A short-term magnetic resonance imaging analysis of acetabular adaptation in developmental dysplasia of the hip by open reduction or open reduction combined with Dega osteotomy

Yan Meng[1,2], Zhao Lu[1], Xiang-Lin Zhang[2], Lian-Yong Li[3], Shi-Nong Pan[1]

[1]Department of Radiology, Shengjing Hospital of China Medical University, Shenyang, Liaoning 110004, China;
[2]Department of Radiology, The First Affiliated Hospital of Jinzhou Medical University, Jinzhou, Liaoning 121000, China;
[3]Department of Pediatric Orthopedics, Shengjing Hospital of China Medical University, Shenyang, Liaoning 110004, China.

Developmental dysplasia of the hip (DDH) is one of the most common limb deformities in pediatric orthopedics. Patients who cannot achieve closed reduction, or cannot maintain concomitant reduction, suffer from repeated dislocation or delay in diagnosis, treatment and need to undergo open reduction (OR) therapy. However, since researchers have demonstrated that patients treated by OR are prone to continue to experience acetabular dysplasia and dislocation,[1] it is recommended that OR and pelvic osteotomy should be performed at the same time in order to correct dysplasia, reduce the incidence of residual acetabular dysplasia and the rate of long-term reoperation. By performing pelvic osteotomy, acetabular coverage can be increased and the occurrence of hip instability can be avoided in the long run.[2] In recent years, Dega osteotomy has been widely applied in clinical practice because of its wide indications, simplicity of operation, low trauma, and lack of necessity to take the history of hip surgery into account.

Nowadays, most studies in the analysis of open reduction combined with Dega osteotomy (ORCWDO) are based on X-ray.[3] Using common X-ray techniques, the degree of reduction cannot be fully understood, because X-rays show posterior femoral positions after reduction and details of the fixed hips poorly and inadequately. Magnetic resonance imaging (MRI) can determine the factors that hinder reduction and deliver a comprehensive assessment of hip recovery after reduction.

To date, there have not been many international studies on ORCWDO using MRI. In this article, MRI was applied to compare and analyze the results of OR and ORCWDO before and after follow-up. Both the recovery on MRI after the two operative short-term follow-ups was compared and the postoperative acetabulum was evaluated. These data can provide the required reference information for clinical treatments of DDH in children and optimize the individualized choice of treatment and prognosis.

The research program was approved by the Ethics Committee of our hospital (No.2017PS28K) and informed consent was obtained from the parents of each examined child. The imaging data of DDH children who underwent OR or ORCWDO from September 2012 to April 2017 in Shengjing Hospital were collected. There were 15 DDH children (16 hips) who underwent OR. Among them, one patient had bilateral dislocation, 10 patients had dislocation of the left hip, and four patients of the right hip. There were 20 DDH patients (21 hips) who underwent ORCWDO. Among them, one case had bilateral hip dislocation, while the dislocation was on the left side in seven cases, and on the right side in 12.

Using a 3.0T (Philips Ingenia 3.0T, Best, Netherlands) superconducting magnetic resonance (MR) scanner, the children were placed in a supine position and the lower limbs were neutral. Anal anesthesia was induced with diluted chloral hydrate (0.5 mL/kg; 1 g of chloral hydrate diluted with 10 mL of 0.9% saline) before the MRI examination.

Imaging was performed using a picture archiving and communication systems (PACS) V5.5.0.5005 imaging diagnosis workstation at the Department of Radiology.

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Correspondence to: Shi-Nong Pan, Department of Radiology, Shengjing Hospital of China Medical University, 36 Sanhao Street, Heping District, Shenyang, Liaoning 110004, China
E-Mail: cjr.panshinong@vip.163.com

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The bony/cartilaginous structure of the acetabulum was measured on MR images.

