ORIGINAL ARTICLE

The Correlation Between Coxa Magna and Final Outcome in Legg-Calve-Perthes Disease

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Abstract: This study evaluated the final outcome of coxa magna that developed as a sequela of Legg-Calve-Perthes disease. The final outcomes at skeletal maturity were assessed by the Stulberg classification in 85 children with unilateral Perthes disease. Among them, 21 children had a bilateral arthrogram at the active stage of the disease, and the arthrogram measurements were compared with those measured at disease healing and at skeletal maturity. Coxa magna was observed in 53% (45/85), with a mean increase in 20.0 ± 7.2%. These coxa magna and resulting acetabular deformities occurred in the early stage of the disease. In 68 hips with mild (1–9% increase) or moderate (10–19%) coxa magna, the final results were Stulberg I or II in 57 hips and III in 11. In 17 hips with severe coxa magna (≥20%), the results were I or II in one hip, III in nine, and IV in seven. This means that 41% of the hips with severe coxa magna might have osteoarthritis later in life.

Key Words: Legg-Calve-Perthes disease, coxa magna, osteoarthritis

(*J Pediatr Orthop* 2005;25:22–27)

The poor long-term results in patients with Legg-Calve-Perthes disease (LCPD) are most often due to secondary osteoarthritis. This late osteoarthritis has been related to deformities in the femoral head as a result of LCPD.[16] Coxa magna is a deformity of the femoral head that often develops in patients with LCPD.[3,5,9]

Shapiro[16] reported two types of coxa magna: one with no long-term negative consequences and the other with more serious long-term consequences. According to his report, long-term problems arise when the growth of the femoral head outpaces that of the acetabulum, and the head is not only large in relation to the acetabulum but is also misshapen such that it relates imperfectly to the acetabulum.

McAndrew and Weinstein,[11] in a study aimed at defining the impairment of hips affected by LCPD, reported a statistically significant correlation between the clinical outcome and the femoral head size ratio over a long-term follow-up study of mean 48 years.

However, the level of coxa magna that results in osteoarthritis later in life has not been clearly determined. Moreover, it is unclear how and when coxa magna develops and progresses. To clarify those problems, this study examined the correlation between the severity of coxa magna and the final outcome of the LCPD hip at skeletal maturity. In addition, in selected patients, bilateral arthrography was performed in the active stage of the disease to determine the correct measurement, and the arthrogram measurements were compared with those measured at disease healing and at skeletal maturity to determine how and when coxa magna develops.

MATERIALS AND METHODS

Patients

This study reviewed the clinical records and radiographs from 85 children with unilateral LCPD who were followed from the active stage of disease, avascular or fragmentation, to full skeletal maturity. The children with bilateral involvement or those with an abnormal bone structure of the opposite hip were excluded from the study. Children who had bone surgery to treat the LCPD were also excluded.

The mean age at diagnosis was 7.0 (range 3.5–12.6) years. There were 66 boys and 19 girls. The mean follow-up period was 14.4 (range 6–25) years. The treatment modalities were an abduction orthosis in 61 hips, an intermittent cast and/or traction in 15 hips, and observation only in 9 hips. The abduction orthosis involved a Tachdjian brace in 19 children and a Scottish Rite brace in 42 children.

All the measurements for the evaluation were made on the anteroposterior view of the radiogram. Among the 85 children, 21 had a bilateral arthrography when they were first seen at the time of the diagnosis. In addition, the arthrogram measurements were compared with those measured at the disease healing stage and at skeletal maturity to confirm how and when coxa magna develops as well as how it progresses.

Arthrography was performed under 2% Procaine local anesthesia, with 2 to 4 mL of 60% diatrizoate meglumine (Hypaque) as the contrast material. The anterior approach was used. After the injection, the hips were mildly manipulated through a range of motion to disperse the contrast substance, and radiograms were made in the anteroposterior and frog-lateral (Lauenstein) projections. The two hips were then compared.

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Measurements

The following parameters were measured from both hips of each patient using the anteroposterior views of the plain radiogram checked at the disease healing stage and at skeletal maturity, and the bilateral arthrograms checked in the active disease period.

