Comparison between magnetic resonance imaging and intraoperative arthrogram in detection of soft tissue obstacles to reduction in developmental dysplasia of the hip

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Background
The spectrum of abnormalities in developmental dysplasia of the hips (DDH) is not limited to osseous changes, but extends to include periarticular soft tissue changes, which could not be visualized by conventional radiographs or computed tomography (CT). Both MRI and conventional arthrogram can evaluate those soft tissue obstacles to reduction.

Patients and methods
In total, 16 children with DDH (21 hips), dated for surgical management by open reduction, were chosen. All patients were examined by preoperative MRI as well as intraoperative arthrogram. Both modalities were used to assess different obstacles to reduction, such as the labrum, pulvinar, ligamentum teres (LT), iliopsoas tendon interposition, and the transverse acetabular ligament (TAL).

Results
Both MRI and conventional arthrogram showed similar sensitivity (100%) for detection of ligamentum teres pathology, labral inversion, and hypertrophied pulvinar. MRI showed higher sensitivity than arthrogram for detection of the iliopsoas tendon interposition (100% vs. 64.5%) and for detection of the thickened transverse acetabular ligament (85.7% vs. 19%).

Conclusions
Both MRI and conventional arthrogram can visualize the soft tissue obstacles to reduction in dysplastic hips. MRI is a noninvasive technique, requiring sedation in the pediatric population. Conventional arthrogram is an invasive technique. However, significant complications can be readily avoided.

Keywords:
conventional hip arthrography, developmental dysplasia of the hip (DDH), magnetic resonance imaging (MRI)

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Introduction

Developmental dysplasia of the hips (DDH) is a common pediatric disorder. It encompasses a wide spectrum of abnormalities, including acetabular dysplasia, hip dislocation or subluxation, abnormal shape of the femoral head, as well as associated soft tissue abnormalities [1].

Many soft tissue obstacles to reduction are seen in DDH. The pulvinar fat is hypertrophied. The labrum can be hypertrophied, with possible inversion and interposition. The transverse acetabular ligament (TAL) may be thickened. The ligamentum teres is usually thickened in DDH. The iliopsoas tendon can be interposed in-between the acetabular introitus and femoral head [2,3].

Preoperative MRI is not routinely performed in cases of DDH, being reserved for challenging nonreducible cases. MRI has the advantage of direct visualization of the soft tissue structures around the hip in addition to the osseous skeleton with no expense in terms of radiation exposure. However, sedation is usually needed to perform MRI in pediatrics due to the relatively long scan duration [4].

The absence or small size of ossific nuclei in pediatric hips with the presence of cartilaginous portions of the epiphyses and apophyses poses a challenge in accurate joint evaluation by plain radiography. This is the rationale of hip arthrogram in pediatric hip. Conventional arthrogram can assess the cartilaginous portions of both the acetabulum and femoral head. It can also evaluate the soft tissue obstacles to reduction. Arthrogram has the advantage of immediate assessment of the adequacy of reduction intraoperatively. However, it is an invasive technique that needs general anesthesia and is more liable to complications [5–7].

The comparison between MRI and conventional arthrography in DDH has not received much attention in the literature. This study aims to compare the efficacy of both modalities in assessment of soft tissue obstacles of dysplastic hips, with reference to the confirmed operative findings.

Patients and methods

Consecutive series of patients attending the Paediatric Orthopaedics and Deformity Clinic at our institution was chosen between July 2019 and December 2020. The study was approved by the Ethics Committee at our institution.. Informed consent was obtained from the legal guardians since the patients were incompetent.

Inclusion criteria included patients with DDH, diagnosed by conventional radiographs. All were 2 years of age or older dated for open-reduction operation. All patients had preoperative MRI as well as intraoperative arthrogram at the time of surgery.

We excluded infants younger than 2 years as they were not planned for open reduction, except after failure of closed reduction. Other causes of hip dislocation were also excluded, such as cerebral palsy, traumatic hip dislocation, and cases of dislocation postseptic hip arthritis.

The study included 16 patients, 5 of them had bilateral DDH and the other 11 patients had unilateral DDH, 7 were right-sided and 4 were left-sided. A total of 21 hips were examined. Mean age at the time of the study was 2.5 ± 0.77 years (range 2–5 years). All the cases were subjected to open reduction.