The degree of dislocation in children with DDH was graded on X-ray images using the Tönnis criteria before operation, and the acetabular index (AI) was measured. Severin imaging evaluation criteria were used for classification of the imaging results to assess postoperative outcomes in the short-term follow-up. The treatment outcome was evaluated as satisfactory (Severin grades I or II) or unsatisfactory (Severin grades III or IV).

SPSS 24.0 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Continuous variables were expressed as mean ± standard deviation, and categorical variables were statistically described by frequency. The measurement parameters of the two groups were compared through an independent sample *t* test, and the degree of dislocation was compared by the Mann-Whitney *U* test. The paired sample *t* test was also used to compare measurement parameters within the group. COX regression analysis was used to compare the prognosis of two surgical short-term images. The receiver operating characteristic (ROC) curve was used to explore the critical value of ORCWDO evaluated by MRI and X-ray. The difference was statistically significant ($P < 0.050$).

Preoperative X-ray Tönnis criteria were as follows: only two hips were classified as grade II before operation, seven were preoperative grade III, and seven were preoperative grade IV and were treated with OR. The postoperative recovery was satisfactory in five hips and unsatisfactory in 11 hips; nine preoperative hips graded III and 12 preoperative hips graded IV were treated with ORCWDO. A total of 14 hips recovered satisfactorily, while seven hips recovered unsatisfactorily. The degree of preoperative dislocation between the two groups were tested by Mann-Whitney *U* test (*P* value 0.275), and there was no statistical difference. The various preoperative and postoperative short-term follow-up MRI measurement indicators of the OR and ORCWDO groups are shown in Supplementary Digital Content, Table 1; http://links.lww.com/CM9/A650, and the postoperative improvement rates of the two operations are shown in Supplementary Digital Content, Table 2; http://links.lww.com/CM9/A650. The improvement in cartilage structure was more obvious than the improvement in bone structure. The bone and cartilaginous structure of the ORCWDO group improved more perceptibly than that of the OR group. The results of preoperative and postoperative MRI measurement of the two surgical methods were compared. The preoperative-only osseous acetabular index (OAI) was statistically significant ($P = 0.047$), The preoperative OAI of the OR group was $29.13 \pm 4.33°$, and the OAI of the ORCWDO group was $32.67 \pm 4.68°$. Based on ROC analysis, it was ascertained that the area under the ROC curve was 0.692, the $P = 0.048$, and the 95% confidence interval (CI) was 0.520 to 0.864, which was used to determine the critical value on the MRI image of ORCWDO, which was 27.50°. On plain radiographs, the AI was >30.50°, the area under the ROC curve was 0.696, $P = 0.043$, and 95% CI was 0.526 to 0.867. The surgical method affected the prognosis of hip dislocation ($P = 0.035$). The risk of poor prognosis of hip dislocation with ORCWDO was lower than that of OR (95% CI: 1.078–8.802). The choice of ORCWDO prognostic osteotomy compared with the same conditions treated by OR led to a good postoperative prognosis.

MRI with good tissue resolution has been used to assess the immature hip joint cartilage and osseous acetabulum anatomy.[4] Early DDH lesions are located on the acetabular side. Changes to the femur in older children are secondary to the pressure the acetabulum or iliac bone exerts on the femoral head. The detection of acetabular development after reduction is essential.

We performed routine MRI on children with DDH who underwent OR and ORCWDO using T1 sequence data to measure, since T1 sequence can clearly discern the anatomical structure. In our study, the cartilage acetabular index (CAI) was restored from 18.81° preoperatively to 11.19° after OR and restoration, while the OAI improved from 29.13° preoperatively to 22.75° postoperatively. The CAI in the ORCWDO group recovered from 20.48° before surgery to 8.95° at the last follow-up. OAI recovered from 32.67° before surgery to 17.10° at the last follow-up. The results of the improvement in the OAI were in accordance with the results of the AI in 26 cases of DDH in children reported by Karlen *et al*[3] from 37.00° before operation to 15.00° after operation. In the past, there was no detailed description of the acetabular cartilage structure in the study of OR and ORCWDO. Our study further contributed to the comprehensive acetabular development analysis and comprehensive comparison and determination of acetabular remodeling.