Coxa Magna

The widest diameter of the femoral head was measured. The coxa magna was categorized when the affected femoral head was 10% or more larger than the unaffected normal femoral head.[17,18]

Coxa Plana

The decrease in the epiphyseal height was measured. The height of the epiphysis was the largest perpendicular distance between the physeal line and the highest points of the epiphysis.

Displacement of Lateral Labral Apex of Acetabulum

The Hilgenreiner's and Perkin's lines were used for the convenience of measurement. The rose thorn projection on the arthrogram clearly outlines the lateral acetabular labrum with its apex. Any positional shift of this apex was measured and compared with a normal hip.

Acetabular Width and Depth

A line from the outermost margin of the acetabulum to the inferior point of the pelvic teardrop was made first. The acetabular width was the length of this line and the depth was the largest perpendicular distance between this line and the acetabular inner wall (Fig. 1).

Acetabular Opening Angle

This was the angle between the line indicating the length of the acetabulum and the line joining the superior and external edges of the Y growth plate to the most inferior point of the pelvic teardrop. The opening angle is the sum of the two angles, the Hilgenreiner's acetabular angle and the angle of the depth (Fig. 1).

Acetabular Head Index

The percentage of the femoral head covered by the acetabulum[8] was calculated.

Final Results

The final outcomes were assessed radiologically using the method reported by Stulberg et al[18] based on the sphericity and congruency of the hip.

Statistical Analysis

Statistical analysis was carried out using the Student *t* test for the variables that showed a normal distribution and a Mann-Whitney test for those that did not. A one-way analysis of variance was used to compare the differences in the three groups. The Pearson correlation coefficient was used for the correlation test. Multivariate regression analysis was used to evaluate correlations between age at disease onset, acetabular depth, and epiphyseal height with coxa magna. Statistical analysis was performed using the SPSS software package (SPSS for Windows Release 10.0, Chicago, IL). $P <$ 0.05 was considered statistically significant.

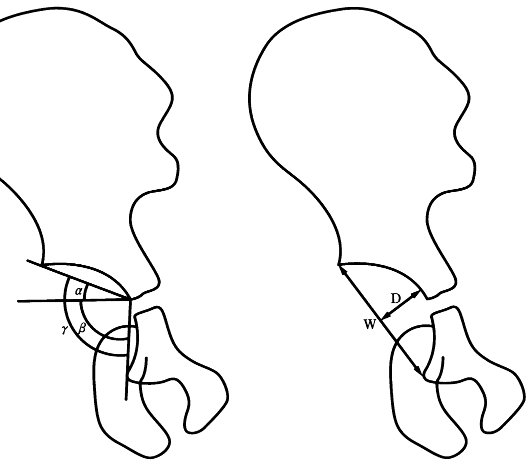

FIGURE 1. Measurement of the opening angle, width, and depth of the acetabulum. The opening angle (γ) is the angle between the line indicating the length of the acetabulum and the line joining the superior and the external edges of the Y growth plate to the most inferior point of the pelvic teardrop. The opening angle (γ) is the sum of two angles: the Hilgenreiner's acetabular angle (α) and the angle of the depth (β). The acetabular width (W) is the length of the line from the outermost margin of the acetabulum to the inferior point of the pelvic teardrop, and the depth (D) is the largest perpendicular distance between the line and acetabular inner wall.

RESULTS

Coxa magna where the affected femoral head was 10% or more larger than the unaffected femoral head at skeletal maturity was observed in 45 children (53%) out of a total of 85 children with LCPD. The mean increase in the 45 children was 20.0 ± 7.2%. The appearance rate of coxa magna was 35% in the children with Catterall group 1 and 2 and 60% in group 3 and 4 (Table 1), which indicates a higher occurrence in the poor-prognosis group ($P < 0.001$). The diameter of the affected femoral head gradually increased according to the increase of age at disease onset (r = 0.219, $P = 0.047$). There were no differences in both the appearance rate and the amount of coxa magna between boys and girls.

