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Analysis of acetabulum in children with developmental dysplasia of the hip by MRI scan

Ying Zhou, MM, Li Ju, MD, Yue Lou, MD, Bo Wang, MM*

Abstract

To review the value of acetabular magnetic resonance imaging (MRI) in children with developmental dysplasia of the hip (DDH) of different ages.

Eighty-eight medical records of children with unilateral DDH who were diagnosed and treated in our hospital between January 2010 and December 2015 were retrospectively analyzed. The affected hips were put into the case group, and the normal hips were put into the control group. All cases were further divided into 3 age groups: infant (<1 year), 16 cases; young children (1–3 years), 48 cases; and children (3–13 years), 24 cases. The differences of the acetabular depth (AD), the bony acetabular index (BAI), and the cartilaginous acetabular index (CAI) between each group were measured and compared for a linear correlation analysis. At the same time, the distribution of the acetabular cartilage in the anterosuperior, top, and posterosuperior parts (the three parts) from the two groups was measured, respectively.

Measurement results from both the case and control groups were as follows: AD was 5.46 ± 2.62 mm and 9.74 ± 2.33 mm; BAI was 33.26 ± 5.49° and 23.50 ± 5.33°; and CAI was 21.04 ± 6.16° and 12.71 ± 4.83°. Differences from the two groups were statistically significant ($t = 11.94, 13.78, 9.16$, $P < .05$); BAI and CAI were linearly correlated ($r = 0.86, 0.75$, $P < .05$). The AD in infant, young children, and children groups from the case group were 4.26 ± 0.42 mm, 4.79 ± 1.74 mm, and 7.31 ± 2.74 mm, respectively, which was statically significant as well ($F = 11.37$, $P < .05$). Under the same grouping criteria, BAI was recorded as 29.04 ± 5.11°, 34.56 ± 4.27°, and 33.12 ± 5.69°; CAI was recorded as 16.62 ± 5.50°, 21.79 ± 6.33°, and 20.91 ± 6.40° separately. There was a linear correlation ($r = 0.78, 0.65$, $P < .05$) between BAI and CAI in young children and children groups. The distribution of acetabular cartilage in the above-mentioned three parts from both young children and children groups was statistically significant ($P < .05$).

MRI is a satisfactory imaging modality to children with DDH of different ages for the assessment of AD, BAI, CAI, and acetabular cartilage in multiple locations. It can provide ample imaging reference to clinical evaluation of the acetabulum development in DDH.

Abbreviations: AD = acetabular depth, BAI = bony acetabular index, CAI = cartilaginous acetabular index, DDH = developmental dysplasia of the hip, MRI = magnetic resonance imaging.

Keywords: acetabulum, children, developmental dysplasia of the hip (DDH), magnetic resonance imaging (MRI)

1. Introduction

Developmental dysplasia of the hip (DDH) refers to a group of hip disorders of the femoral head and acetabulum affecting the pediatric population. Physical approaches alone are no longer sufficient to meet current clinical needs; an objective DDH assessment requires meticulous evidence with the support of imaging studies. In this study, the acetabular depth (AD), the bony acetabular index (BAI), and the cartilaginous acetabular index (CAI) in children with DDH were measured separately by magnetic resonance imaging (MRI) scan, and quantitative observations on the distribution of acetabular cartilage in multiple locations were made accordingly. The above indexes in case and control groups as well as the 3 age groups were then compared for a correlational analysis, in the hope that a valid radiologic reference to the study of the acetabulum development of DDH could be provided accordingly.

2. Materials and methods

2.1. Clinical information

Eighty-eight children with unilateral DDH who were diagnosed and treated in our hospital between January 2010 and December 2015 were taken as study samples. The affected hips with dysplasia were put into the case group, and the normal hips without disease were put into the control group. Secondary dysplasia of hip joint caused by cerebral palsy, trauma, pyogenic hip arthritis, and multiple arthrogryposis were excluded from our samples. All the 88 cases received bilateral nonenhanced MRI scan of the hip. There were 16 males and 72 females out of the 88 children with unilateral DDH. Among all the cases, 64 were left side DDH and the remaining 24 were right side DDH. The age range was from 5 months to 12.7 years, and the average age was 3.5 years. Sixteen cases were found in the infant group (<1 year);

Editor: Michael Albert Thomas.