Examination method for MRI

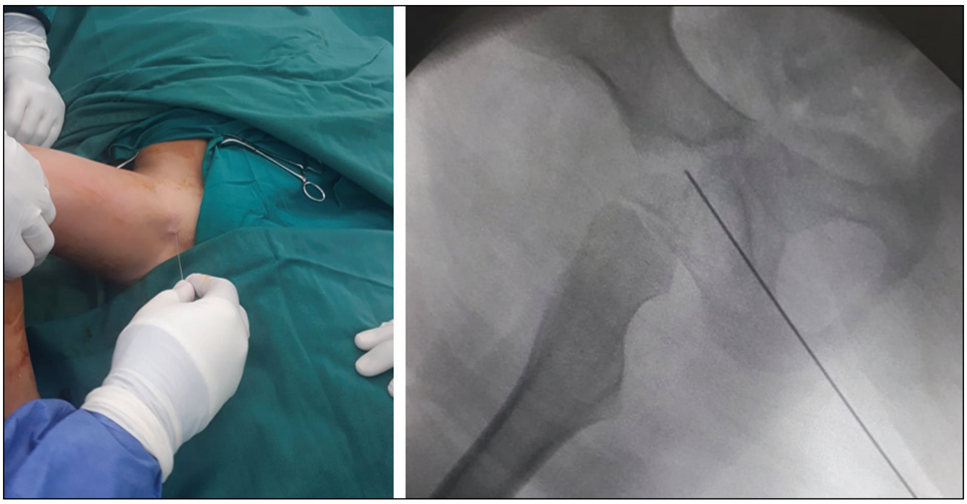
A superconducting 1.5-T closed MRI machine (Model GE Explorer) by General Electric (GE, USA) was used. The examination was done under sedation by an anesthesia specialist in supine position using a body coil. Scan range extended from the upper parts of the iliac wings till the upper part of the femoral shaft.

The following fast SE pulse sequences and scanning parameters were applied: T1 coronal and axial (TR 423 msec, TE 10 msec), T2 coronal and axial (TR 3555 msec, TE 102 msec). PD FS coronal, axial, and sagittal (TR 3928 msec, TE 40 msec). For the SE sequences, FOV 220 × 180 mm, matrix size was 320 × 224 mm, ETL was 16, slice thickness was 3 mm, slice gap was 0.3 mm, and NEX was 4. The total scan duration was 15 minutes 30 s.

Arthrogram

Arthrogram was done at the time of surgery, under general anesthesia. The surgeon scrubbed and arthrogram was done under complete aseptic technique. The hip was flexed and externally rotated (about 30–60°). The adductor tendon was palpated. Under radiographic guidance, a 22-G spinal needle was inserted underneath the adductor tendon and directed superlaterally toward the anterior superior iliac spine, while being kept parallel to the surgical table. The position of the needle tip was checked under fluoroscopy guidance, and the needle is introduced into the joint capsule (Fig. 1).

Figure 1



The hip is flexed and externally rotated, with the needle inserted under the adductor tendon directed toward the anterior superior iliac spine. The position is checked by imaging guidance before injection of contrast medium.

Contrast medium was injected into the joint capsule (about 3–5 cc). We used 300 mg of iodine Omnipaque contrast medium. The concentration was 3 cc of contrast medium added to 7 cc of saline. After withdrawal of the needle, the hip was passively moved to help distribution of contrast medium into the joint space.

Assessment of findings

The MRI findings were reported through conjoint reading by two radiology consultants. The arthrograms were performed and interpreted by two orthopedic surgeons and were blinded to the preoperative MRI findings.

Statistical analysis of the data

No complex statistical tests were used.

