Acta orthop. Scandinav. 43, 45–55, 1972

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HYPERTROPHY OF THE FEMORAL HEAD IN LEGG-CALVÉ-PERTHES' SYNDROME—L. C. P. S.

A Study of Twenty-nine Patients Treated by Femoral Osteotomy

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Accepted 28.x.71

Coxa magna is a well-known sequelae to L. C. P. S. after healing is complete and can easily be recognised on plain roentgenograms (Ferguson & Howorth 1935, McMurray 1947). Edgren (1965) measured the radius of sixty-three heads in patients with unilateral healed L. C. P. S. He used a plastic protractor (Figure 1) and ignored slight flattening of the bony epiphysis. He found that only eight heads were equal in size bilaterally, whereas the remainder were larger on the affected side by an average of 3.3 mm in radius. This was the only study we were able to find which quantitatively documented head hypertrophy.

When and how coxa magna develops has not been the subject of much investigation. Meyer (1966) explains it as a compensatory mechanism of the epiphyseal growth plate which attempts to maintain a spherical outline in the face of epiphyseal flattening. This suggests that a reciprocal relationship should exist between epiphyseal size and metaphyseal growth, since a significant portion of metaphysis forms a part of the femoral head (Figure 2). Thus, although "shrinkage" of the affected ossific epiphysis has been reported as a characteristic early roentgenographic sign of the disease (Bergstrand & Norman 1965, Blanchard 1917, Kemp & Boldero 1966, Ponseti & Cotton 1961), this should not be confused with diminishing head size. On the contrary, it has been shown on arthrography that true hypertrophy of the osteocartilagineous caput is a frequent finding, even in the initial stages of the disease (Axer & Schiller).

Katz (1968) noted "moderate" enlargement in "fragmentation" stage

Supported by the Grant 19-P-48058-F-01 Social Rehabilitation Services, U.S. Health Education and Welfare Department Washington, D.C. administered by the Ilan Foundation for Crippled Children in Israel.

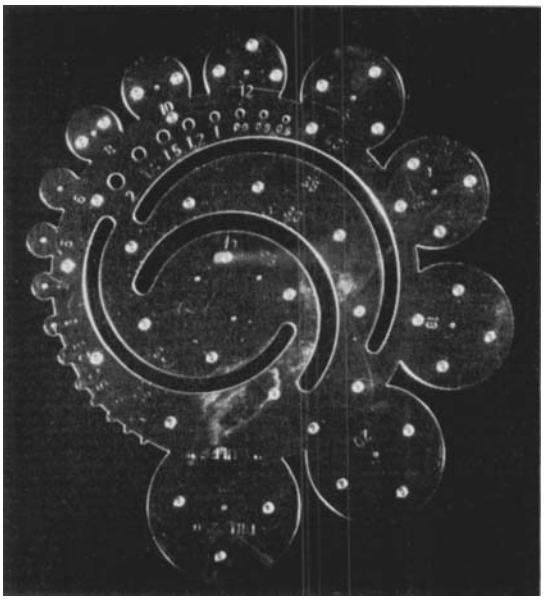

Figure 1. Edgren's transparent template for measurements of the sphericity of the femoral head and its size.

and striking enlargement of the head in later reparative stages of the disease. He did not mention the size of the caput in hips in the "necrotic" stage, but there were only three patients in this category in his series. Jonsater (1953) examined eleven hips in the "necrotic" stage by arthrography and did not notice any measurable differences between the two sides. He did not mention the size of the head in discussing other stages of the disease. Evans (1958) noted both epiphyseal and metaphyseal enlargement on plain roentgenograms as a constant early finding "giving the appearance of a large head" and stated that this inequality usually diminished later.

In L. C. P. S., when radiographies are made in supine position, a tilt of the pelvis occurs along its longitudinal axis towards the side of the diseased hip, this being probably due to gluteal atrophy on the diseased side (Schiller & Axer). With such pelvic asymmetry it has been shown that in normal children the head on the "low" side would appear either smaller, or equal in size to its mate, but never larger. Thus the detection of an early caput hypertrophy in L. C. P. S. becomes more significant (Axer & Schiller).

