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ORIGINAL STUDY

MRI evaluation of femoral and acetabular anteversion in developmental dysplasia of the hip

A study in an early walking age group

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MRI assessment of acetabular and femoral anteversion was done in 45 children with developmental dysplasia of the hip in an early walking age group of 12 to 48 months. Femoral anteversion, acetabular anteversion, acetabular anteversion of the cartilage anlage and acetabular index were measured by MRI in 45 dislocated hips and in a control group of 37 normal contralateral hips of index cases. We found that there was no statistically significant difference between these two groups for femoral anteversion. The acetabular anteversion was found to be significantly increased in the dislocated group compared to the normal group. Similar results were obtained for the cartilage anlage of the acetabulum. There was a positive correlation between acetabular anteversion and acetabular index, while there was no correlation between femoral anteversion and other parameters. We conclude that femoral anteversion is not increased, while the acetabulum is excessively anteverted on the dislocated side in developmental dysplasia of the hip in an early walking age group. Analysis of femoral and acetabular anteversion is an essential part of pre operative planning in developmental dysplasia of hip, and for this MRI is a good modality as it is radiation free.

Keywords : developmental dysplasia of the hip ; MRI evaluation ; femoral anteversion ; acetabular anteversion ; acetabular index.

INTRODUCTION

The association of femoral and acetabular anteversion with developmental dysplasia of the hip (DDH) has always been a matter of investigation. Initial studies of anatomical specimens and clinical observations reported increased femoral anteversion (FAV) as well as acetabular anteversion (AAV) (*10,14,16,17*). However before the advent of CT and MRI it was difficult to objectively document the exaggerated acetabular or femoral anteversion. Several studies based on CT and MRI showed various results regarding the acetabular anteversion, and they were conducted in various age groups (*1,4, 12,19,21*). Occurrence of exaggerated femoral anteversion in DDH has always been a matter of debate, both in favour and against (*12,15,19,21*). Also several surgeons achieved varying results by doing or not doing a femoral derotation osteotomy in DDH (*2,7,13*). However, a only few of them

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determined the femoral anteversion by preoperative radiology.

The role of radiology has always been limited in the diagnosis of DDH till the development of CT. The introduction of CT provided a complete evaluation of the femoral and acetabular structures in hip disorders (*1,12*). Several CT studies reported increased FAV or AAV in DDH (*1,12,19*), while a few others have found no increase in FAV or AAV (*5*). A major concern with CT is radiation exposure, especially in children. It is recommended to replace CT wherever practical with US or MRI to decrease radiation exposure (*3*). Though no proven evidence exists that the radiation dose of CT for this analysis has ill effects, an imaging study like MRI that does not use ionizing radiation would be preferred to CT. Tomczak *et al* in 1997 described a technique for MRI measurement of femoral anteversion (*22*). Shneider concluded that MRI is as accurate as CT in evaluation of FAV (*18*).

Measurements of FAV and AAV are important and essential before performing osteotomies in patients with DDH, as these surgeries have long term consequences. The aim of this study is to assess the FAV and AAV of patients with DDH in an early walking age group as it is the most common age group in which surgical treatment is planned. Hence we limited the study to the age group of 1-4 years and we have chosen MRI as imaging modality to achieve this goal.

MATERIAL AND METHODS

This prospective study was conducted at PGIMER, Chandigarh, India. All cases with unilateral hip dislocation in children of early walking age, who presented to our pediatric orthopaedic department from January 2006 to December 2008 were included in this study.

We limited the study to patients aged 12-48 months with typical DDH. We excluded the patients who had previous operative or non-operative treatment for DDH because the treatment could alter the acetabular and femoral neck anatomy. Also the patients with neuromuscular disease or teratologic dislocations (e.g. arthrogryposis or genetic syndromes) were excluded from this study.