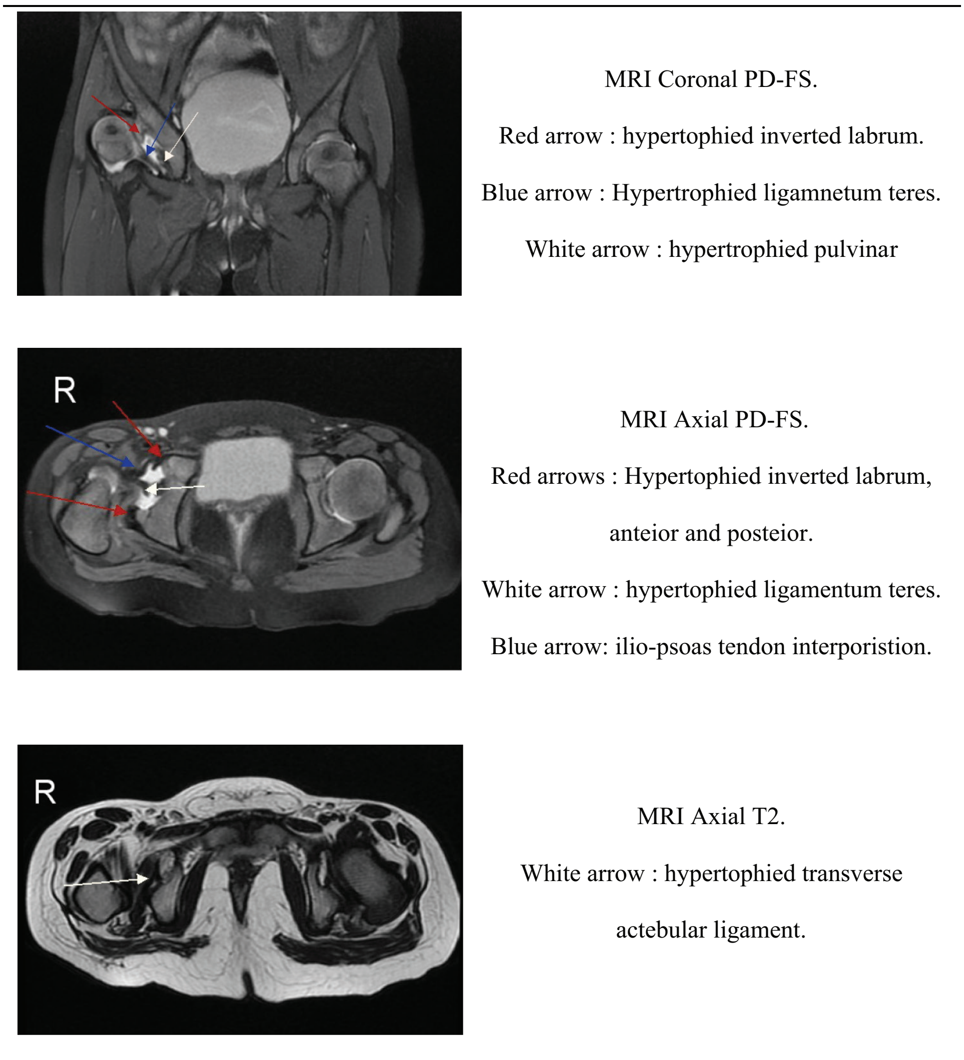
Results

MRI was used to assess the soft tissue obstacles to reduction (Fig. 2). The iliopsoas tendon was interposed in 100% of the cases (21/21). Pulvinar was hypertrophied in 100% of the cases (21/21). The labrum was inverted and hypertrophied in 100% of the cases (21/21). Ligamentum teres was hypertrophied in 71.4% of the cases (15/21) and torn in 18.6% of the cases (16/21). TAL was thickened in 85.7% of the cases (18/21), and normal in 14.3% of the cases (3/21).

Arthrogram was used to assess the soft tissue obstacles to reduction (Fig. 3). Hour-glass constriction by the iliopsoas tendon was present in 57.5% of the cases (23/40), and absent in 42.5% of the cases (17/40). Pulvinar was hypertrophied in 100% of the cases (21/21). The labrum was inverted and hypertrophied in 100% of the cases (21/21). Ligamentum teres was hypertrophied in 71.4% of the cases (15/21) and torn in 18.6% of the cases (16/21). TAL was thickened in 19% of the cases (4/21), and normal in 81% of the cases (17/21).

Operative data were obtained in all the 21 cases that underwent open reduction, where capsulotomy was

Figure 2

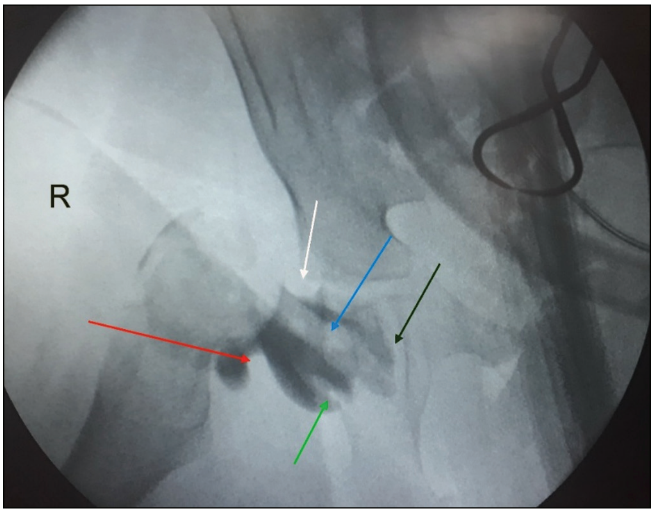


Magnetic resonance imaging findings of right developmental hip dislocation.

performed and compared with the findings of MRI and arthrogram. All cases (21/21) showed interposition of the iliopsoas tendon, labral hypertrophy and interposition, hypertrophied pulvinar, and thickened transverse acetabular ligament. Ligamentum teres were hypertrophied in 76.2% of the cases (16/21) and torn in 23.8% of the cases (5/21).