Coxa magna has been reported following septic or tuberculous arthritis (McMurray 1947) and after transient synovitis of the hip (Ferguson & Howorth 1935, McMurray 1947, Neuhauser & Wittenborg

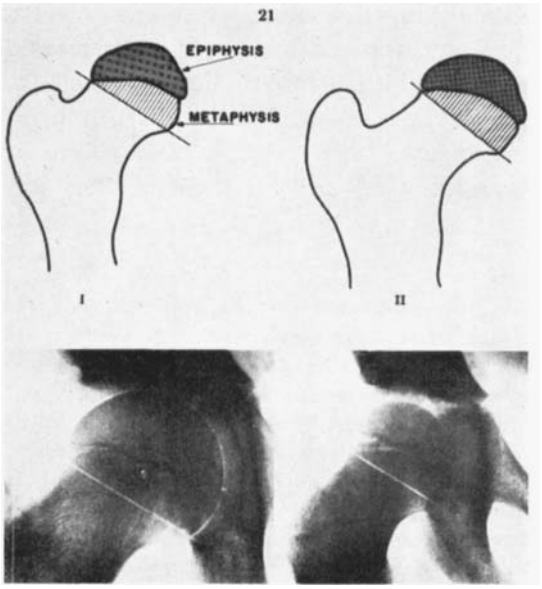

Figure 2. The "true" femoral head in child consisting of epiphysis and of a sizable part of metaphysis.

1963). It has been suggested that in the early "necrotic" stages of L. C. P. S., where bony enlargement is not present, but arthrographic evidence of hypertrophy of the head exists (Axer & Schiller), the enlargement of its cartilagineous part may be responsible for it. An increased blood supply to the proximal end of the femur, due either to inflammation or to the reactive hyperaemia (Kemp & Boldero 1966), could be responsible for this occurrence. This would also help to explain why these hypertrophied heads are not only wider but also higher, thus maintaining their sphericity.

McKibbin's experiment (McKibbin & Holdsworth 1966) on lamb's epiphyses provides supportive evidence for this theory: sixty days after excision of a wedge of articular cartilage together with subchondral bone in a lamb's knee, and its immediate replacement with interposition of a nylon film to separate it from the host bone, the latter was removed and the osteocartilaginous fragment was again replaced and exposed to a lush vascular supply. Twenty-eight days later internal cellular activity in the articular cartilage of the wedge was present with a resulting considerable increase in cartilage thickness. The early caput hypertrophy of the diseased femoral head in children was indeed observed to be due to the primary enlargement of its cartilaginous part (Axer & Schiller).

We think that incongruity in size between a quickly hypertrophying head and the acetabulum becoming rapidly too small for it, may constitute an important factor in the pathogenesis of the deformity in L. C. P. S. by virtue of the disruption of the normal weight bearing alignment (Axer & Schiller). In this paper a quantitative study of the changes in head size throughout the course of the disease is presented.

MATERIALS AND METHODS

An assessment was made of radiographies of twenty-nine consecutive patients with unilateral L. C. P. S. who were treated with subtrochanteric derotation varus osteotomy. The minimum post-operative follow-up period was two years. There were twenty-three males and six females.

Since an adequate number of patients with arthrography was not available, we have applied the plastic device used by Edgren (1965) on plain antero-posterior roentgenograms in such a manner that also in young children the size of the osseous head (H. S.) could be measured in millimeters radius (Figure 3). Below five years of age the medial edge of osseous caput is interrupted because the epiphysis is small and situated slightly laterally on the metaphysis. By ignoring the medial gap of the unossified caput, a suitable transparent circle can be chosen and the size of the osseous head measured. The H. S. was thus established