In this study, cartilage measurement was also considered as one of the prognostic indicators, rather than simply the bone structure. Cartilage measurements were improved in follow-up, and the improvement of cartilage was more obvious than that of the bony structure. The remodeling ability of acetabular cartilage is limited, but more attention should be paid to the evaluation of cartilage structure, so as to understand the real coverage of the acetabulum of the femoral head, and provide more accurate information for clinical diagnosis and treatment.

In the comparison of the center-edge angle of the final follow-up between the two groups, it was confirmed that there was a difference between the two groups. In the short term, ORCWDO was more helpful to restore biomechanical stimulation in the head and to achieve concentric reduction. After analysis, the results of postoperative recovery in the two groups showed that the ORCWDO group had better recovery than the OR group. When patients experience delayed diagnosis, manual reduction failure, and repeated dislocation, ORCWDO can be performed for children with DDH to achieve femoral head and acetabular concentric reduction and restoration of hip function. The Dega osteotomy does not require internal fixation and does not require secondary surgery to remove the internal fixation. If there is a need to be able to correct both sides at the same time, this will not cause a difference in leg length between the lower limbs. Kothari *et al*[1] confirmed that the long-term reoperation rate of OR was 56.00%, while the rate of ORCWDO was 11.00%.

OR combined with pelvic osteotomy can reduce avascular necrosis of the femoral head and produce good clinical and imaging results. In addition, OR combined with additional pelvic osteotomy can eliminate residual acetabular dysplasia. The Dega osteotomy had a lower risk of tissue structure damage than other osteotomy, and Dega osteotomy could reposition and reshape the acetabulum, and the osteotomy was performed before the closure of the tri-radiate cartilage. OR and simultaneous pelvic osteotomy can thus be used to avoid dysplasia due to the enlarged hip space.

Based on the above studies we confirmed that the prognosis following ORCWDO is better than that after OR; thus when the OAI is >27.50°, ORCWDO should be performed for DDH children to ensure the normal development of acetabular cartilage and provide sufficient coverage for the femoral head to restore the concentric reduction. At the same time, we measured the outcomes of ORCWDO when the AI > 30.50° on X-ray film. Karashima *et al*[2] followed up children aged 24.4 to 48.6 months for at least 2 years. They report that pelvic osteotomy should be performed at the first operation when the central marginal angle is <0.00° (severe dysplasia of the hip) or when the central marginal angle is 3.50 to 14.50° (moderate dysplasia). Avascular necrosis (AVN) of the femoral head is one of the common postoperative complications in children with dysplasia of the hip. Some scholars have followed up children aged 1.2 to 12.8 years old with DDH after Dega osteotomy for 3 to 9 years, and the incidence of AVN was 5.80%. They thus consider that Dega osteotomy can obtain better results. OR combined with pelvic osteotomy can effectively treat hip dysplasia and maintain hip stability.[5]

The phased and continuous functional MR examination will establish the basis of a diagnosis and treatment platform for children's hip diseases based on noninvasive, multi-dimensional, and high-resolution MRI analysis. MRI is the best way to evaluate DDH after operation. It is noninvasive and has higher sensitivity and specificity, it can confirm the location of the acetabulum and femoral head after reduction, and it can avoid occurrence of occult subluxation and incomplete dislocation.

This study has the limitation of being based on a small number of cases; we will continue to collect cases and conduct long-term follow-up. Using MRI, we will further evaluate and report the outcomes of ORCWDO of DDH patients.

To summarize, ORCWDO could achieve more satisfactory imaging results than OR. When the OAI was >27.50° (X-ray was >30.50°), we could perform ORCWDO on children ≤3-year-old with the aim of achieving concentric reduction of the femoral head. ORCWDO was an effective way to correct DDH in children.

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Conflicts of interest

None.

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