Thirty-four patients were studied throughout the evolution of Perthes’ disease. The acetabular changes included osteopenia of the roof, irregularity of its contour, and decrease in its depth. These changes were proportional to the femoral head involvement. The purpose of the study was to assess the effect of the morphological changes of the femoral head on the acetabulum and the outcome, and to determine the extent to which coxa magna and acetabular enlargement induced by Perthes disease in childhood persist into adolescence.

Radioisotope scans of the hip were examined in fourteen children with unilateral Perthes’ disease and comparison was made with the contralateral hip. These scans showed increased uptake on the lateral part of the acetabulum and no uptake over the avascular part of the femoral head. Average follow-up was ten years and children were followed up on average from six years to fifteen years of age. Six readings of the measurements of various dimensions of the acetabulum and the femoral head were done. CT scan also showed irregularity in the acetabulum. Statistical tests lead to the conclusion that the decrease in the depth of the acetabulum was secondary to the femoral head subluxation and enlargement. Also the remodelling potential of the acetabulum decreases as the child grows older. Therefore containment procedures could be done by femoral osteotomy in younger children, whereas acetabular osteotomy may benefit older children.

INTRODUCTION

Perthes’ disease is believed to be caused by multiple episodes of interruption of the blood supply to the femoral head (17). Radiographic studies consequently have focused predominantly on the changes in the femoral head and neck (4, 11). Prognosis has been predicted from the epiphyseal and metaphyseal changes of the proximal femur and therefore classifications have concentrated only on the femoral aspect (4, 11, 20). Few investigators have attempted to study the acetabulum in Perthes’ disease (2, 14, 25).

Our objectives of the present study were to:

1. note the changes in the acetabulum
2. establish the time during the course of the disease at which these acetabular changes appeared
3. see whether the decrease in the acetabular depth was primary or secondary to the femoral head subluxation and enlargement
4. determine the extent to which coxa magna and acetabular enlargement induced by Perthes disease in childhood persist into adolescence.
5. decide between femoral or acetabular osteotomy for containment.

From Alder Hey Children’s Hospital, Eaton Road, Liverpool, Merseyside, UK.
Sanjeev Madan, National Paediatric Orthopaedic Fellow.
James Fernandes, Consultant Paediatric Orthopaedic Surgeon.
John F. Taylor, Consultant Paediatric Orthopaedic Surgeon.
Correspondence: Sanjeev Madan, Department of Orthopaedics, Sheffield Children’s Hospital, Western Bank, Sheffield S10 2TH, United Kingdom. E-mail: ssmadan1@juno.com.
METHODS

Medical case notes and radiographs were examined from seventy-two children with Perthes’ disease from Alder Hey Children’s Hospital, Liverpool over a period of ten years from 1986 to 1996. Of these 72 patients only 34 who had unilateral Perthes and were treated conservatively were included in the study. Clinical information of the progress of the patient’s condition was assessed from the clinical notes and various measurements were done on the radiographs. All the measurements were done on each patient beginning at the average age of six years and following them up to the age of fifteen years, thus taking a total of six readings for each patient, at periodic intervals.

Sixty-eight hips were measured in thirty-four children with unilateral Perthes’ disease. These observations were analysed and statistical tests were applied to the data to study the acetabular remodelling that occurred with time. The parameters that were measured are as follows:

1. Osteopenia of the acetabular roof (13)
2. Acetabular contour (13, 23, 25)
3. ACM angle, a measure of the depth of the acetabulum (24) (fig 1)
4. Femoral head radius measured with the Mose’s circles (13, 19, 21, 24)
5. Femoral head containment (9, 12, 14)
6. Pelvic rotation quotient = transverse diameter of the right obturator foramen/ transverse diameter of the left obturator foramen. Normal range = 0.56-1.8 (24)
7. Pelvic tilt index = vertical diameter of the obturator foramen/ distance from pubis to Hilgenreiner’s line. Normal range = 0.75-1.2 (1).

Table I. — Osteopenia of the acetabulum and irregular contour of the acetabulum

<table>
<thead>
<tr>
<th></th>
<th>Osteopenia</th>
<th>Irregular contour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of cases</td>
<td>Percentage of total</td>
</tr>
<tr>
<td>Catterall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Group 2</td>
<td>3</td>
<td>8.9</td>
</tr>
<tr>
<td>Group 3</td>
<td>20</td>
<td>59</td>
</tr>
<tr>
<td>Group 4</td>
<td>5</td>
<td>14.9</td>
</tr>
<tr>
<td>Herring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>11.9</td>
</tr>
<tr>
<td>B</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>20.9</td>
</tr>
</tbody>
</table>

In order to study the acetabular disease we measured the depth of the acetabulum and assessed the irregularity of the acetabulum. To determine the persistence of coxa magna and acetabular enlargement we measured the femoral head radius, the ACM angle and the femoral head containment.