The sensitivity of MRI and arthrogram to visualize soft tissue obstacles was calculated with reference to the confirmed operative findings. Both MRI and arthrogram showed similar high sensitivity (100%) for detection of the labrum, ligamentum teres, and pulvinar fat pad. MRI was superior to arthrogram in detection of iliopsoas tendon interposition (100% vs. 64.5%) and for thickened TAL (85.7% vs. 19%). Table 1

Figure 3



Arthrogram of right developmental hip dislocation. White arrow: inverted labrum. Red arrow: hourglass constricion by iliopsoas tendon. Blue arrow: hypertrophied ligamentum teres. Green arrow: large transverse acetabular ligament. Black arrow: hypertrophied pulvinar.

Case illustration

Discussion

This study aimed at assessing the role of MRI and intraoperative arthrogram in assessment of the soft tissue obstacles to reduction of femoral head, with comparison to the findings of the operative data as the gold standard.

Iliopsoas tendon

Interposition of the tight iliopsoas tendon between the dislocated femoral head and the acetabulum leads to constriction of the joint capsule and hinders reduction. Fukiage *et al*. [8] showed that MRI can easily detect the iliopsoas tendon interposition. Jia *et al*. [9] emphasized the need for iliopsoas tenotomy to facilitate femoral head reduction. This was in concordance with our study, where tenotomy was done in all patients.

Arthrogram showed lower sensitivity to iliopsoas tendon interposition compared with MRI (64.5% vs. 100%), possibly as arthrogram indirectly detects the interposition by the joint capsule indentation, which in turn depends on the degree of tendinous tightness. Many studies have assessed the role of intraoperative arthrogram in DDH. Ahmed and Fadel [5] found hour-glass constriction by the iliopsoas tendon in 13.9% of the hips assigned for closed reduction. In our study, we showed higher percentage and this finding may be due to that we included only patients with higher age group.

Labrum

The utility of MRI in detecting labral pathology is well-known in the literature [10,11]. Rosenbaum *et al*. [2] discussed the efficacy of MRI in evaluating the labrum in dysplastic hips. They also described the process of 'limbus formation' that is a fibrous proliferative process at the chondrolabral junction, where the everted labrum,

Table 1 Comparison between magnetic resonance imaging and arthrogram with reference to the operative findings (*n*=21)

Data	MRI			Arthrogram		
Operative	True positive	False negative	Sensitivity %	True positive	False negative	Sensitivity %
Iliopsoas tendon						
Interposed	21	0	100	16	5	64.5
Labrum						
Inverted, hypertrophied	21	0	100	21	0	100
Ligamentum teres						
Torn	5	0	100	5	0	100
Hypertrophied	16	0		16	0	
Total	21	0		21	0	
Pulvinar						
Hypertrophied	21	0	100	21	0	100
Transverse acetabular ligament						
Hypertrophied	18	3	85.7	4	17	19

hypertrophied acetabular cartilage, and related capsular thickening and fibrosis act together as an obstacle to reduction of the femoral head, with narrowing of the acetabular introitus.

Many studies have assessed the role of arthrogram in evaluating the labrum of dysplastic hips. Ahmed and Fadel [5] found an inverted labrum in 16.7% of their cases. Studer *et al.* [4] found 2 cases of inverted labrum, out of 38 hips. Both studies had lower age range compared with our study. This explains the higher percentage of labral inversion in our study (21/21).

Although similar sensitivity and specificity were found for MRI and arthrogram (100% for both), arthrogram had the advantage of being dynamic, a major advantage over MRI. This is highlighted by other authors such as Studer *et al.* [4] who showed that arthrogram still plays an important role in decision-making in DDH cases assigned for closed reduction.

The status of the labrum also carries prognostic importance for outcome even after successful reduction. Khoshhal *et al.* [12] found a statistically significant difference regarding avascular necrosis of the femoral capital epiphysis in cases with inverted labrum as compared with those with everted labrum. In all of our cases, all the labra were reduced after capsulotomy, and no labral incisions were needed. This was superior to the results of other authors in which radial cuts in the labrum were needed for concentric reduction [2,13].