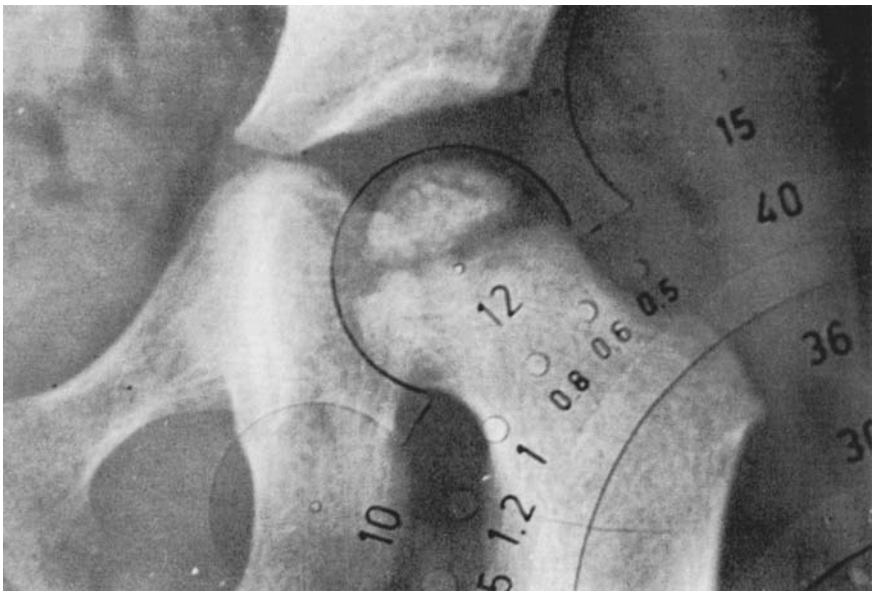

Figure 3. The template superimposed on a femoral head of a child of three years and eight months. To measure the size of the ossific head, the nonossified parts of epiphysis have to be ignored.

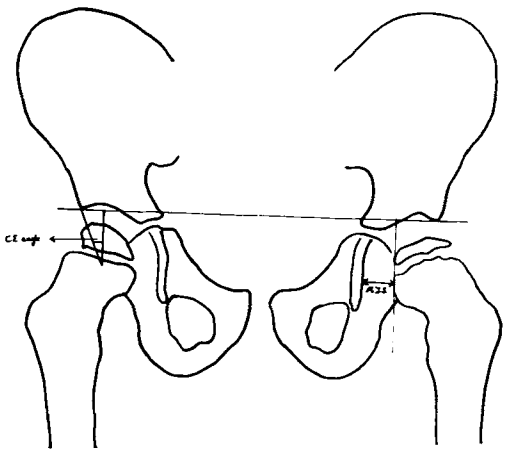

Figure 4. The method of measurement of the medial joint space (M. J. S.) and of the centre edge (C–E) angle of Wiberg.

in each patient on the earliest and the latest available roentgenogram and whenever possible in the "necrotic", "fragmentation", and "early regeneration" stages. The last examination was performed on every patient within six months of the completion of this study. The epiphyseal quotient (E. Q.), acetabular quotient (A. Q.) and the acetabular head quotient (A. H. Q.) were also measured in each case on every examination, according to Heyman & Herndon (1950). The centre edge (C–E) angle of Wiberg (1939) was measured pre- and post-operatively in each patient, as well as the preoperative medial joint space (M. J. S.) (Axer & Schiller) (Figure 4). The state of the growth plate on the last preoperative x-ray was also assessed.

All values were statistically analyzed by computer. One of three possible results was obtained from every correlation. Strong correlation means that only a one per cent chance of error exists. Good correlation means that a five per cent chance of error exists, and any error greater than this is considered to indicate no correlation (Snedecor 1946). Correlations may be positive or negative, which means directly or indirectly proportional.

Although there were twenty-nine initial osteotomies, four patients required a second procedure because insufficient acetabular containment of the diseased head was achieved primarily. In these patients the time of surgery should be understood to mean the time of the last surgery.

OBSERVATIONS, CORRELATIONS AND DISCUSSION

The mean calculated time of onset of the disease in these patients (Axer & Schiller) was six years and two months (range two years and nine months to eleven years). On the initial roentgenogram nineteen cases were in the necrotic stage. Two of these heads were smaller by an average of 1.5 mm radius, two were enlarged by 1 mm radius each, and fifteen heads were equal to their mates in size. There were ten

*Table 1. Correlation between head size, E. Q., A. Q., C–E angle and stage of disease at the time of surgery.**

Mose end results	Number of cases at: Necr. stage	Fragm. stage	Regen. stage	Mean head size increase in involved heads (mm radius)	Mean E. Q.	Mean A. Q.	Mean C–E angle
Good	6	6	2	0.7	60%	89%	20°
Fair	2	1	7	1.2	48%	80%	17°
Poor	2	–	3	0	58%	91%	18°

* In one poor and three fair cases a second osteotomy procedure was done. Values are taken from last x-ray preceding this operation.