The ages ranged from 12 to 48 months with a mean of 21.2 months. All the patients had typical DDH and all had unilateral dislocation. A total of 45 patients (90 hips) with a male:female ratio of 5:40 were included. Of these 90 hips, according to Ishida's classification (*10*), by using plain antero-posterior pelvic radiographs, there were 45 dislocated hips, 37 normal hips, 5 subluxated hips and 3 dysplastic hips. Because the number of dysplastic and subluxated hips (total of 8) was not enough for statistical analysis, we only compared 45 dislocated hips with the 37 normal hips which served as controls.

MRI was done in our institution on a 1.5 T SIEMENS VISION super conducting unit. The patients were sedated with oral sedative (Triclofos 30 mg/kg) given an hour prior to MRI. A standard head coil was used for imaging. The patients were placed supine inside the coil with both limbs in symmetrical position. A gradient echo (FLASH) sequence with 500-600 ms, TE 11.0 ms, FA 60 degrees, NEX 2 and slice thickness of 3 mm was used for evaluation of both hips in coronal, axial and oblique sagittal planes with image time ranging from 2-4 minutes for each sequence.

AAV was analyzed in the axial sections placed parallel to the pelvic obliquity showing both the triradiate cartilages. AAV was expressed as the angle between a line perpendicular to the trans-triradiate line and a line drawn across the margins of the acetabulum, from its posterior to anterior edge (fig 1). Similar measurements were also made for the cartilaginous model (*4*).

FAV was analyzed by the method described by Tomczak *et al* (*22*). Oblique axial to sagittal sections were

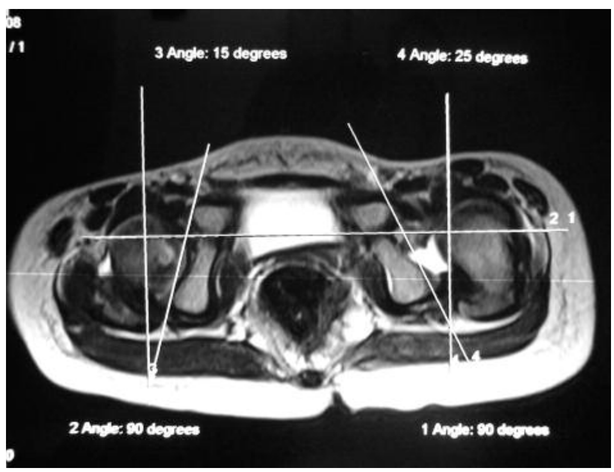

Fig. 1. — 12-month-old female child with dislocated hip on the left side. T2-weighted MRI image showing excessively anteverted acetabulum on the dislocated side. The angle of acetabular anteversion on the dislocated side is 25° compared to 15° on the normal side.

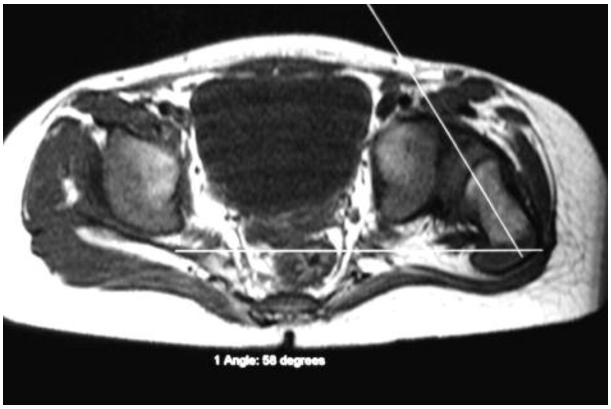

Fig. 2A. — 24-month-old female child with right dislocated hip. T1-weighted MRI image showing the entire neck in profile. The alpha angle between the femoral neck axis and the horizontal reference line is measured to be 58°.