Funding: The project of this thesis was supported by the Foundation for Development of Science and Technology from Nanjing Medical University, Nanjing, Jiangsu Province, China (Grant No. 2017NJMU064).

The authors have no conflicts of interest to disclose.

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Medicine (2019) 98:3(e14054)

Received: 1 August 2017 / Received in final form: 7 December 2018 / Accepted: 17 December 2018

http://dx.doi.org/10.1097/MD.0000000000014054

48 cases in the young children group (1–3 years), and 24 cases in the children group (3–13 years), respectively. Informed consents were signed by the patients and/or parents, and this project was approved by the ethics committee of Children's Hospital of Nanjing Medical University.

2.2. Examination methods

A superconducting-type 1.5 T MRI scanning equipment (Model: GE Signa Hde 1.5T) by General Electrics (GE) of the United States of America was used in this study. Scanning parameters: body coil, SE sequence was adopted: coronal and axial positions T1W1 TR 476–623 ms, TE 22–23 ms, matrix was 512×336, FOV was 300×300 mm; fast spin echo (FSE) sequence, coronal position T2W2 TR 3450–4000 ms, TE 88–95 ms, matrix was 512×336, FOV was 250×250 mm; coronal position STIR TR 4760–5280 ms, TE 55–82 ms, matrix was 256×256, FOV was 300×300 mm. Scanning position: hip performed in neutral position with 15° internal rotation. Scanning range: from the upper edge of the ilium wing to the upper and middle part of the femur; excitation times: 1–2; slice thickness: 2 mm; and slice interval: 0.1 mm.

2.3. Image analysis, measurement index, and methods

MRI images were measured and analyzed by two radiologists specializing in pediatric orthopedic radio-diagnosis, and all the measurement results were averaged. Based on the Murray measurement method[1] and the Fisher measurement method,[2] we selected the maximum surface of the femoral epiphysis from coronal T1W1 sequence as the measurement surface for our calculation (Fig. 1): O1AD: taking the outer edge of the acetabular cartilage as the baseline, connecting the upper outer edge of the acetabulum with the ipsilateral pubic symphysis joint angle, the AD was described as the vertical distance from the deepest point of the acetabulum to this line (the BO line); O2BAI: the angle (∠ACH) with one side of the connection between the outer edge of the bony acetabulum and the Y cartilage midline and another side of the horizontal connection between the bilateral Y cartilage centers. O3CAI: the angle (∠BCH) with one side of the connection between the outer edge of the cartilaginous acetabulum and the Y cartilage midline and another side of the horizontal connection between the bilateral Y cartilage centers. O4: The thickest cartilaginous surface from the MRI images was measured in the anterosuperior, top, and posterosuperior parts in the coronal and axial positions, and the distribution of cartilaginous acetabulum was observed accordingly. All the images from case group and control group were measured with the above indexes, and their corresponding values were recorded.

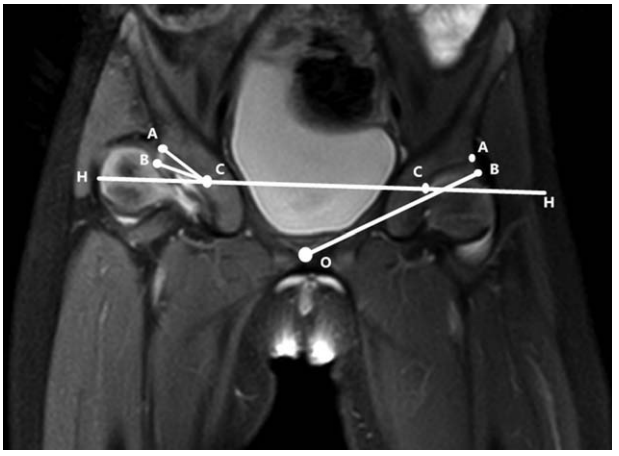

Figure 1. Measurement (Right side DDH. Spot A: outer edge of bony acetabulum. Spot B: outer edge of cartilaginous acetabulum. Spot C: Y cartilage center. Spot O: outer edge midpoint of pubic symphysis).

