Original article

Acetabular anteversion angle from early stage of Perthes disease to adolescence

Takashi Yoshida^{*}, Wook-Cheol Kim, Atsushi Nishida, Yoshinobu Oka, Toshiharu Shirai, Kazuya Ikoma, Keiichiro Ueshima, Hiroyoshi Fujiwara, Toshikazu Kubo

Department of Orthopaedics, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan

ARTICLE INFO

Article history:

Received 4 August 2016

Accepted 14 August 2016

Available online 29 August 2016

Keywords:

Perthes disease

Acetabular retroversion

Cross-over sign

ABSTRACT

Objective: This study aimed to assess acetabular anteversion angle (AAA) from the early stage of Perthes disease to adolescence.

Methods: Twenty-five patients treated conservatively were examined. Changes in AAA from initial to final measurement were compared between the two groups (G-group: Stulberg classes I and II; P-group: classes III and IV).

Results: In the G-group, AAA decreased significantly in the affected hip compared with the unaffected hip, whereas AAA decreased in both hips in the P-group.

Conclusion: Acetabular retroversion may occur only in the affected hip or in both hips; in the latter case, the treatment outcome may be poor.

© 2016 Prof. PK Surendran Memorial Education Foundation. Published by Elsevier, a division of RELX India, Pvt. Ltd. All rights reserved.

1. Introduction

Acetabular retroversion is a cause of pincer-type femoro-acetabular impingement (FAI) and thus has been a focus of attention in recent years.¹ The prevalence of acetabular retroversion in adult hips was reported to be 4–6% in normal hips, 20% in osteoarthritis, 18% in acetabular dysplasia, and 6% in idiopathic osteonecrosis of the femoral head, and it is particularly high (31–42%) in Perthes disease.^{2–4} With respect to acetabular retroversion, Kawahara et al.⁵ reported that symmetric acetabular deformities occurred in both the affected and unaffected hips after Perthes disease. However, in those studies, the prevalence of acetabular retroversion in various hip disorders was investigated using the presence of the cross-over sign (COS) on anteroposterior pelvic radiographs; no studies have evaluated acetabular version in the axial plane of the pelvis. In young children, the greater growth potential of the femoral head and the acetabulum allows residual deformities to grow out.⁶ However, no studies to date have evaluated changes in acetabular version from onset of Perthes

disease to adolescence, nor are there reports on the timing of the exhibition of retroversion after onset, the amount of change, and the relationship between retroversion and treatment outcome.

In this study, acetabular anteversion angle (AAA) was measured on axial magnetic resonance images obtained after the onset of Perthes disease, and serial AAA values were investigated for groups classified according to treatment outcome. In addition, the presence or absence of COS at the final examination was also determined, and changes in AAA over time with differences in the presence or absence of COS and the relationship with treatment outcome were also investigated.

2. Patients and methods

From June 1992 through November 2007, 45 patients with unilateral Perthes disease were treated with a non-weight-bearing hip abduction brace (new Pogo-stick brace⁷) at our department. Of these patients, 25 (23 boys and 2 girls) were followed until 13 years of age or older and axial magnetic resonance images were obtained multiple times. The affected hip was the right hip in 11 cases and the left in 14. The mean age at onset was 7 years and 2 months (3 years and 7 months to 11 years and 2 months), and the mean follow-up period was 8 years and 2 months (3 years and 2 months to 13 years and 8 months).

AAA was measured using the method of Sankar and Flynn.⁴ On the axial cut magnetic resonance image with the largest femoral

^{*} Corresponding author at: Kyoto Prefectural University of Medicine, Department of Orthopaedics, Graduate School of Medical Science, 465 Kajii-cho, Kawaramachi-Hirokoji, Kamigyo-ku, Kyoto 602-8566 Japan. Tel.: +81 75 251 5549; fax: +81 75 251 5841.

E-mail address: mohi72@koto.kpu-m.ac.jp (T. Yoshida).