Pulvinar

MRI easily detects the hypertrophied pulvinar due to its characteristic signal on MRI, being hyperintense on T1 and T2, with suppression on fat sat sequence, a finding confirmed by other authors [9]. Hypertrophied pulvinar is soft due to its fatty nature. It filled the acetabular cavity and was easily removed at surgery. It was not considered a significant obstacle to femoral head reduction, even in cases of closed reduction. Other authors showed similar observation. Benjamin *et al.* [14] stated that small amounts of hypertrophied pulvinar can even be absorbed after femoral head reduction, and did not impose great impedance to femoral head reduction. Dwek JR *et al.* concluded similar results [15].

Ligamentum teres

The ligamentum teres was the most significant obstacle to reduction and was resected during the surgical procedure. Our study showed 100% sensitivity in detecting ligamentum teres pathology both for MRI and arthrogram. The ligamentum teres was hypertrophied in 16/21 of the cases and torn in the rest. This is similar to the results of other authors, such as Devit *et al.* [16], who showed high sensitivity for MRI over 90%. They also demonstrated the importance of resection of ligamentum teres, not only to facilitate reduction, but also to decrease the incidence of avascular necrosis. Jia et [9] al concluded similar results regarding MRI sensitivity.

Many studies have assessed the usefulness of arthrography in detection of the ligamentum teres pathology associated with DDH. Drummond *et al.* [17] reported sensitivity about 78% for detection of hypertrophied ligamentum teres in children below the age of 18 months, which is relatively lower compared with our study (100%), possibly due to variation in age population. Ligamentum teres hypertrophy increased with age and long-standing dislocation.

Similarly, Ishii Y *et al.* [18] showed about 88% sensitivity for arthrogram, with 36 arthrographically detected cases out of 41 operatively proven cases. The 5 false-negative cases were likely due to excessive accumulation of contrast medium within the capsule. This emphasizes the importance of good technique. In our study, we used 300 mg of iodine contrast medium, and not 350 mg of iodine alternative, to avoid excessive opacification. Also, we diluted the injected contrast medium with saline, with ratio 3: 7, respectively (30% dilution), for the prepared 10 cc for injection. Only 3–5 cc were injected.

Transverse acetabular ligament

The TAL is a deep structure that is easily palpated intraoperative than being visualized. On MRI, it is seen as a hypointense structure bridging between the lower parts of the acetabular introitus. We found mildly lower MRI sensitivity for detection of thickened TAL, reaching 85.7%. Studer *et al* [4] found thickened TAL in only 2 out of 38 hips. Possible explanation is the lower age of the cases at their study.

In our study, we found lower sensitivity for arthrogram for detection of thickened TAL, reaching about 19% (4/21 of surgically proven cases). This was similar to the findings found by other authors, such as Ahmed and Fadel [5], who found TAL to be hypertrophied in 19.4% of their cases (7/36). Other authors reported higher sensitivity for arthrogram, such as Drummond *et al* and Ishii Y *et al.* [17,18]. The possible explanation to his discrepancy and the lower sensitivity for arthrogram is the orientation of the TAL, bridging between the anterior and posterior portions of the inferior labrum strictly in the axial plane. Thus, it is oriented end face in the coronal plane and would be seen as a round-filling defect in the conventional AP arthrography.

Complications

MRI is a noninvasive modality and despite the need of sedation during the examination, it was performed by an anesthesia specialist and no complications were encountered.

Arthrogram is an invasive procedure that is more liable to complications. In our study, no significant complications were noted. Only 4 (10%) cases showed mild extravasation of contrast medium along the iliopsoas tendon. However, this extravasation did not degrade the quality of the arthrogram as the hip joint was not overlayed by the contrast. We used a low-osmolar contrast medium and also only a small amount (about 3–5 cc) of diluted contrast was injected intra-articular.

Limitations of the study

First, we only included patients aged 2 years or more, who were assigned for open reduction, to obtain operative confirmation for the MRI and arthrographic findings. Second, we could not assess the specificity of MRI and arthrograms, due to the absence of false-positive findings.

Conclusion

Both MRI and conventional arthrogram have an important role in assessment of the soft tissue obstacles to femoral head reduction in DDH cases. MRI has the advantage of being a noninvasive technique. However, sedation is required for the pediatric population. Conventional arthrograhy is an invasive technique. However, significant complications can be easily avoided and it has the advantage of being dynamic.

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Nil.

Conflicts of interest

No conflict of interest.

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