2.4. Statistical methods

SPSS 19.0 (Professional Edition) was used in this study for data analysis. The distribution of the measurement results of AD, BAI, and CAI is expressed in terms of mean ± standard ($\overline{x} \pm s$). There was no statistically significant difference between each group ($P > .05$). Data difference between the two groups was analyzed by the two-sample T test, and the comparison of multiple means was made under the one-way ANOVA method. The correlation coefficient r was obtained by linear correlation analysis between BAI and CAI values in case group, control group, and each age group (infant, young children, and children) from case group. Difference ($P < .05$) was statistically significant.

3. Results

Results are simply embodied in the flow diagram (Fig. 10).

AD (5.46 ± 2.62 mm) in case group was significantly smaller than that in control group (9.74 ± 2.33 mm) (Fig. 2), while BAI and CAI values (33.26 ± 5.49° and 21.04 ± 6.16°) in case group were significantly greater than that in control group (23.50 ± 5.33° and 12.71 ± 4.83°) (Figs. 3 and 4). The differences of AD, BAI, and CAI between case group and control group were statistically significant ($t = 11.94$, 13.78, 9.16, $P < .05$).

In case group, AD in infant, young children, and children groups (4.26 ± 0.42 mm, 4.79 ± 1.74 mm, and 7.31 ± 2.74 mm) increased gradually with age (Fig. 5), and the differences between each group were statistically significant ($F = 11.37$, $P < .05$). The highest values of BAI and CAI were found in young children group (34.92 ± 4.26° and 21.79 ± 6.33°), followed by children group (33.12 ± 5.69° and 20.91 ± 6.40°) and infant group (29.04 ± 5.11°, 16.62 ± 5.50°) in case group (Figs. 6 and 7). There was difference ($F = 3.27$, $P = .03$) of BAI among different age groups from case group, while there was no difference of CAI ($F = 0.74$,

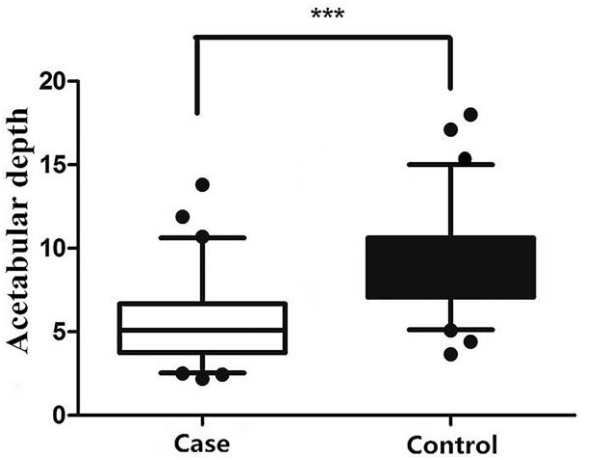

Figure 2. AD in case and control groups.

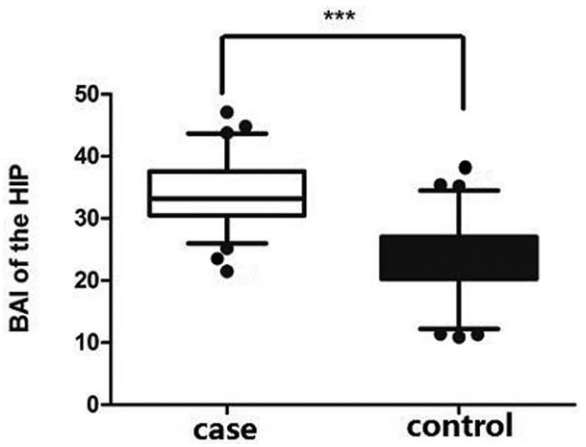

Figure 3. BAI in case and control groups.