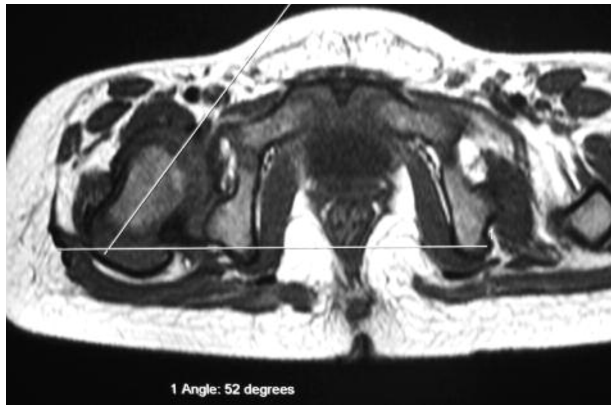

Fig. 2B. — T1-weighted MRI of the same child showing the left normal hip. The alpha angle between femoral neck axis and horizontal reference line is 52°.

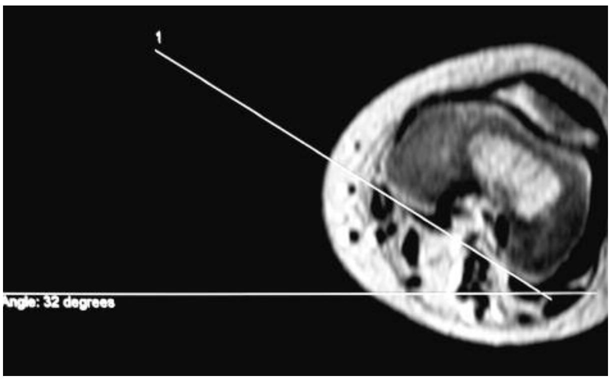

Fig. 2C. — T1-weighted MRI image of the right distal femur (dislocated side) of the same child measuring the beta angle between the posterior condylar axis and the horizontal reference line which is 32°. Hence femoral anteversion is 58(alpha) – 32(beta) = 26°.

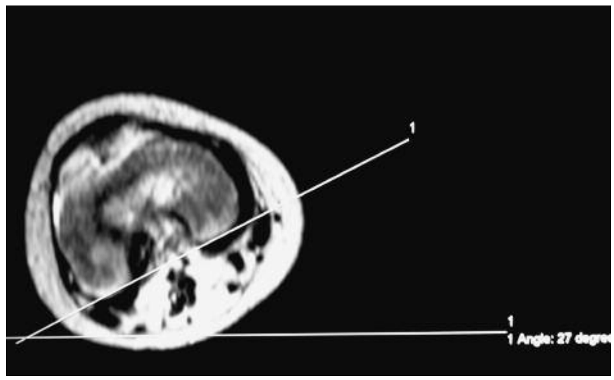

Fig. 2D. — T1-weighted MRI image of the left distal femur (normal side) of the same child measuring the beta angle between the posterior condylar axis and the horizontal reference line which is 27°. Hence femoral anteversion is 52(alpha) – 27(beta) = 25°.

placed parallel to the femoral neck axis exactly perpendicular to the table. A single image that showed the center of the femoral head and neck and therefore allowed visualization of the true neck axis was obtained. The alpha angle between the neck axis and a horizontal reference line was measured (fig 2A & 2B). Further an axial section through the center of the distal femoral condyles was obtained. The beta angle between the posterior tangent to the femoral condyles and a horizontal reference line was determined (fig 2C & 2D). Because of the rotation, femoral anteversion was calculated by substraction (external rotation) of the beta angle from the alpha angle (*6*).

The AAV, FAV and AI values of the 37 normal hips which served as controls were also evaluated. Unpaired t-test was applied to analyze the statistical significance of the difference between the two groups.

To assess the reproducibility of the method of measurement of various parameters, all the variables were re-evaluated by the same surgeon 4 weeks later. Intra-class correlation coefficient was applied to assess the reproducibility. All the statistical analyses were done using the SPSS 12.0 software.