Fourteen children had two pelvic radiographs taken at interval of six weeks with a slightly different pelvic rotation. These pairs of films were used to establish the reproducibility of the measurements. All the thirty-four patients were treated non-operatively without any attempt at operative or non-operative containment. Seven children had traction from four to six weeks to relieve pain and regain movement. Two children had adductor tenotomy to relieve the adduction deformity. The hips were classified as per the Catterall (4) or Herring (11) classification. Fourteen patients had radiosotope scan (6) to diagnose Perthes’ disease.

Fig. 1. — Acetabular radius and ACM angle.
A- superior edge of acetabulum; M- midpoint of the line drawn from the teardrop to superior edge of acetabulum; C- point where perpendicular drawn from M reaches acetabular floor.

Five patients had CT scan during the course of their disease. The irregularity of the acetabulum was morphologically assessed as round, flattened or rough on plain radiographs and CT scan. Rough and flattened acetabula were considered as irregular.

The number of patients as per Catterall’s and Herring’s classifications is shown in table I.

The depth measured by the ACM angle of the acetabulum was assessed as per the severity of the involvement of the femoral head. Graphs were constructed of the data that was collected and statistical tests were applied to the observations. Each patient had six readings taken over a ten-year period from the time of presentation. Comparative observations were made on the affected and the non-affected contralateral hip and two sets of measurements were obtained for each patient with unilateral Perthes’ disease. The femoral head radius and the ACM angle were measured between the diseased and the normal side and compared. Two-tailed test of significance was applied to the each pair of observations. Correlation coefficients were calculated for the relationship between the femoral head radius and the acetabular ACM angle.

Pelvic rotation and AP pelvic tilt can invalidate the observations. Therefore to prevent significant distortions in the measurements, the quotient of pelvic rotation of Tönnis and Brunken (24), and pelvic tilt index of Ball and Komenda (1) were used.

The magnification of the radiographs was 10%. The stage of the disease was classified as per Waldenstrom’s classification (26).

**RESULTS**

Thirty-four children were studied with a mean age at presentation of 6.67 years. The male to female ratio was 3.8:1. The clinical features were evaluated and nineteen had fixed flexion deformity, twelve had adduction deformity, sixteen had restriction of internal rotation and seven had external rotation deformity. These findings were present at the time of first presentation. Adduction deformity resolved in 7 patients in one year (9 months to 1.9 years) and 2.6 years (2.1 to 3.4 years) for the other 5 patients. External rotation deformity resolved in the seven children after 3.6 years (2.2 to 4.4 years). There was residual loss of internal rotation of 20° (10 to 45°) in 9 children at the age of 15 years. True shortening of greater than one centimetre was present in six patients in the stage of fragmentation. The maximum true shortening was one and a half centimetre. Eventually eleven patients had poor results in the form of shortening, decreased movements or a limp.

The transverse diameters of right and left obturator foramen were measured and if the ratio between the two sides was within 0.56 to 1.8, then the radiographs of the children were considered comparable for pelvic rotation. Similarly if the pelvic tilt index was between 0.75-1.2 then the pelvic angulation in the sagittal plane was corrected for errors in comparison of films between children. This along with the measurements made of all the dimensions on 14 children at 6-week interval was used to minimise the error and improve the reproducibility of the measurements.

**Radiological results :**

Most of the children presented before the fragmentation stage. The changes studied were:

1. Osteopoenia of the acetabulum
2. Irregularity of the acetabular contour
3. Dimensional changes
4. Decreased uptake of the radioisotope in the involved part of the femoral head and increased uptake in the acetabular roof.
5. Acetabular changes on the CT scan.

**Osteopoenia of the acetabulum :**

Osteopoenia of the acetabulum was present in 83% of patients at presentation (table I). All the patients who had bone scan had counts determined digitally over the acetabular roof by a computer, and these were compared with the contralateral acetabulum. There was osteopoenia on plain radiograph assessment i.e. decrease in bone density when compared to the contralateral acetabular roof, in all the patients who had increased uptake over the acetabular roof on radioisotope bone scan. Weighted kappa assessment was done for inter-observer error between two radiologists and the author (SM). The results showed that the weighted kappa coefficient was 0.74. Thus there was a good interobserver agreement in assessing the
osteopenia of the roof of the acetabulum. At the healing stage, osteopenia of the acetabulum decreased. This change was directly proportional to the extent of the involvement of the femoral head and severity of the disease. There was more osteopenia in Catterall group 3 and group 4 and Herring type B and C. Also patients with marked osteopenia had greater acetabular irregularity (fig 4).