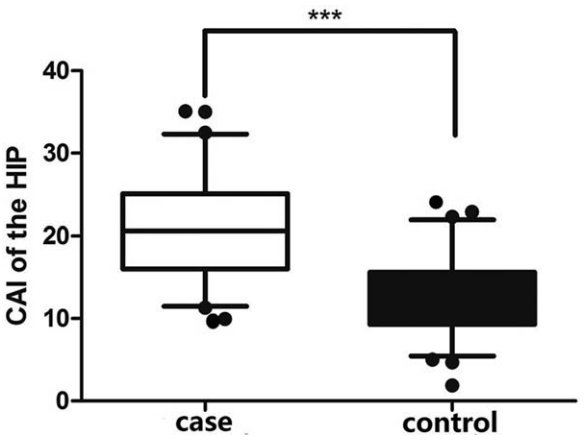

Figure 4. CAI in case and control groups.

$P = .27$) under the same grouping principle. There existed positive linear correlation between BAI and CAI in case and control groups as well as young children and children groups from case group ($r = 0.78$, 0.65, 0.80 and 0.62, $P < .05$) (Figs. 8 and 9).

The acetabular cartilage morphology and its distribution of the affected side had some abnormal manifestation (Fig. 1): acetabular cartilage of the affected side was significantly thicker than that of the normal side, with a noticeable thickening of

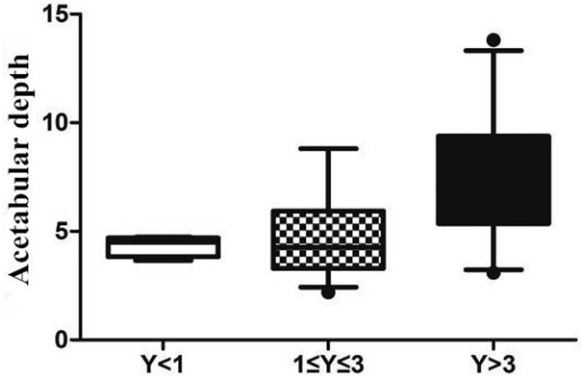

Figure 5. AD of the case in each age group.

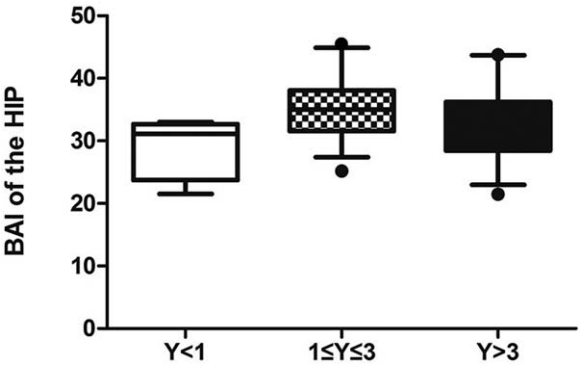

Figure 6. BAI of the case in each age group.