RESULTS

Analysis of all four variables : femoral anteversion, acetabular anteversion, acetabular anteversion of the cartilage anlage and acetabular index in both

Table I. — Femoral anteversion, acetabular anteversion, acetabular anteversion of the cartilage anlage and acetabular index measurements in 45 dislocated and 37 normal hips

	Dislocated hips		Uninvolved hips		p-value
	Mean ± SD	Range	Mean ± SD	Range	
Femoral anteversion	23.62 ± 3.71	13-29	22.86 ± 3.81	14-29	0.367
	(22.93 ± 3.39)	(14-29)	(22.56 ± 3.32)	(15- 27)	(0.626)
Acetabular anteversion	21.93 ± 3.85	14-29	15.18 ± 2.94	10-21	0.000*
	(21.80 ± 4.08)	(13-29)	(14.97 ± 2.96)	(10-21)	(0.000)*
Acetabular anteversion (cartilage Anlage)	20.44 ± 3.69	9-27	14.32 ± 3.09	7-20	0.000*
	(19.84 ± 4.31)	(7-29)	(14.24 ± 3.24)	(9-23)	(0.000)*
Acetabular Index	43.06 ± 3.99	35-55	23.29 ± 3.44	17-34	0.000*
	(42.82 ± 4.34)	(34-53)	(22.75 ± 3.32)	(16-32)	(0.000)*

Values in degrees.

Values in brackets are statistics of all the 4 variables evaluated after 4 weeks. Statistical results are calculated using the unpaired t-test.

* Significant.

the dislocated and normal hips is shown in table I. The difference in femoral anteversion between the dislocated and normal groups was found not to be statistically significant ($p > 0.05$) while it was significant for acetabular anteversion ($p < 0.00$). Correlations of the various angles in the dislocated group are shown in table II. There was significant positive correlation between AI and AAV, AI and AAV of the cartilage anlage and AAV and AAV of the cartilage anlage. There was no significant correlation between FAV and other angles.

The intra class correlation coefficient analysis showed that the acetabular anteversion of the cartilage anlage was less reproducible as compared to the other three parameters as shown in table III.

DISCUSSION

In evaluation and diagnosis of DDH, plain radiographs remain a gold standard. In 1925, Hilgenreiner (*9*) radiologically described hip dysplasia as 1) an abnormal shape of the acetabulum, increased acetabular angle, loss of the concavity of the acetabular roof, and blunting of its superolateral margin ; 2) subluxation ; and 3) delayed appearance and decreased size of the capital femoral epiphysis. Though plain radiographs are standard for diagnosis of DDH, they are not adequate for surgical planning.

In developing nations like ours (India), the most common presentation of DDH is a limping child, in the early walking age. Hence we limited our study to children of 12-48 months of age. In this age group the management options narrow down only to surgical means and pre operative planning based on CT/MRI is essential to avoid complications. Secondly, in accordance with few others (*2,19*) we believe that the primary pathology lies in the acetabulum. There occurs a germinal failure of development of the postero-superior buttress of the ilium leading to a flat socket and the changes occurring in the femur are considered to be secondary adaptive changes (*2*). According to this, adaptive changes like increased femoral anteversion in the early walking age group should not be seen. So this is the best age group to prove that increased femoral anteversion is not a part of the primary pathology.

In the literature there are several studies based on 2D CT analysis of femur and acetabulum in DDH with varying results. Kim *et al* (*12*) reported that the difference in findings of investigators using 2D CT to study AAV in DDH was likely explained by the use of patient populations with a wide age range and by using different methods and different levels of measurement within the acetabulum.

Suzuki used three-dimensional MRI and showed that the dysplastic acetabulum is anteverted compared with normal hips (*21*). Contrary to this, Duffy

Table II. — Spearman's correlation coefficients between Femoral anteversion, Acetabular anteversion, Acetabular anteversion of the cartilage anlage and Acetabular index in dislocated hips

	Femoral anteversion	Acetabular anteversion	Acetabular anteversion (cartilage anlage)	Acetabular Index
Femoral anteversion		-0.216 (0.22 5)	-0.233 (-0.209)	-0.113 (-0.202)
Acetabular anteversion			0.794* (0.671)*	0.435* (0.509)*
Acetabular anteversion (cartilage anlage)				0.362* (0.272)
Acetabular Index				

* Significant
Values in brackets are correlation coefficients measured for the data recorded after 4 weeks.