Fig. 1. The measuring method of acetabular anteversion angle (AAA) according to Sankar and Flynn.⁴ A line was drawn perpendicular to base line passing through the center of the femoral head. The angle between this line and a line tangential to the bony edges of the acetabulum was defined as the AAA.

head cross-section, a line tangential to the most posterior points of both iliac bones was drawn. A second line was then drawn perpendicular to this line passing through the center of the femoral head. The angle between this second line and a line tangential to the bony edges of the acetabulum was defined as the AAA (Fig. 1). The initial axial images were obtained at a mean time of 6.5 months (1–31 months) after onset, and the final axial images were obtained at a mean time of 48.5 months (9–94 months).

Radiographic severity of Perthes disease was classified using the modified lateral pillar classification of anteroposterior pelvic radiographs taken from necrosis to the fragmentation phase.⁸ The final femoral head shape was classified using the Stulberg classification based on anteroposterior pelvic radiographs taken at the final examination.⁹ Stulberg classes I and II were defined as the good outcome group (G-group), and classes III and IV were the poor outcome group (P-group) (Table 1).

1. Evaluation of changes in AAA over time in the affected and unaffected hips classified according to treatment outcome.

Changes in AAA over time in the affected and unaffected hips were evaluated and compared between the G- and P-groups.

2. Evaluation of changes in AAA over time in the affected and unaffected hips according to differences in the presence or absence of COS.

The presence or absence of COS was determined on anteroposterior pelvic radiographs at the final examination using the method of Reynolds et al.¹⁰ The mean age at the final examination was 15 years and 9 months (13 years and 2 months to 24 years and 11 months). Patients were classified into COS-positive and COS-negative groups depending on the presence or absence of COS in the affected hip. AAA was measured in the affected and unaffected hips on the initial and final images and compared between the COS-positive and COS-negative groups. The relationship between the presence or absence of COS and the radiographic severity and treatment outcome of Perthes disease was investigated.

Statistical analysis of the G- and P-groups and changes in AAA over time was performed using unpaired or paired t-tests. The chi-square test for independence was used to examine the radiographic severity of Perthes disease and treatment outcome. Differences were assumed to be statistically significant based on a level of significance of less than 5% (* $p < 0.05$, ** $p < 0.01$).

3. Results

On the initial axial images, AAA in overall patients was $8.8 \pm 3.4^\circ$ (mean $\pm$ standard deviation) in the affected hip and $9.4 \pm 3.2^\circ$ in the unaffected hip. On the final images, AAA was $7.4 \pm 3.4^\circ$ in the affected hip and $9.4 \pm 4.6^\circ$ in the unaffected hip. No significant differences were found between the affected and unaffected hips or the initial and final images (Fig. 2).

Table 1

List of patients.

Case	Sex	Side	Age at onset	Modified lateral pillar classification	Stulberg classification	Follow-up period	Initial AAA ($^\circ$)			Final AAA ($^\circ$)			Cross-over sign
							Affected hip	Unaffected hip	Months from onset	Affected hip	Unaffected hip	Months from onset	
1	M	R	3y 7m	C	2	11y 5m	14	12	4	5	8	69	Negative
2	M	L	4y 4m	C	2	9y 11m	8	9	3	3	19	21	Negative
3	F	R	4y 8m	B/C	1	9y 0m	11	7	9	12	14	23	Positive
4	M	L	5y 0m	B/C	2	9y 5m	2	7	13	7	9	50	Positive
5	M	R	5y 3m	B/C	2	8y 5m	8	10	3	9	10	43	Negative
6	M	R	5y 10m	B	1	7y 8m	13	15	31	13	11	94	Negative
7	M	L	6y 1m	B/C	4	6y 11m	11	11	5	6	7	43	Positive
8	M	R	6y 3m	A	1	8y 7m	4	4	4	4	5	9	Positive
9	M	R	6y 4m	B/C	2	10y 0m	9	16	3	10	14	51	Positive
10	M	R	6y 4m	B/C	2	9y 8m	8	6	3	4	2	55	Positive
11	M	L	6y 7m	B	2	9y 1m	9	8	6	10	4	74	Positive
12	M	L	6y 10m	C	3	11y 3m	11	10	3	6	10	61	Negative
13	M	L	7y 2m	C	3	7y 7m	3	3	16	3	0	51	Positive
14	M	R	7y 4m	B/C	2	8y 7m	8	10	1	7	9	56	Positive
15	M	R	7y 5m	B	1	7y 2m	8	8	2	9	9	37	Positive
16	M	R	7y 9m	B/C	3	7y 3m	9	4	1	4	5	54	Positive
17	M	L	7y 10m	B	2	6y 2m	9	12	1	11	12	75	Positive
18	M	L	8y 0m	B	2	7y 7m	5	8	23	2	5	29	Positive
19	M	L	8y 1m	C	3	3y 2m	9	9	9	10	8	32	Negative
20	M	L	8y 5m	B	1	8y 0m	10	10	3	2	11	55	Negative
21	M	L	9y 2m	B/C	1	6y 6m	10	12	8	8	14	27	Negative
22	M	R	9y 4m	B	2	6y 5m	17	12	2	12	18	59	Negative
23	M	L	9y 5m	B/C	1	4y 9m	5	9	2	8	12	41	Negative
24	M	L	10y 1m	B/C	4	6y 3m	11	9	6	10	6	57	Positive
25	F	L	11y 2m	B/C	4	13y 8m	7	13	2	12	10	46	Positive