Table 2. Correlation between head size, E. Q., A. Q. and C–E angle at last examination (average follow-up six years after surgery).

Mose end results	Mean head size increase on involved side (mm radius)	Mean E. Q.	Mean A. Q.	Mean C–E angle
Good	1.3	89%	89%	26°
Fair	6.1	50%	69%	12°
Poor	4.6	52.8%	72%	25°

cases in the fragmentation stage. One head was smaller by 1.0 mm radius, one head was equal to its mate, and eight heads were hypertrophied by an average of 2.7 mm radius (1 to 7 mm). No hips were initially seen in the regeneration stage.

The anatomical results were assessed according to Mose's method (1964), using the same template of Edgren for measurement of the sphericity of the femoral head. Good results comprised circular heads whose radius was equal on antero-posterior and lateral radiogram and the epiphyseal quotient (E. Q.) was above 60 per cent. Fair results comprised heads which deviated from a circle by up to 2 mm. Poor results had heads which were irregular in shape with outlines differing by more than 2 mm. There were fourteen good (49 per cent) ten fair (34 per cent) and five poor (17 per cent) results (Axer & Schiller).

The mean preoperative H. S., E. Q., A. Q. and C–E angle values are presented in Table 1, and their postoperative values in Table 2. Figures for the pre-operative assessment in cases which required a second osteotomy were taken from roentgenograms prior to the last operation.

It can be seen that the good group had a minimal average postopera-

Table 3. Return of head size to normal at follow-up (i.e. equal to the contralateral normal side).

Mose end results	Number of cases with equal head size	Total cases in group
Good	7	14
Fair	0	10
Poor	0	5

Table 4. Correlation of A. H. Q. before surgery and at last examination.

Mose end results	Pre-op. A. H. Q.	Last A. H. Q.	Mean medial joint space difference pre-op. (mm)
Good	89%	96%	3
Fair	78%*	90%	3
Poor	79%	87%	6.5

* Note that under eighty per cent A. H. Q. represents considerable lateral protrusion of the head from the acetabulum.

tive increase in H. S. after an average six years of follow-up, although of these fourteen patients none travelled the course of the disease without some enlargement of the head at one stage or another of the disease. Nonetheless in seven patients the head sizes equalized by the time of the last examination (Table 3) and in seven, hypertrophy ranging from 1 mm to 5 mm in radius (mean 2.6 mm radius) was noted.

In the fair group the moderate enlargement of the head at the time of surgery was seen to increase considerably and none of the patients had an equal head size on final examination.

In the poor group three of the five cases were equal in size and two were smaller by 1 mm at the time of operation. The final examination revealed marked enlargement of H. S. although not as great, on an average, as in the fair group.

Further evidence is reflected in the A. H. Q. measurements before surgery and at follow-up (Table 4). It has been previously shown that in normal children in supine position with an artificially produced pelvic "tilt" (similar to that caused in L. C. P. S. by gluteal atrophy) the A. H. Q. ranges between ninety-seven and one hundred per cent (Schiller & Axer). In the good group the A. H. Q. was the highest preoperatively, although it was not entirely within normal limits. In the

fair and poor groups the A. H. Q. were considerably lower (78 and 79 per cent), which indicated that a significant lateral protrusion of the head already existed before operation. These findings coincide with the increased medial joint space (M. J. S.) in the diseased hip preoperatively in the poor group, but not in the fair one. In all three groups the A. H. Q. improved following the operation, however, to a lesser degree in the poor group than in the good and fair ones.

The comparison of the mean E. Q. reflected quite faithfully the degree of the deformity of the head preoperatively and at the last examination (Tables 1 and 2). As could have been expected, in the good group the E. Q. improved from its mean preoperative value of 60 per cent to 89 per cent at the last examination, whereas in the fair and poor groups it remained almost unchanged at the low level of about 50 per cent.

Also the A. Q. deteriorated significantly in the fair and poor groups, while in the good group it remained close to 90 per cent.