### Table II. — Correlation between the femoral head radius and other dimensions

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Correlation coefficient with</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM angle#</td>
<td>Femoral head radius* 0.981</td>
</tr>
<tr>
<td>ACM angle#</td>
<td>Femoral head containment - 0.997</td>
</tr>
<tr>
<td>Femoral head radius*</td>
<td>- 0.991</td>
</tr>
</tbody>
</table>

* in millimetres
# in degrees.

2. **Acetabular contour irregularity:**

The extent of the irregularity of the acetabulum was directly proportional to the extent of femoral head involvement i.e. Type C > Type B > Type A (Herrings’ classification) (table II). The acetabulum was assessed on AP and lateral radiographs to see whether it had a smooth curvature or whether there was a bump at the level of the triradiate cartilage, like the shape of ‘3’. Acetabular irregularity was also assessed on CT scan for the smooth contour or irregularity on the surface of the acetabulum (fig 4).

3. **Dimensions of the acetabulum and the femoral head:**

The ACM angle and the femoral head radius increased, and the femoral head containment decreased much more in the hips affected by Perthes’
than the normal side. (fig 5-10) ; (table II, III) (fig 1-3). We also found that the change in the depth of the acetabulum measured by the ACM angle from age 6 years (51.73°) through age 15 years (54.20°) was not proportionately as great as the change in the femoral head radius at those ages (18.35 mm at age 6 years to 25.17 mm at age 15 years) [table III]. This difference between the acetabular depth change and the change in the coxa magna was statistically very significant (two-tailed p < 0.0001).

4. Radioisotope study:

   Isotope bone scan done on the fourteen patients showed a cold spot on the affected part of the femoral head and a hot spot on the acetabulum just adjacent to the involved part of the femoral head (fig 2).

Table III. — Dimensions of the hip measured at age 6 years and age 15 years: paired sample statistics, correlation and t-test of significance

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Age (years)</th>
<th>Mean</th>
<th>SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM angle#</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Perthes</td>
<td>6</td>
<td>51.73</td>
<td>3.79</td>
<td>0.009</td>
</tr>
<tr>
<td>Normal</td>
<td>6</td>
<td>47.52</td>
<td>2.73</td>
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</tr>
<tr>
<td>2. Perthes</td>
<td>15</td>
<td>54.20</td>
<td>3.39</td>
<td>0.030</td>
</tr>
<tr>
<td>Normal</td>
<td>15</td>
<td>45.61</td>
<td>3.02</td>
<td></td>
</tr>
<tr>
<td>Femoral head radius*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Perthes</td>
<td>6</td>
<td>18.35</td>
<td>4.24</td>
<td>0.000</td>
</tr>
<tr>
<td>Normal</td>
<td>6</td>
<td>17.64</td>
<td>3.32</td>
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<tr>
<td>2. Perthes</td>
<td>15</td>
<td>25.17</td>
<td>3.84</td>
<td>0.000</td>
</tr>
<tr>
<td>Normal</td>
<td>15</td>
<td>19.17</td>
<td>3.07</td>
<td></td>
</tr>
<tr>
<td>Femoral head containment@</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Perthes</td>
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<td>0.88</td>
<td>0.081</td>
<td>0.000</td>
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<tr>
<td>Normal</td>
<td>6</td>
<td>0.94</td>
<td>0.065</td>
<td></td>
</tr>
<tr>
<td>2. Perthes</td>
<td>15</td>
<td>0.75</td>
<td>0.010</td>
<td>0.035</td>
</tr>
<tr>
<td>Normal</td>
<td>15</td>
<td>0.93</td>
<td>0.061</td>
<td></td>
</tr>
</tbody>
</table>

# in degrees
* in millimetres
@ ratio.
5. Acetabular changes on the CT scan:

There was increase in the acetabular size and a decrease in the acetabular depth on the affected side. The acetabular contour was irregular and there was osteopenia on the affected side. This was secondary to the femoral head involvement (fig 4).  

**DISCUSSION**

1. Osteopenia of the acetabulum:

The increased uptake of the acetabular roof on the bone scan corresponded to the osteopenia of the acetabulum on the plain radiograph. The osteopenia may be due to the hyperaemia in the synovium and the subchondral bone of the acetabulum (fig 2). The cause of osteopenia is difficult to prove conclusively, but because there are reactive changes in the synovium and subchondral bone during the healing process due to multiple episodes of ischemia, it is possible that this could contribute to the decrease in acetabular roof bone density.