Fig. 2. In the G-group, AAA decreased in the affected hip; on the final images, the difference between the affected and unaffected hips had increased significantly. In the P-group, there were decreases in both the affected and unaffected hips between the initial and final images, and acetabular retroversion including the unaffected hip occurred. In overall patients, there were no significant differences between the affected and unaffected hips or in the changes over time.

1. Evaluation of changes in AAA over time in affected and unaffected hips classified according to treatment outcome (Fig. 2).

Eighteen patients (72%) were placed in the G-group and 7 patients (28%) were placed in the P-group. Initial AAA in the G-group was $8.8 \pm 3.6^\circ$ in the affected hip and $9.7 \pm 3.1^\circ$ in the unaffected hip; initial AAA in the P-group was $8.7 \pm 2.9^\circ$ in the affected hip and $8.4 \pm 3.6^\circ$ in the unaffected hip. Final AAA in the G-group was $7.5 \pm 3.5^\circ$ in the affected hip and $10.3 \pm 4.6^\circ$ in the unaffected hip; final AAA in the P-group was $7.3 \pm 3.4^\circ$ in the affected hip and $6.6 \pm 3.5^\circ$ in the unaffected hip. Although AAA in the affected hip in the G-group decreased between the initial and final images, the difference was not significant; however, the difference between the affected and unaffected hips was significant on the final images ($p < 0.05$). In the P-group, AAA decreased in both the affected and unaffected hips between the initial and final images, and this

difference was significant in the unaffected hip ($p < 0.05$). There was also a significant difference in AAA in the unaffected hip between the G- and P-groups on the final images, and in the P-group, acetabular retroversion including the unaffected hip also occurred.

2. Evaluation of changes in AAA over time in affected and unaffected hips according to differences in the presence or absence of COS (Fig. 3).

Fifteen patients (60%) were placed in the COS-positive group and 10 patients (40%) were placed in the COS-negative group. In the first axial image measurements, AAA in the affected hip was $7.6 \pm 2.9^\circ$ in the COS-positive group and $10.5 \pm 3.4^\circ$ in the COS-negative group; AAA in the unaffected hip was $8.4 \pm 3.6^\circ$ in the COS-positive group and $10.8 \pm 1.9^\circ$ in the COS-negative group. In both the affected and unaffected hips, AAA was significantly lower in the COS-positive group, suggesting the presence of acetabular retroversion ($p < 0.05$, $p < 0.05$). In the final measurements on axial images, AAA in the affected hip was $7.4 \pm 3.4^\circ$ in the COS-positive group and $7.5 \pm 3.5^\circ$ in the COS-negative group; AAA in the unaffected hip was $7.4 \pm 4.1^\circ$ in the COS-positive group and $12.1 \pm 3.6^\circ$ in the COS-negative group. The change over time was slight in the affected and unaffected hips in the COS-positive group. However, in the COS-negative group, AAA decreased significantly between the initial and final measurements only in the affected hip, and retroversion in the affected hip increased ($p < 0.05$). On the final images in the COS-negative group, significant differences were observed between the affected and unaffected hips ($p < 0.05$), and there was a significant difference in AAA in the unaffected hip between the COS-positive and -negative groups ($p < 0.01$).