TABLE 1. Increase of Femoral Head Diameter at Skeletal Maturity in Children With Unilateral LCPD Treated by Conservative Means

		Patients With Coxa Magna (≥10%)		
Catterall Group	**Pt. No.**	**No. (%)**	**mm mean ± SD (range)**	**% mean ± SD (range)**
I + II	23	8 (35)	9.6 ± 3.4 (6–16)	17.7 ± 5.3 (11–27)
III + IV	62	37 (60)	11.3 ± 4.3 (6–23)	20.4 ± 7.5 (11–41)
Total	85	45 (53)	11.0 ± 4.1 (6–23)	20.0 ± 7.2 (11–41)
P value		<0.001	0.052	0.061

The distribution of acetabulo-femoral congruency in 85 hips was spherical congruency (Stulberg I + II) in 58 hips, aspherical congruency (Stulberg III + IV) in 27 hips, and aspherical incongruency (Stulberg V) in none. Severe coxa magna (≥20%) was observed in only 1 of 58 hips showing spherical congruency and 16 of 27 hips showing aspherical congruency. The distribution of subluxation (acetabular head index) in 85 hips was 80% or more coverage in 43 hips, 70% to 79% in 29 hips, and 69% or less in 13 hips. Severe coxa magna was observed in 3 of 43 hips showing an acetabular head index of 80% or more, in 5 of 29 hips showing 70% to 79%, and in 9 hips showing 69% or less.

The related morphologic changes in the femoral head and the acetabulum were evaluated by measuring the coxa plana, the acetabular depth and width, the opening angle of the acetabulum, the acetabular head index, and the final outcomes (Table 2; Figs. 2 and 3). The severity of coxa magna was arbitrarily divided into three groups according to the percentage of coxa magna: mild (1–9% increase), moderate (10–19% increase), and severe (≥20% increase). Generally, the associated deformities in the femoral head and acetabulum showed a gradual increase as the extent of the coxa magna increased. In detail, the mean percentage decrease in the epiphyseal height (coxa plana) was 23% in the mild cases, 30% in the moderate cases, and 36% in the severe cases (P = 0.014). The mean percentage increase in the acetabular width was 2% in the mild cases, 4% in the moderate cases, and 9% in the severe cases ($P < 0.001$). The mean percentage decrease in the acetabular depth was 3% in the mild cases, 11% in the moderate cases, and 20% in the severe cases ($P < 0.001$). The mean percentage increase in the acetabular opening angle was 2% in the mild cases, 6% in the moderate cases, and 10% in the severe cases ($P < 0.001$). The parameters indicating an acetabular deformity became gradually worse as the coxa magna increased. The acetabulo-femoral relationship assessed by the acetabular head index showed a gradual decrease in the femoral head coverage with an increasing coxa magna by showing a percentage coverage of 82% in the mild cases, 78% in the moderate cases, and 71% in the severe cases ($P < 0.001$).

The final results assessed by the Stulberg classification[18] showed significant differences in the three groups ($P < 0.001$). There were 38 good hips (class I + II) and 2 fair hips (class III) in the mild cases and 19 good hips and 9 fair hips in the moderate cases. In contrast, there was 1 good hip, 9 fair hips, and 7 poor hips in a total of 17 hips with severe coxa magna.

To determine how and when coxa magna develops and progresses, bilateral arthrography was performed at the active stage of the disease in 21 children with LCPD, and the parameters on the arthrogram were measured to compare them with those checked at the disease healing stage and at skeletal maturity (Table 3). The percentage coxa magna was 9% at the active disease stage, 17% at disease healing, and 13% at skeletal maturity. According to these results, coxa magna develops even in the early active stage of the disease, avascular or fragmentation, and progresses during the course of the disease (P = 0.11). Subsequently, coxa magna improved with growth until skeletal maturity (P = 0.186). Coxa plana representing the percentage decrease in the epiphyseal height was 16% at the active disease stage, 20% at disease healing, and 25% at skeletal maturity. The placement of the labral apex observed on the arthrogram showed an early displacement to the upward (3.5 mm in mean) and lateral (1.9 mm in mean) directions to adapt to the enlarged femoral head.

The acetabular measurements, including the opening angle, depth, and width, showed the early appearance of a deformity in the active stage of the disease. However, a progression of the acetabular deformity with time was not observed.

The acetabular head index showed a tendency for the slight progress of the reduced coverage with time. The percentage coverage of the femoral head was 70% in the active stage, 76% after disease healing, and 78% at skeletal maturity (P = 0.011).