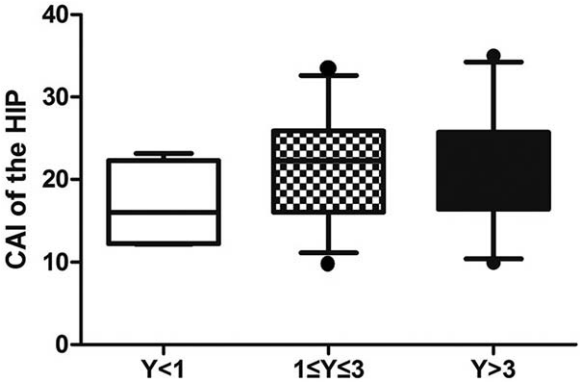

Figure 7. CAI of the case in each age group.

cartilage in the posterosuperior part. While comparing data from case group with control group, we found that there was no statistically significant difference in the distribution of the acetabular cartilage in the anterosuperior and top parts of infant group, but there was statistical significance in the distribution of acetabular cartilage in young children and children groups ($t = 12.33$, 13.05, 13.48, 11.75, 12.23, 9.98, $P < .05$) (Table 1).

4. Discussion

DDH is a common disease in pediatric orthopedics where early diagnosis is of great importance to both treatment effect and good

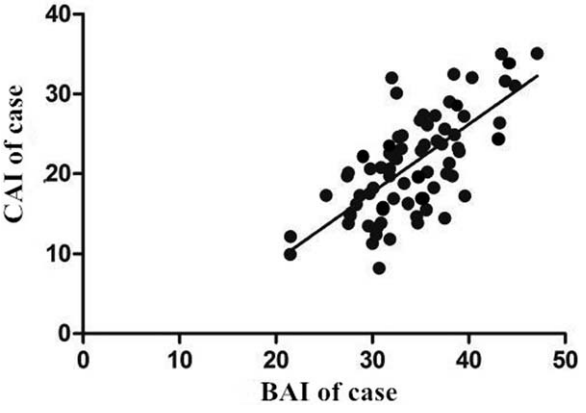

Figure 8. BAI and CAI correlation in case group.

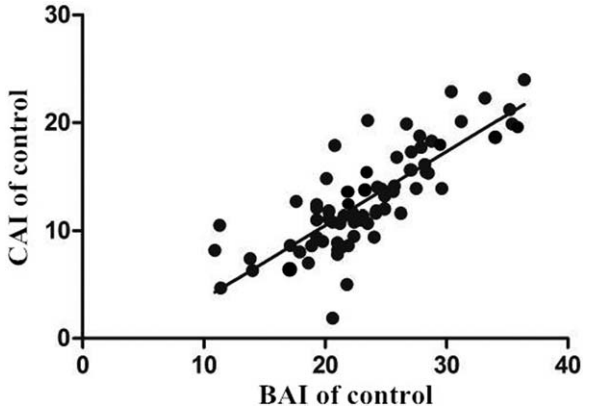

Figure 9. BAI and CAI correlation in control group.

prognosis. Currently, missed diagnosis or over-diagnosis would occur under routine clinical examination circumstances.[3] X-ray and CT are commonly applied to assist the diagnosis of DDH. However, only the bony structure of the hip, not the acetabular growth and morphology, can be reflected through these two devices, let alone the accurate assessment of the pathological changes of the intra- or peri-articular soft tissues.[4,5] MRI scan that has a unique soft tissue imaging capabilities makes up the lack of the above two. It can provide coronal, sagittal, cross-section images while at the same time distinguish between bone, cartilage, muscle, and joint capsule within a very short period of time in a noninvasive but high sensitivity manner. By MRI scan, it becomes more straightforward to evaluate the acetabulum and femoral head; describe the anatomical condition of the hip; observe the soft tissues around the articular cartilage, glenoid labrum, round ligament, and iliopsoas to determine if they are associated with joint effusion or adipose hyperplasia; thus the observation accuracy of the pathological changes and their correlations of the intra- or peri-articular soft tissues can be improved extensively.[6] The comprehensiveness of scientific disease assessment can be achieved under MRI scan without sacrificing high resolution of the image. On top of that, MRI scan brings no harm to human body, which serves a better reference to DDH clinical work.[7–10]