Radiographic severity of the 15 COS-positive patients (modified lateral pillar classification) was Herring A, 1; Herring B, 4; Herring B/C, 9; and Herring C, 1. In the 10 COS-negative patients, radiographic severity was Herring A, 0; Herring B, 3; Herring B/C, 3; and Herring C, 4. No significant relationship was found between radiographic severity and the presence or absence of COS (Table 2).

Ten patients in the G-group and 5 patients in the P-group were positive for COS, and 8 patients in the G-group and 2 patients in the P-group were negative for COS. No significant relationship was found between the presence or absence of COS and treatment outcome (Table 3).

Fig. 3. In the COS-positive group, AAA on the initial image was significantly lower in both the affected and unaffected hips as compared to the COS-negative group, indicating relative acetabular retroversion. In the COS-negative group, AAA decreased significantly over time only in the affected hip, and retroversion of the affected hip increased.

Table 2

Radiographic severity in COS-positive and -negative groups.

Modified lateral pillar	A	B	B/C	C
COS (+) (n = 15)	1	4	9	1
COS (–) (n = 10)	0	3	3	4

Table 3

Treatment outcome in COS-positive and -negative groups.

Group	G	p
COS (+) (n = 15)	10	5
COS (–) (n = 10)	8	2

4. Discussion

In recent years, there has been much research on the pathology of FAI.^{1,11} In pincer-type FAI caused by acetabular retroversion, there is concern regarding not only impingement of the acetabulum and anterior femoral neck but also osteoarthritis of the hip due to the decrease in the load area of the posterior acetabulum.^{12,13}

Overall, AAA in the affected hip decreased between the initial and final images; however, no significant differences were found between the affected and unaffected hips or the initial and final images. Nevertheless, when classified according to treatment outcome, a significant difference in AAA between the affected and unaffected hips was seen on the final images in the G-group. Thus, acetabular retroversion increased in the affected hip. In the P-group, AAA decreased in both the affected and unaffected hips, with more relative retroversion in the unaffected hip. The reason for this was, as reported by Kawahara et al.⁵, that additional version in the entire pelvis might occur due to interactions between the affected and unaffected hip during the growth process, thereby increasing the possibility of a poor outcome.

Most research on acetabular retroversion after Perthes disease in adults has focused on COS as a radiographic indicator. The prevalence of COS was high in radiographically severe forms of Perthes disease.^{3,4} In the present study, the proportion of COS-positive patients based on radiographs taken at a mean age of 15 years and 9 months was 60%, similar to past reports.⁵ In the COS-positive patients, both the affected and unaffected hips had already been retroverted since a mean of 6.5 months after the onset of Perthes disease. Although the changes in AAA were slight in both the affected and unaffected hips in the COS-positive group, AAA was significantly lower in the affected hip in the COS-negative group, and retroversion increased. Sankar and Flynn⁴ investigated AAA in 44 patients with a mean age of 7 years and reported that acetabular retroversion did not occur in the early stage of Perthes disease. However, their study comprised a single observation in the early stage of the disease. The present study, conducted from a mean time of 6.5 months to 48.5 months after onset, showed that acetabular retroversion had already developed during the early stage. In some cases, acetabular retroversion occurred only in the affected hip, while in others it was present in both hips; in the latter case, treatment outcome was likely to be poor. However, there was no relationship between the presence or absence of COS and radiographic severity, and treatment outcome was not affected even when COS was present.