In addition, we performed a multivariate regression analysis to determine the relative effects of age at disease onset and epiphyseal height decrease and acetabular depth decrease with the coxa magna. A significant linear association was found between coxa magna and acetabular depth decrease ($P < 0.001$), age at disease onset (P = 0.005), and epiphyseal height decrease (P = 0.034).

DISCUSSION

Coxa magna is one of the major residual deformities that often develops in patients with LCPD.[3,5,19] Stulberg et al[18]

TABLE 2. Severity of Associated Morphological Changes According to Degree of Coxa Magna

Coxa Magna	Mild (1–9%) (n = 40) mm	Mild %	Moderate (10–19%) (n = 28) mm	Moderate %	Severe (≥20%) (n = 17) mm	Severe %	*P* Value
Coxa plane (mean) (decrease of height)	4.7	23	6.4	30	7.2	36	0.014
Increase of acetabular width (mean)	1.5	2	2.7	4	6.4	9	<0.001
Decrease of acetabular depth (mean)	0.6	3	2.5	11	4.4	20	<0.001
Increase of opening angle (mean)	1.6°	2	6.2°	6	11.4°	10	<0.001
Acetabular head index (mean)		82		78		71	<0.001
Final results (number of hips)							<0.001
Stulberg I + II (good)	38		19		1		
Stulberg III (fair)	2		9		9		
Stulberg IV + V (poor)	0		0		7		