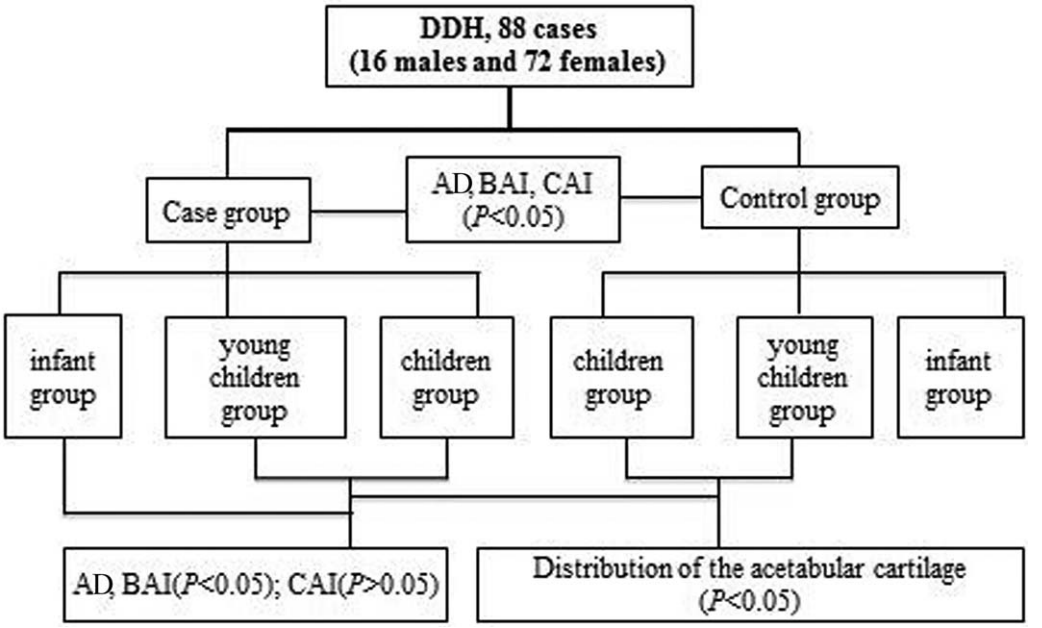

Figure 10. The flow diagram of results.

Table 1

DDH acetabular cartilage distribution measurement results (mm, as of $\bar{x} \pm s$).

	Infant group		Young children group		Children group	
	Case group	Control group	Case group	Control group	Case group	Control group
Antero-superior	3.77 ± 0.46	2.19 ± 0.58	4.38 ± 0.91	3.49 ± 0.74	4.07 ± 1.04	3.12 ± 0.98
t	2.48		12.33		11.75	
P	0.19		0.00		0.00	
Top-superior	5.38 ± 2.19	1.97 ± 0.22	3.29 ± 1.16	2.25 ± 0.74	3.78 ± 1.92	3.22 ± 1.24
t	3.96		13.05		12.23	
P	0.08		0.00		0.00	
Postero-superior	5.14 ± 0.67	2.83 ± 0.79	4.64 ± 1.29	2.73 ± 0.68	4.28 ± 1.82	2.68 ± 0.89
t	4.39		13.48		9.98	
P	0.04		0.00		0.00	

DDH = developmental dysplasia of the hip.

