The bicompartmental acetabulum in Perthes’ disease

3D-CT AND MRI STUDY

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The bicompartmental acetabulum is one of the morphological changes which may be seen in children with Legg-Calvé-Perthes’ disease. Three-dimensional CT and MRI were used to analyse the detailed morphology of the acetabulum with special reference to its inner surface, in 16 patients with Perthes’ disease and a bicompartmental acetabulum.

The bicompartmental appearance was seen on the coronal plane image through the acetabular fossa. The lunate surface was seen to grow laterally resulting in an increased mediolateral thickness of the triradiate cartilage. On the horizontal plane images, the acetabular fossa had deepened and had a distinct prominence at its posterior border. The combination of these morphological changes resulted in a bicompartmental appearance on plain radiography. Acetabular bicompartmentalisation appears to be the result of an imbalance of growth between the cartilage-covered lunate surface and the cartilage-devoid acetabular fossa.

A bicompartmental acetabulum showing medial and lateral bony pockets is one of the morphological changes which may be seen in Legg-Calvé-Perthes’ disease. This appearance is thought to be associated with lateral extrusion of the femoral head and overgrowth of cartilage. The arthrographic findings have been described by Joseph. He postulated that increased metabolism and growth cause thickening of the acetabular cartilage, and the resultant appositional growth at the triradiate cartilage leads to bicompartmentalisation. Few authors have mentioned the significance of this change. Yngve and Roberts considered it to be a poor prognostic feature because patients in their study with a bicompartmental acetabulum who were not operated upon frequently required cheilectomy. On the other hand, Hoikka et al reported that a bicompartmental acetabulum did not influence the post-operative containment obtained by an intertrochanteric varus femoral osteotomy.

The acetabulum is a complex three-dimensional structure. Therefore two-dimensional (2D) plain radiography or arthrography cannot fully delineate its morphology. Three-dimensional (3D)-CT, especially its multiplanar reconstruction mode can be useful in defining the detailed morphology of the acetabulum. MPR-mode 2D images can be used to provide any standardised plane in which the examiner is interested. They give better anatomical information about the deep structures which may be poorly visualised on 3D images. Quantitative analyses are possible by measuring the distance between designated anatomical landmarks.

We have investigated the 3D morphology of the bicompartmental acetabulum using 3D-CT in its multiplanar reconstruction mode together with MRI.

Patients and Methods

From a group of patients with severe Perthes’ disease who had undergone pre-operative evaluation by 3D-CT, those whose plain radiographs showed a bicompartmental acetabulum were selected for study. Their 3D-CT images were analysed retrospectively. The Institutional Review Board had granted approval for this project.

Fourteen boys and two girls with a mean age of 7.5 years (5 to 11) at the time of the 3D-CT study were included. Seven hips were classified as Catterall group III and nine as group IV. Eleven hips were in the fragmentation stage, four in the initial stage and one in the healing stage. The mean time interval between the onset of symptoms and the 3D-CT study was 10.6 months (4.5 to 22). Two patients, who had suffered from Perthes’ disease in their contralateral hip, were included but were excluded from any comparative analysis of the affected versus the contralateral hip. All the...
Coronal plane two-dimensional reconstructed images through different levels of the acetabulum. Figure 1a – The left acetabulum appears unicompartmental at the level of the vertical limb of the triradiate cartilage (dotted line). Figure 1b – The left acetabulum is bicompartmental at the acetabular fossa (dotted line).

Figure 2a – An MPR image showing the method of measuring the mediolateral thickness of the triradiate cartilage in the coronal plane at the level of acetabular fossa. It was significantly thicker on the affected side (left) than on the contralateral side (right). Figure 2b – Comparison of measurements of the mediolateral thickness of the triradiate cartilage on the affected and unaffected contralateral sides. The thick lines represent mean values and SDs.
patients had been diagnosed at their local hospital and referred to us without prior treatment. After the 3D-CT study they were treated by various methods, seven by varus femoral osteotomy, four by shelf acetabuloplasty, two by valgus femoral osteotomy and three by soft-tissue release and the wearing of a Petrie plaster cast.\(^5\)

**3D-CT study.** Spiral CT was performed using a CT HiSpeed Advantage scanner (GE Medical Systems, Milwaukee, Wisconsin) at 120 kVp and 200 mA in the first two patients and subsequently by a MX8000 four-detector row spiral CT scanner (Marconi Medical Systems, Cleveland, Ohio) at 120 to 140 kVp and 120 to 140 mA in the remainder. 3D images were reconstructed with a slice thickness of 1 to 3 mm using the 3D-CT Rapida program (INFINITT Technology, Seoul, Korea). Most patients had some degree of flexion and/or adduction contracture of the hip. As a result, the pelvis was not in the normal anatomical position in the CT gantry. The reconstructed 3D images of the pelvis were repositioned so that both anterior superior iliac spines and the symphysis pubis were on the same coronal plane. Using the MPR mode of this program standardised images in the coronal and horizontal planes were obtained with the pelvis in the anatomical position.