Table III. — The intra class correlation coefficient measured to evaluate the reproducibility of all 4 variables which were evaluated 4 weeks apart

Variable	Intra class correlation coefficient
Femoral anteversion	.933
Acetabular anteversion	.975
Acetabular anteversion (cartilage anlage)	.865
Acetabular index	.990

et al (*4*) in their MRI analysis of 73 hips found that the mean anteversion of the acetabulum in the involved group was 15° ranging from 5° to 30° and in the uninvolved group 11° ranging from 0° to 20°. The difference was not found to be statistically significant. Hence they concluded that Salter's osteotomy is not recommended as Salter's osteotomy retroverts the acetabulum (*4*). However, the mean age of the patients in their study was 7.6 months and they compared dysplastic hips which included dysplastic, subluxated, and dislocated variants with normal hips. Sezgin *et al* in 2005 analyzed 27 patients with DDH of early walking age by 2D CT and their observations showed that AAV is significantly increased in the dislocated compared to the normal group (*19*). The mean age of the patients in our study and in the study by Sezgin *et al* is 21.2 months and 32.3 months respectively, but the modality of evaluation was by CT in their study compared to MRI in our study.

Several reports have been published about the FAV in DDH (*1,12,19*). In a normal individual, FAV is neutral in the first half of intrauterine life, increases to 30-35° at birth and then slowly decreases to the adult value of 10-15° (*8*). The mean FAV in the normal adult population is approximately 13° (*1*). The widely held belief is that there is increased femoral anteversion on the involved side in DDH ; and so derotational femoral osteotomies are believed to be required. But 2D CT analysis in an early walking age group with DDH by Sezgin *et al* (*19*) showed that there was no significant difference in femoral anteversion between dislocated and normal hips.

Though femoral anteversion can be measured by both CT and MRI, the technique differs among these two modalities. In the CT method, the centre of the greater trochanter is taken as one of the landmarks. Hence the values obtained do not represent the real anteversion but instead report the constantly higher, head-trochanter angle (*6*). A true profile of the entire neck can be visualized by placing cuts in an oblique axial plane with MRI while this is not feasible with CT. As the technique involves serial cuts at various levels in a fixed rotation of the limb, any slight movement of the subject alters the results. With MRI even the slightest movement is detected by distortion of the image, while it is not possible with CT. MRI presents also a better ability to show the cartilaginous anlage of the acetabulum, the unossified femoral head and at the same time MRI also evaluates the soft tissue pathoanatomy in DDH (*6*).

In our study, femoral anteversion measured 23.62 ± 3.71° (evaluated after 4 weeks : 22.93 ± 3.39°) on the dislocated side, and 22.86 ± 3.81°

(22.56 ± 3.32°) on the normal side. The difference is statistically not significant ($p > .05$). Similarly Sezgin *et al* (*19*) found a femoral anteversion of 32.9 ± 6.4° in the dislocated group and 30.7 ± 6.1° in the normal group. The difference was not significant ($p = 0.378$). Though the results obtained in both studies are similar, the mean femoral anteversion in Sezgin's study was higher compared to our study. This can be explained by the difference in the technique used. They used CT as mode of evaluation and with CT the head-trochanter angle is measured, which is higher than the true neck angle.

Our finding with MRI evaluation was that, as the severity of DDH increased the AAV also increased ; on the other hand FAV remained constant. This was shown by a strong positive correlation between AAV and AI, which is considered to be a good predictor of the severity of the disease, while there was no correlation with FAV. So we conclude that the majority of the abnormalities in early walking age patients with DDH are on the acetabular side and changes on the femoral side in older children seem to be secondary to pressure effects on the femoral head from the acetabulum or ilium due to the persistent dislocation. Hence we conclude that evaluation of femoral and acetabular patho-anatomy is essential rather than an adjunctive in pre-operative planning for DDH and for this we recommend MRI as the method of choice, as a radiation free imaging is always preferred.

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