This study took a close look at the measurement of AD. The results showed that AD was significantly smaller in the case group than that in the control group. With the increase of age, the increase of AD from the affected side was significantly smaller than normal hips, which indicated a relevance of the abnormal stress stimuli received by the affected acetabulum as well as a smaller size of the affected acetabulum. In the case group, AD increased gradually with age, suggesting that the acetabulum received stress stimulus unceasingly from the femoral head even when the hip was dislocated. There was a tendency that the stress stimuli would increase with the change of age and weight. Through the measurement of BAI and CAI, we found that BAI and CAI in the case group were significantly higher than that of the control group and there was a linear correlation between BAI and CAI in the case group. While there was difference in BAI among different age groups, no difference was found in CAI. A linear correlation between BAI and CAI in young children and children groups, excepting the infant group, was recorded, which may suggest no stress change occurs in acetabular cartilage of the hip throughout the infancy. The BAI progression was decided mainly by the ossification of acetabular cartilage and the mechanical stress stimuli played a very crucial role in such progression.[11] Because the dislocated hip separated itself from the normal acetabular fossa, resulting in a nonconcentric femoral head, the acetabular cartilaginous ossification would suffer from disorder, delay, acetabular cartilage proliferation, uneven distribution due to a lack of normal biomechanical stimuli to the femoral head. This in turn would continue to affect the growth and development of the subchondral bone structure, causing an abnormal increase of BAI and CAI. Cartilaginous changes occurred in young age and bony changes in succession to biomechanical changes took place following the cartilaginous changes. The degree of the femoral head dysplasia, the different position, and the time span that stress stimuli acted on acetabulum were some of the main reasons for such changes. That's why the change of BAI became significant along with the increase of age.[12]

MRI scan could accurately observe the pathological changes of the soft tissue in and around the hip in children with DDH. The three-dimensional reconstruction functionality provided a multilevel observation on joint structure, thus an all-round study of pathological changes of the hip in children with DDH could be done scientifically.[13,14] With the growth of children with DDH, the development of acetabulum gradually evolved into abnormality, the shape and distribution of acetabular cartilage also developed differently from the normal hip, exhibiting labrum varus (in some cases, valgus), cartilaginous proliferation, or uneven distribution conditions. The acetabular morphology and the distribution of acetabular cartilage in infant group were not significantly abnormal, whereas a significant different distribution of acetabular cartilage was found in the affected hips among young children and children groups. This may explain why the dislocated acetabulum was normal at birth, but with the growth of the children with DDH, the dysplasia condition worsened continuously. Lack of normal stress and stimuli from the femoral head, the intensity and direction of stress altered remarkably, causing a partial thickening of the cartilage from the anterosuperior, top or posterosuperior parts; an incompetent reduction of the femoral head to perform lower extremity abduction, internal rotation. In the long run, this development would result in shallow and narrow acetabulum, abnormal distribution of cartilage, and deformity aggravation.[15,16]

While the age in children with DDH increased, the course of disease extended, the condition worsened, and the degree of the dislocated hip aggravated gradually. The severity of acetabular cartilaginous lesions cannot be ignored. For instance, a significant proliferation, an uneven distribution of stress, a follow-up buffer stress reduction as well as a decrease in friction—all these not only symptomized the severity of the disease but also demonstrated the present stability of the hip and the possible development of the acetabulum in the near future.[17,18] If not properly treated, the reduction would be seriously affected. If information about the AD, BAI, CAI and distribution of acetabular cartilage were received properly, forced reduction that usually leads to abnormal development of the acetabulum and femoral head could be avoided. Subsequently, the distribution of hip load could be adjusted, the acetabular damage could be lessened, and both the function and stability of the affected hip could be improved thereafter.

In conclusion, MRI scan has the advantage of high resolution and contrast on soft tissue imaging. The pathological changes of the hip can be manifested distinctly; the AD, BAI, CAI, and distribution of acetabular cartilage of DDH children with different age can be calculated accurately, thus promoting a stable and mature assessment of the hip.[19,20] Hence, MRI scan is a more comprehensive assessment modality in clinical treatment to children with DDH. The limitations of this study could be found in the sample size, which is not large enough; the samples were not divided according to the types of the DDH. For future studies, analysis can be done from a biochemical perspective, with support from high magnetic field MRI or delayed enhanced MRI for functional imaging. The number of samples could be increased to undertake dynamic follow-up interviews with patients for the purpose of further observation on DDH. All these shall contribute to a more scientific and comprehensive study on DDH.

Acknowledgment

We would like to thank the radiology department for providing the images shown.

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Supervision: Bo Wang, Yue Lou.
Writing – original draft: Ying Zhou.
Writing – review & editing: Bo Wang, Li Ju.

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