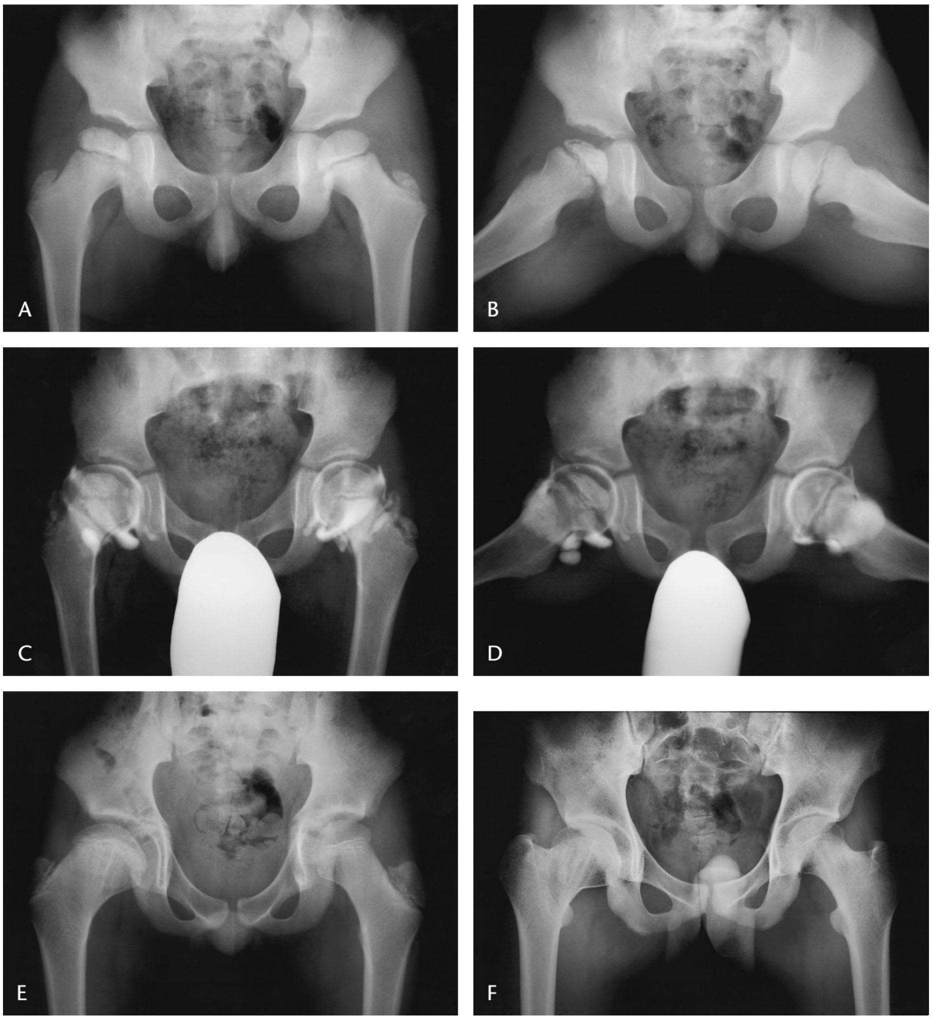

FIGURE 2. Radiographs of a child showing moderate coxa magna following LCPD. A, B, Plain radiographs at age 6 years 9 months show Catterall group 3 LCPD of the right hip. C, D, Arthrographs at diagnosis show a 10% increase in the femoral head diameter, a 17% decrease in the epiphyseal height, and superolateral displacement of a rose thorn in the LCPD hip. E, Plain radiograph at age 11 years 2 months shows healing of the disease with a 23% increase in the femoral head diameter, a 29% decrease in the epiphyseal height, and a 5% increase in the acetabular opening angle. F, Plain radiograph at skeletal maturity at age 17 years 1 month shows a spherical and congruent femoral head with a 19% increase in the femoral head diameter, a 24% decrease in the epiphyseal height, and a 15% increase in the acetabular opening angle.

reported that 57% of LCPD hips showed a 10% or greater increase in the femoral head diameter. Bowen et al[3] reported a similar incidence (58%) of coxa magna. In contrast, McAndrew and Weinstein[11] reported a higher incidence: they observed coxa magna in 86% of patients with LCPD. In this study, coxa magna was observed in 45 of a total of 85 patients, giving an overall incidence of 53%.

With regard to the clinical significance of this common complication of LCPD, the correlation between coxa magna and the final outcome of the hip function has been a subject of

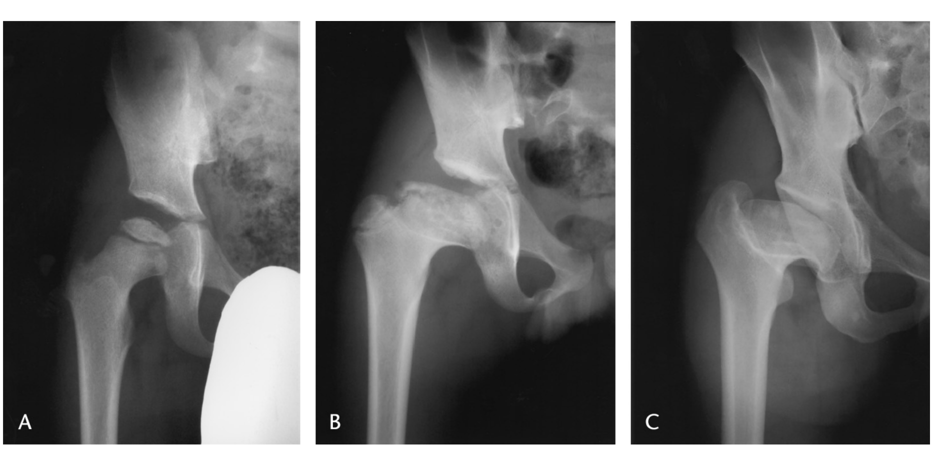

FIGURE 3. Radiographs of a child showing severe coxa magna following LCPD. A, Catterall group 4 LCPD in the right hip was diagnosed at age 5 years 8 months. B, Radiographs in disease healing at age 10 years 2 months show healing of the disease with a 42% increase in the femoral head diameter, a 31% decrease in the epiphyseal height, and an 11% increase in the acetabular opening angle. C, Radiographs at skeletal maturity taken at 22 years 5 months show Stulberg class IV hips with a 33% increase in the femoral head and a 2% increase in the acetabular opening angle.