The inner surface of the acetabulum was studied on coronal plane images (Fig. 1). The mediolateral thickness of the triradiate cartilage was measured on the coronal plane image at the acetabular fossa and compared with that of the contralateral side (Fig. 2). The inner surface of the acetabulum was studied on the horizontal plane scans. The mediolateral thickness of the acetabular floor was measured at the level where the diameter of the femoral head of the contralateral hip was maximal (Fig. 3). The posterior border of the acetabular fossa was also studied on the horizontal plane image at the same level, and classified into four grades. If there was no distinct demarcation between the acetabular fossa and posterior lunate surface, it was classified as smooth. If the acetabular fossa could be delineated from the posterior lunate surface by a subtle prominence between the two, it was classified as borderline. If the two areas were divided by a sharp-angled prominence, it was classified as sharp-angled and if the acetabular fossa was stepped off from the posterior lunate surface it was regarded as stepped-off (Fig. 4a).

**MRI.** In four patients MRI of the hip had been performed within three months of the 3D-CT study. The acetabular cartilage, ligamentum teres, triradiate cartilage and femoral epiphyseal cartilage were evaluated on these MR scans, and the findings correlated with the CT studies.

**Statistical analysis.** Comparative studies of the affected and contralateral hips were performed using the paired \(t\)-test for continuous variables and the chi-squared homogeneity test for categorical variables. A \(p\) value < 0.05 was considered to be statistically significant.

**Results**

3D reconstructed images of the hip allowed the deformed and laterally displaced bony femoral capital epiphysis to be visualised. 3D images of the acetabulum revealed a deepened acetabular fossa on the affected side, but it was difficult to explain the precise reason for the bicompartamental appearance on plain radiography.

On the coronal plane 2D images, reconstructed using the MPR mode, at or anterior to the level of the vertical limb of the triradiate cartilage, the contour of the acetabulum was unicompartamental, forming a single concentric circle (Fig. 1a). By contrast, on coronal plane images at the centre of the acetabular fossa, the contour of the acetabulum was bicompartmental (Fig. 1b), as seen on plain radiography. The acetabular contour at this level was divided into medial and lateral pockets by the posterior horizontal limb of the
Figure 4a – Multiplanar reconstruction images showing the variation in the morphology seen at the posterior border of the acetabular fossa. It was assessed on a horizontal plane image at the level of the widest diameter of the contralateral femoral head, and classified into four grades of smooth, borderline, sharp-angled and stepped-off. Figure 4b – Histogram showing the number of affected and unaffected contralateral hips in each grade.

Figure 5

MR coronal images showing that the acetabular cartilage contacts with the femoral head anterior to (a), and at the level of the vertical limb of the triradiate cartilage (b). The acetabular fossa which is devoid of cartilage loses contact with the femoral head (c). The MR horizontal image shows a deepened acetabular fossa filled with hypertrophied ligamentum teres. The femoral head remains in contact with the lunate surface of the acetabulum (d). MR images on both planes show cartilaginous hypertrophy on both the femoral head and acetabulum of the affected hip.
triradiate cartilage, which protruded into the joint space. The lateral pocket formed an arc from the triradiate cartilage to the lateral corner of the acetabulum. The laterally displaced femoral head articulated with this lateral pocket. The mediolateral thickness of the triradiate cartilage at this level was greater on the affected side than on the contralateral side by a mean of 14% (0.4% to 29%; \( p < 0.001 \)) (Fig. 2). The medial pocket formed an arc from the triradiate cartilage to the bottom of the teardrop. The femoral head did not articulate with this medial pocket. The inner surface of the ischium in this part of the acetabulum was acutely concave, an appearance described as ‘kyphotic’ by Joseph.\(^2\)

We believe this results from deepening of the acetabular fossa and thinning of its floor, leading to the change seen in the shape of the teardrop. These findings were consistent in all cases in this series.

