (Figure 6b)

4. AP relationship and dysplasia of acetabulum and acetabular dysplasia-which is measured by acetabular index (Figure 7).

Figure 7: T1W coronal image of showing normal acetabular index on left side and abnormal on right side.
Acetabular index is the angle between horizontal line through sourcil and line through the acetabular roof.
Normal</= 15° and >15° is abnormal.
Sourcil-area of subchondral condensation in acetabular roof.

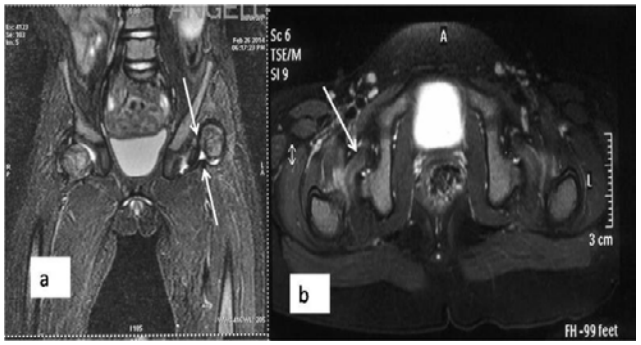

Figure 8 a&b: (a) Left DDH. T2W FS Coronal image showing the superiorly displaced left femoral head with redundant ligamentum teres (large arrow) and posterior capsule) (arrow) causes hindrance in reduction.
(b) Bilateral DDH. T2 W FS axial image depicting the interposition of iliopsoas tendon on right side (arrow) another cause of failed reduction.

Acetabular index measures the weight-bearing surface of the acetabulum or sourcil. Sourcil represents the area of subchondral osseous condensation in the acetabular roof. It is the angle sustained between the horizontal and a tangential line extending from the medial and lateral edges of the sourcil. Normal acetabular index is equal or less than 15° and more than 15° is abnormal (Figure 7).

5. Interposition of ligamentum teres and iliopsoas tendon (Figure 8 a&b).

Essential sequences to be performed in DDH include:

1.Axial T1W: For the detailed anatomical evaluation and is best in looking the ossific nucleus which show intermediate signal on T1W and to see for pulvinar hypertrophy which looks hyperintense on T1W.

2. Coronal T1W: for the displacement of femoral head and acetabular dysplasia.

3. Axial T2W: To see for the complications associated with DDH

like ischemic necrosis and joint effusion.

4. PD FS Coronal: To see for the interposed iliopsaos tendon, labral changes and to evaluate the labral coverage beyond the lateral margin of bony acetabulum relative to the femoral capital epiphysis.

5. PD FS Saggital image: To look for interposed iliopsoas tendon which prevents the reduction?

6. Post contrast T1W FS: To see for the ischemic necrosis.

Failure of reduction

Possible hindrance in reduction include flipped labrum, prominent pulvinar, redundant ligamentum teres, capsule or iliopsoas tendon which may become interposed into the joint.

Role of MRI in management

The main aim of the treatment for DDH is the concentric closed or open reduction of femoral head and to achieve the maximum stability with a good anatomical and functional outcome using splint device. However if the hip is unstable or non concentric, the additional procedures such as debridement, capsulorraphy, acetabular and femoral osteotomies can be performed. Coronal MR shows the acetabular labral coverage beyond the lateral margin of bony acetabulum relative to femoral capital epiphysis which is important in determining the coverage of femoral head and the need for increased coverage through osteotomy and conservative management if there is proper coverage.

Patients with delayed diagnosis or patients who are refractory to treatment, MR imaging is important in preoperative assessment of femoral head deformity, acetabular dysplasia and femoral head coverage by the bony acetabulum. DDH can also predispose to osteoarthritis due to chronic stress on the labrum with chondral injury [11].

MRI is also required in immediate post operative period after reduction to assess for the adequacy of the reduction. As in young infant, unossified nuclei are present so the joint space is not visible on conventional x-ray. On MRI the ossific nucleus of the femoral head should lie anterior to the line joining the triradiate cartilages after reduction. Eimear et al reported the use of axial STIR MRI to confirm the femoral head reduction in DDH [12].

Role in post reduction ischemia

As the infants are placed in abduction and flexion position in spica cast for weeks after reduction, femoral head should be held in safe zone as little abduction can result in redislocation and too much abduction can cause Avascular Necrosis (AVN) which can further lead to proximal femoral growth deficiency. The blood supply to the femoral head is through circumflex femoral vessels which enter the femoral epiphysis and ramify in the femoral head. Incidence rate of AVN is upto 47% [13]. Post reduction CT can be done to see for the femoral head position, however non ossified nucleus cannot be visualised and vascularity cannot be detected which are important in determining the completeness and the safety of the reduction. Moreover radiation is also a concern. Tailored approach can be done to evaluate for the ischemia which includes coronal Fast gradient echo localiser images, axial spin echo T1W images before contrast administration and dynamic post contrast FS T1W images after

Figure 9: Septic arthritis of right hip .T2W FS coronal image shows superiorly dislocated head with joint effusion on right side (arrow) with edema in adjacent muscle sequalae to infection.

contrast administration [6]. Images are obtained at section thickness of 4mm and a section gap of 1mm.Average duration of is sequence is 1 min 30 sec. The sequence was obtained repeatedly for an interval of 5-10 min. Enhanced epiphysis and physis vascular phase is obtained. Ischemic changes in the femoral head are either seen as diffuse hypoenhancing without focal abnormality or focal areas of decreased enhancement. The anterolateral head is more prone for ischaemia. The avascular zone is well demarcated area and is geographic and is easily demonstrated on imaging.

Salter and colleagues classified avascular necrosis as either asymmetric or focal or diffuse on dynamic enhanced MRI. MR showing global decrease in enhancement showed ten times more chances of developing AVN [14].

MRI can detect the ischaemic areas at the earliest when it is still reversible [15].

Delayed imaging is also required to see for the reduction of the bulk of the pulvinar which imposes on the proper reduction. If there remains residual subluxation due to increased pulvinar fat, majority of cases resolve without therapy. Associated labral tear or degeneration can also be evaluated on MRI. Long term follow up MR imaging is required in cases of painful hip to know the cause which is attributed to the original pathology or avascular necrosis to plan for further management.

Differential diagnosis

Very few differentials of DDH are there on imaging including post traumatic and post infective dislocated. MRI also plays a significant role in differentiating DDH from post infective sequalae of dislocated head. Non visualisation of ossific nucleus with dislocation of femoral head, altered marrow signal intensity, inflammatory changes in adjacent muscles and significant joint effusion helps in differentiating post infective dislocated head from DDH (Figure 9).

Conclusion

With recent advancement in orthopaedic imaging technique, MRI

has assumed an important role in the early detection and evaluation of DDH especially in children less than 6 months when the ossific nucleus is not seen on conventional x-ray. MR scanning is useful in the pre as well as post operative imaging in DDH. MRI is useful in looking for causes of intrinsic and extrinsic causes of failed reduction. Depending on the acetabular coverage, pre operative MRI also helps in the management to go for the conservative reduction or osteotomy to increase the acetabular coverage. With dynamic contrast enhanced MRI, MRI has the ability to determine the vascularity of the femoral head after reduction to identify the hips which are at increased risk of ischemia and subsequent AVN which can further lead to the development of AVN which is reversible compared to the months it takes to manifest radiographically. Post operative MRI is also useful in evaluating the adequacy of closed reduction. However limitations include need for proper sedation due to long scanning, cost and the MR compatible implants in post operative cases.

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