TABLE 3. Measurements Made on Bilateral Arthrography at Active Stage of Disease in 21 Unilateral LCPD Were Compared With Their Plain Radiography Checked at Both Stages of Disease Healing and Skeletal Maturity

	Active Disease (Bilateral Arthrography)		After LCPD Healing (Plain Radiography)		Skeletal Maturity (Plain Radiography)		
Stage	mm	%	mm	%	mm	%	*P* Value
Femoral head							
Coxa magna (increase of diameter)	3.7	9	7.6	17	7.0	13	0.013
Coxa plana (decrease of height)	2.8	16	3.5	20	4.8	25	0.186
Acetabulum							
Displacement of labral apex							
Upward displacement	3.5						
Lateral displacement	1.9						
Increase of width	2.8	5	3.5	6	2.6	4	0.578
Decrease of depth	0.8	5	0.7	3	2.6	11	0.074
Increase of opening angle	4.5°	4	5.5°	5	6.3°	6	0.483
Acetabular head index		70		76		78	0.011

Data shown as mean values.

considerable debate. Stulberg et al[18] reported a different incidence of coxa magna according to his classification of the radiologic results. The incidence of coxa magna was 0% in Stulberg class I cases, 77% in class II cases, 96% in class III cases, 95% in class IV cases, and 28% in class V cases. However, they reported that there was little correlation between the coxa magna and the functional hip score. In contrast, McAndrew and Weinstein[11] reported a significant correlation between the clinical outcome and the ratio of the unaffected-to-affected femoral head sizes.

Shapiro[16] mentioned two possible types of coxa magna: one with no long-term negative consequences and the other with more serious long-term consequences.

This study found that coxa magna develops more often in the poor-prognosis group (Catterall group 3 and 4) and that there is a strong correlation between the severity of coxa magna and the final outcome of the hip. In 40 patients with mild coxa magna (<10%), all the hips belonged to Stulberg class I and II except for two Stulberg class III hips. In the 28 patients with moderate coxa magna (10–19%), there was 19 class I and II hips and 7 class III hips. In contrast, 17 patients with severe coxa magna (≥20%) showed 9 class III hips, 7 class IV hips, and only 1 class II hip. The distribution of the final outcome means that 41% of those with severe coxa magna can expect osteoarthritis in later life.

The other clinical importance of coxa magna is the secondary morphologic changes in the acetabulum that develop as an adaptation to an enlarged femoral head.[4,7,16] Cahuzac et al[4] reported the early appearance of acetabular deformities in the earliest stage of the disease in half of the patients with LCPD. Shapiro[16] reported that serious long-term consequences could arise when the growth of the femoral head outpaces that of the acetabulum. In the current study using a bilateral arthrogram, the earliest evidence of morphologic changes in the acetabulum was shown; that was the proximolateral shift of the lateral acetabulum, which has hitherto held little significance and has rarely been reported. A deformity in the hip with LCPD occurs primarily in the capital epiphysis, and its subsequent broadening immediately begins to exert pressure on the acetabular labrum. The lateral shift in the labrum means the beginning of its deformation. Other acetabular parameters, including the depth, width, and opening angle of the acetabulum, also showed concomitant changes according to the severity of the coxa magna.

With regard to the causative factors of coxa magna, many mechanisms have been proposed. Bohr[2] and other groups[1,6,9,15,20,21] observed, with the aid of arthrography and histologic observations, the early hyperplasia of the cartilaginous part of the epiphysis. Kemp and Boldero[10] and others[12,14] reported a possible relationship between coxa magna and the increase in the local blood supply due either to an inflammation or reactive hyperemia. Meyer[13] proposed a compensating growth process of the femoral neck, trying to maintain normal sphericity in the face of epiphyseal flattening. His explanation might be correct in the later healing stages of the disease.

This study showed a decrease in the epiphyseal height that occurs early in the disease process and persists with gradual aggravation with time until skeletal maturity. Interesting points were that this decrease in the epiphyseal height was closely related to the coxa magna in terms of the appearance time and its amount. These results suggest that a decrease in the epiphyseal height might be a factor in the increase in its diameter. A compression force to the plastic epiphysis might cause these changes. As to the mechanism of coxa magna, it is believed that reactive hypertrophy of the cartilaginous part and mechanical compression play an important role in producing early coxa magna, and that a compensating growth process of the femoral neck to maintain normal sphericity in the face of epiphyseal flattening is a contributing factor in the late remodeling stage of the disease.

In conclusion, we showed that the deformation of both the epiphysis and acetabulum develops early, even in the avascular and fragmentation stages, and that the decrease in the epiphyseal height contributes to the increase in its diameter (coxa magna). This study also found a strong correlation between coxa magna and the final outcomes in LCPD by showing a high incidence (41%) of a poor outcome in hips with severe coxa magna.

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