On the horizontal plane images, the medial wall of the acetabulum was seen to consist of the acetabular fossa and the lunate surface anterior and posterior to it. This distinction was highlighted in the morphology of the posterior border of the acetabular fossa adjoining the posterior lunate surface of the acetabulum, which was significantly more distinct in affected than in contralateral hips (\( p < 0.001 \)) (Fig. 4). The affected hips were stepped-off in 12, sharp-angled in one, and borderline in three, whereas the unaffected contralateral hips were sharp-angled in two, borderline in eight, and smooth in six. The affected hip consistently had a higher grade of demarcation between the acetabular fossa and the posterior lunate surface than the unaffected contralateral hip.

The acetabular floor at the acetabular fossa was thinner in affected hips than in unaffected contralateral hips in 15 of the 16 cases (\( p = 0.0017 \)). In 11 (68.8%), the mediolateral thickness of the acetabular floor in the affected hip was less than 90% of that of the unaffected contralateral side (Fig. 3). Even in those cases which had borderline or no
thinning of the acetabular floor, the acetabular fossa was deepened relative to the posterior lunate surface, probably because of enhanced endochondral growth of the lunate surface.

In four patients, MRI was available within three months of the 3D-CT study. On coronal MR images at the level of or anterior to the vertical limb of the triradiate cartilage, the lunate surface was lined with acetabular cartilage, and maintained contact with the cartilaginous femoral head. On the coronal MR image at the level of the acetabular fossa, only the superior acetabulum (iliac part) was lined with acetabular cartilage, which was continuous with the triradiate cartilage. The medial (ischial) part of the acetabular fossa was devoid of acetabular cartilage, and was not in contact with the cartilaginous femoral head. On transverse MR scans, the deepened acetabular fossa was seen to be filled with a hypertrophic ligamentum teres and hypervascular synovial tissue. The acetabular cartilage over the posterior lunate surface on the ischium was hypertrophied in affected hips. The cartilaginous femoral head remained in contact with the posterior lunate surface, although it had lost contact with the deepened acetabular fossa (Fig. 5).

Pathoanatomically, certain changes occur to allow a bicompartamental acetabulum to appear. The floor of the acetabular fossa is thinned down, altering the appearance of the teardrop on plain radiography, while the posterior acetabular wall and the triradiate cartilage have grown out laterally, separating the acetabular fossa and the lunate (articular) surface of the acetabulum. The lunate surface is covered with hyaline cartilage, which is called acetabular cartilage, but functions as articular cartilage in its superficial layer and as physeal cartilage in its deep layer where endochondral ossification takes place during growth. By contrast, the acetabular fossa is naturally devoid of hyaline cartilage.

MR images, which were available in only four patients, revealed that both the acetabular and triradiate cartilage were hypertrophied while the deepened acetabular fossa was filled with hypertrophic ligamentum teres and hypervascular synovium. These findings suggest that both cartilage hypertrophy and soft-tissue swelling contribute to lateral displacement of the femoral head, and the development of a bicompartamental acetabulum. Synovitis associated with ischaemic necrosis of the capital femoral epiphysis may result in hypertrophy of the triradiate, acetabular and femoral head cartilage. The lunate surface of the acetabulum appears to be involved in this cartilaginous hypertrophy and enhanced endochondral ossification which results in lateral displacement of the femoral head. The acetabular fossa, which is devoid of acetabular cartilage, is not involved in this process. The pressure from the swollen soft tissues may be the cause of the deepening of the acetabular fossa.

Based on these observations we believe that the bicompartamental appearance of the acetabulum is not a response of the acetabulum to the subluxed femoral head, but rather that it develops from an imbalance of growth between the cartilage-covered lunate surface and the cartilage-devoid acetabular fossa. The femoral head in a hip with a bicom-
partmental acetabulum appears to sublux laterally leaving a wide gap between the medial acetabular wall and the femoral head. However, based on the detailed morphology of the bicompartamental acetabulum seen in our study the amount of true lateral displacement of the femoral head from the medial wall of the acetabulum should be measured as the distance from the femoral head to an imaginary arc extending medially and inferiorly from the lateral pocket (Fig. 7).

The multiplanar reconstruction mode of the 3D-CT software program has been very useful in analysing the detailed morphology of the acetabulum. The advent of new CT technology such as multidetector row spiral CT has reduced the radiation exposure to the patient. However, its use can only be justified when the information to be obtained outweighs any radiation hazard. We have limited the use of 3D-CT to patients with severe disease in whom marked pathological changes have necessitated its use before the undertaking of reconstructive surgery.

References