A normal C–E (centre-adge) angle of Wiberg is 25° or greater. The average C–E angles of the three groups preoperatively were almost the same, and all were below normal. This may have been due to lateral subluxation of the femoral head concomitantly with an increase of the medial joint space. This is a well documented occurrence in L. C. P. S. (Caffey 1968, Kemp 1966, Korvin 1947, Strange 1965). Another cause, which to the best knowledge of the authors had not been previously drawn attention to, is the effect of caput hypertrophy on the relationship of the centre of the head to the acetabulum. As the head enlarges its centrum moves laterally, thus causing the C–E angle to decrease (see below), unless the acetabular roof becomes elongated laterally pari-passu. The last mean C–E angle improved and reached normal values in the good group and it decreased even further in the fair group at follow-up examinations. This finding indicates that poor only, and two of them had well contained although deformed heads, which may be responsible for the normal average C–E angle in this group at follow-up examinations. This finding indicates that poor anatomical results in L. C. P. S. may occur not only in truly subluxated hips.

The presence of premature closure of the epiphyseal plate was found to be closely correlated with the degree of hypertrophy of the head (Table 5).

* C–E angle of 20° is recognised as normal by some authors, but values below it are definitely pathological.

Table 5. Relationship between head size at follow-up and premature closure of the epiphyseal plate.

	Number of cases	Follow-up head size (mm rad.)
Cases with premature closure of plate	13	5.3
Cases with irregular but not prematurely closed plates	3	4.3
Cases without premature closure of plate	13	1.4

The above presented and analysed data were correlated and the following relationships were found to exist:

With an increasing flattening of the epiphysis, the entire head hypertrophies. Conversely, if the E. Q. increases after treatment, the head size decreases. This indicates that in those hips with smaller head size, the incidence of good anatomical results is increased. Fifty per cent of the hips belonging to the good group had, in fact, equal head sizes.

If the head is enlarged at the early regeneration stage, there is a strong probability that it may remain permanently enlarged. However, the coxa magna may not necesserily be synonymous with an irregular or flattened head; it may be quite spherical.

When the head increases in size, the acetabulum becomes shallower and wider and the head becomes less well covered by the acetabular roof. Thus a decrease in the A. Q., A. H. Q. and in the C–E angle takes place. The decrease in the A. Q. values may develop as a compensatory response of the acetabulum to the hypertrophied femoral head.

The above correlations indicated that a lateral protrusion of the femoral head may be due to two specific, pathological head-socket relationships in L. C. P. S.: a true subluxation with a lateral shift of the femoral head, accompanied by an enlargement of the M. J. S. and to a simple caput hypertrophy, resulting in its partial protrusion from within the too small confines of the acetabulum, without significant enlargement of the M. J. S. Thus the C–E angle need not be low only when true subluxation exists.

We feel that the excessive pressure exerted on the necrotic and fragmented head by the lateral segment of the acetabular roof, in the presence of markedly deranged joint dynamics (Axer & Schiller) due

to coxa magna, may be responsible for a low E. Q. and it may possibly contribute to the premature closure of the epiphyseal growth plate.

It can be expected that adaptive acetabular changes will create a sloping and widened socket in individuals with enlarged but quite spherical femoral heads. To date no study with a follow-up of fifty years or more is available to tell us whether this will increase the incidence of degenerative arthritis. Eaton (1967), in a study with an average of nineteen years follow-up, states that coxa magna in itself did not cause disability, although it was present in forty-five per cent of his patients. Thus our primary aim should be to achieve a spherical head, even if it would be larger in size than normal and therefore protruding laterally from the acetabulum, although we suspect that fifty or more years later such a head may be functionally inferior to one adequately covered by the acetabular roof.

SUMMARY AND CONCLUSIONS

Enlargement of the size of the femoral head in L. C. P. S., which starts quite early in the disease process, occurs frequently in patients in whom the proximal femoral epiphysial growth plate becomes prematurely fused. It is also very often accompanied by a decrease in the epiphyseal quotient and by inferior anatomical results. However, the increase in head size, or the so-called coxa magna, may be quite frequently observed in spherical heads as well.

Enlarged head size often causes a decrease in Wiberg's C–E angle without necessarily causing a true subluxation of the hip joint. The insufficiency of the coverage of the laterally protruding and enlarged but spherical head is reflected in these instances by a low acetabular and acetabular-head quotients.

The long-term (fifty years and above) follow-up of L. C. P. S. patients with a spherical coxa magna is not available. Hence the functional, long-term results in these patients are not known.

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