The causes of acetabular retroversion remain unclear. Although there was a high prevalence of COS after Perthes disease in the present study, acetabular retroversion had already been present in both the affected and unaffected hips since the early stage of

disease in the COS-positive group. A pathological condition similar to the mild dysplasia of the posterior acetabulum reported by Fujii et al.³ in developmental dysplasia of the hip may have been present in these patients. However, as the COS-negative group developed retroversion only in the affected hip, these acetabular changes are considered to have occurred as a result of inflammation of the hip joint, changes in hemodynamics, or some form of mechanical interaction with the femoral head shape. In the P-group, changes in acetabular version over time in both hips are thought to be due to lumbar kyphosis, genetic factors, or responses to mechanical stimulation to the triradiate cartilage or to cytokines accompanying arthrosynovitis. Further investigations of factors related to retroversion and its pathological significance are needed.

5. Conclusions

1. Changes in AAA over time in the affected and unaffected hips were evaluated in patients with unilateral Perthes disease treated conservatively.
2. With regard to treatment outcome, AAA significantly decreased in the affected hip compared with the unaffected hip in the G-group, whereas AAA decreased in both hips in the P-group, with more relative retroversion in the unaffected hip.
3. In Perthes disease, acetabular retroversion may occur only in the affected hip or in both hips. In the latter case, the treatment outcome may be poor.
4. Although the COS-positive group had acetabular retroversion in both the affected and unaffected hips from an early stage of Perthes disease, the changes over time were slight. In the COS-negative group, AAA decreased significantly over time in the affected hip.
5. The presence or absence of COS was not associated with radiographic severity or treatment outcome.

Conflicts of interest

The authors have none to declare.

References

1. Siebenrock KA, Schoeniger R, Ganz R. Anterior femoro-acetabular impingement due to acetabular retroversion. Treatment with periacetabular osteotomy. *J Bone Jt Surg Am.* 2003;85:278–286.
2. Ezoe M, Naito M, Inoue T. The prevalence of acetabular retroversion among various disorders of the hip. *J Bone Jt Surg Am.* 2006;88:372–379.
3. Fujii M, Nakashima Y, Yamamoto T, et al. Acetabular retroversion in developmental dysplasia of the hip. *J Bone Jt Surg Am.* 2010;92:895–903.
4. Sankar WN, Flynn JM. The development of acetabular retroversion in children with Legg-Calvé-Perthes disease. *J Pediatr Orthop.* 2008;28:440–443.
5. Kawahara S, Nakashima Y, Oketani H, et al. High prevalence of acetabular retroversion in both affected and unaffected hips after Legg-Calvé-Perthes disease. *J Orthop Sci.* 2012;17:226–232.
6. Ippolito E, Tudisco C, Farsetti P. The long-term prognosis of unilateral Perthes' disease. *J Bone Joint Surg Br.* 1987;69:243–250.
7. Kim WC, Hosokawa M, Tsuchida Y, et al. Outcomes of new pogo-stick brace for Legg-Calvé-Perthes' disease. *J Pediatr Orthop B.* 2006;15:98–103.
8. Herring JA, Kim HT, Browne R. Legg-Calvé-Perthes disease. Part I: classification of radiographs with use of the modified lateral pillar and Stulberg classifications. *J Bone Jt Surg Am.* 2004;86:2103–2120.
9. Stulberg SD, Cooperman DR, Wallensten R. The natural history of Legg-Calvé-Perthes disease. *J Bone Jt Surg Am.* 1981;63:1095–1108.
10. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. *J Bone Joint Surg Br.* 1999;81:281–288.
11. Kim YJ, Novais EN. Diagnosis and treatment of femoroacetabular impingement in Legg-Calvé-Perthes disease. *J Pediatr Orthop.* 2011;31:235–240.
12. Dandachi W, Islam SU, Liu M, et al. analysis to determine acetabular retroversion and the implications for the management of femoro-acetabular impingement. *J Bone Joint Surg Br.* 2009;91:1031–1036.
13. Giori NJ, Trousdale RT. Acetabular retroversion is associated with osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;417:263–269.