2. Acetabular contour irregularity:

Thirty nine percent of the patients had an irregular acetabulum. The acetabulum appeared double domed or bicompart mentalised in only two hips of
Catterall group 4 (25). This was seen especially in severe degree of Perthes. Also the acetabulum was most irregular in the fragmentation stage (fig 5, 6). Thus the degree of acetabular irregularity closely followed the changes of the femoral capital epiphysis, and was directly proportional to it (table II, III ; fig 1-3). The superolateral cartilaginous part of the acetabulum, due to the non-containment, remodelled and became sloping and shallow.

**Fig. 11.** — ACM angle increases significantly with remodeling in Perthes disease. This shows that the acetabulum becomes shallow.

**Fig. 12.** — Femoral head containment decreased significantly with remodeling in Perthes disease.

**Fig. 13.** — Femoral head radius increases significantly with remodeling in Perthes disease.

### Alteration of dimensions of the acetabulum and the femoral head

It was seen that with the abnormal shape and abnormal increase in the radius of the femoral head there was significant decrease in the containment of the femoral head (fig 1-3 and tables II, III). The ACM angle, and femoral head radius showed significant relationship with the femoral head containment (fig 1-3). The acetabular depth was inversely proportional to the increase in the femoral head radius and these changes were statistically significant (table III). At no stage of the disease and age of the patient did the acetabulum remodel independently of the femoral head changes. Thus the acetabulum remodelled and became shallower and more sloping secondary to the abnormal shape and size of the femoral head and also due to the loss of containment from the acetabular socket.

We also observed that with growth in Perthes hip, the femoral head increased in size to a significantly greater extent than the acetabular depth (p < 0.0001) (table III). There was enlargement of the acetabulum in the sagittal plane. In the coronal plane the increase in acetabular depth did not correlate with the increased femoral head size. It is our view that the relative diminution of coronal growth is due to lateral pressure from the deforming femoral head. This would be expected to inhibit
growth in the region of the superior labrum. We infer that prevention of lateral extrusion of the femoral head could prevent the shallow development and remodelling of the acetabulum. Therefore an attempt should be made to contain the femoral head and prevent the shallow development of the acetabulum either by femoral osteotomy or pelvic osteotomy or both. A similar study where the femoral head has been adequately contained, and measurement of the acetabular dimensions as it remolds from childhood to skeletal maturity would permit further evaluation of this concept.

Embryonic bones were grown in tissue culture by Fell (7). An isolated chick patella grew in the tissue culture to a fairly normal shape but did not develop the concave surfaces normally present. She concluded that the opposing femoral condyles were necessary for the concavities to develop in the patella. Coleman et al (5) also showed in their experiments in puppies, that after resecting their femoral heads and filling the acetabulum with either a cube or a sphere of titanium the acetabulum at maturity had developed in a cube or a sphere shape depending on the shape of the implant inserted. From these experiments it is clear that the acetabulum is moulded as per its contents.

The changes in the acetabulum were not due to the fixed deformities because these were transient, mild and were present for less than half of the duration of the remodelling process of the acetabulum, and were not present in all the children. Moreover the morphological changes of the acetabulum viz. the irregularity, flattening or roundness corresponded to the shape and dimensions of the femoral head (fig 1-3 and 5-10). However the depth of the acetabulum was less than expected for the size of the femoral head at skeletal maturity.

The acetabular osteopenia may be due to inflammation, probably a low-grade synovitis that could secondarily increase the intracapsular pressure in the hip joint and hence jeopardise the blood supply to the femoral head. At the age of fifteen years the patients with Perthes’ hips showed persistent increase in ACM angle (fig 1, table III).

These changes imply that the patients might develop early secondary osteoarthritis. Since this study is not long enough, this presumption is made on the basis of a long-term study done by Stulberg et al (23). Therefore the incongruity that persists after skeletal maturity, would not resolve with ageing as the acetabulum and the femoral head would not remodel further. Whether these changes can be affected by femoral osteotomy or pelvic osteotomy early in the disease could be a subject for another study.

Since the acetabular contour changes followed the femoral head morphological shape, in early disease stage or at a younger age, one could plan a femoral containment osteotomy, and use the femoral head to produce a congruent acetabulum at maturity. This could perhaps improve the depth of the acetabulum. In later stages of the disease process or in older children acetabular realignment may help because of poor remodelling of the acetabulum due to loss of biological plasticity.

REFERENCES


