Monitoring of Containment in Perthes' Disease: Can Ultrasonography be Helpful?

Key words: Perthes disease, MRI, ultrasonography, diagnostics

SUMMARY

Background. Prevention of loss of containment has become an accepted principle in the treatment of Perthes' disease. The pre-requisite is early recognition. It is based on evaluation of plain radiographs and more recently, on the study of Magnetic Resonance (MR) images which allow discrimination of early cartilaginous changes. Ultrasonography (US) allows visualisation of the lateral cartilaginous portion of the femoral head and the acetabular rim including the labrum and measurement of femoral head protrusion/lateralisation. The purpose of this paper is to highlight its potential for monitoring of containment.

Materials and methods. We present typical MR and US images to demonstrate the anatomic landmarks of the normal hip joint and to define the parameters of protrusion in Perthes' disease. We selected three illustrative cases that had undergone routine imaging of both hip joints by MR imaging and ultrasound for evaluation of containment. Radiographs of the hips were also available.

In radiographs we assessed the coverage of the femoral head, i.e. containment, by the well established Acetabulum-Head Index (AHI) and in MR imaging by the Cartilaginous Acetabulum-Head Index (CAHI). In US we assessed the uncoverage, i.e. protrusion, by the Lateral Cartilage Distance (LCD).

In the important morphological MR containment features were also noted.

Results. There was a significant increase in the LCD in all Perthes hips (6.2, 7.4, 11.6 mm) when compared to the unaffected side (5.2, 5.1, 4.1 mm) and also when compared to the published mean normal value (5.4 ± 0.9 mm). Correspondingly, the CAHI values were significantly decreased (75, 69, 67% versus 87, 79, 81%), also in comparison to the published limits (77, 75, and 73% respectively). As for the AHI only the value of 71% in the third case represented a definite decrease below published normal limits (86 and 80.7% respectively).

In the 1st case we diagnosed adequate containment, in the 2nd containment at risk, and in the 3rd loss of containment.

In the 2nd case the AHI of 90 % suggested adequate containment whereas considerable protrusion/lateralisation was evident in MR imaging and US. The CAHI was only 69%. It showed that assessment by plain radiographs is less reliable because the cartilaginous portion of the hip joint is not included in interpretation.

We were able to demonstrate a good agreement between LCD and CAHI in our cases.

Conclusion. US can be helpful for monitoring of containment in Perthes' disease allowing a closer follow-up and a reduction of serial radiographs and MR exams.

BACKGROUND

A cartilaginous enlargement of the femoral head is seen early in the course of Perthes' disease. This will lead to a decrease of femoral coverage by the acetabulum. The head protrudes and radiologically lateralisation can be noted. In an unfavourable course gross joint incongruity may result, a condition for which the term loss of containment has been coined. The characteristic osseous and cartilaginous changes are well known from post mortem studies by Catterall [1]. Protrusion and indentation of the epiphysis as well as a labrum lift above horizontal position are the most important features [2]. Associated sequelae are permanent lesions of growth zones which are relevant for the final outcome.

Prevention of loss of containment has become an accepted principle in the treatment of Perthes' disease. The pre-requisite is early recognition. Clinical findings are of limited value. Radiographs may show
„head at risk signs” [1], such as lateralisation, but cannot depict the important cartilaginous changes. Arthrography is suitable but undesirable for serial examinations. Therefore Magnetic Resonance Imaging (MRI) has become a tool for the assessment of „true containment” in clinical practice [2,3,4,5,6,7]. It is expensive however.

The introduction of ultrasonography (US) in the diagnostics of congenital hip dislocation by Graf (1980) aroused an interest in application to Perthes’ disease [8,9,10,11,12]. Wirth et al. and Terjesen showed that a standard longitudinal lateral scan allows not only visualization of the lateral cartilaginous part of the femoral head and the acetabular rim including the labrum but also measurement of femoral head protrusion/lateralisation [9,10,11].

The aim of this paper is to highlight the potential of ultrasonography for monitoring of changes in the lateral hip joint which arise during the process of loss of containment in Perthes’ disease.

Note on Hip Joint Terminology and Parameters in Perthes’ Disease

As mentioned above there is an early enlargement of the femoral head in Perthes’ disease but – as far as we know – no concomitant growth of the acetabulum, only widening. This leads to an uncovering of the head, i. e. an impairment of containment (to put it one way) or protrusion (to put it another way).

If widening of the acetabulum occurs, there will be no extrusion of the head. If it does not widen or not sufficiently, there will be some extrusion (lateral displacement, lateralisation) which can be well visualized by T2-weighted MR images showing an increase in the distance between the innermost surface of the head and the floor of the acetabulum (lateral border of the „teardrop”). There will be, however, no true (progressive) lateral migration, no true (progressive) subluxation with the potential of dislocation, comparable to the situation in hip of a cerebral palsy patient!

Therefore we chose to use the terms containment and (lateral) protrusion („bulging”), the former for coverage, the latter for uncoverage. We occasionally added the historic term lateralisation to pay tribute to the radiological aspect and facilitate understanding by the reader.

Further support for the general use of the term protrusion in both imaging techniques, MRI and US, is provided by the fact that above the age of one year the presence of a large ossific nucleus limits the penetration depth of ultrasound and prevents discrimination between protrusion („bulging”) and lateralisation (extrusion, lateral displacement) of the femoral head.

To make our measurements clear:

In radiographs we assessed the coverage of the femoral head, i. e. containment, by the well established Acetabulum-Head Index (AHI) [13] and in MRI by the more recently advocated Cartilaginous Acetabulum-Head Index (CAHI) [2,3,14]. The AHI and CAHI values represent percent head coverage.

We did not assess the uncoverage in radiographs which would be appropriate in spastic hips (by means of the Migration Percentage [15]).

In US, however, we did assess the uncoverage, i. e. protrusion. Due to the denoted constraints in hip imaging at the age when children get affected by Perthes’ disease, we measured the Lateral Cartilage Distance (LCD) [9,10,11]. It is noted in millimeters.

MATERIAL AND METHODS

We present typical MR and US images to demonstrate the anatomic landmarks of a normal hip joint and define the parameters of protrusion in a hip with Perthes’ disease (Figs. 1 and 2).

We also present three illustrative cases out of our Perthes clinic that had undergone routine imaging of both hip joints by MRI and ultrasound for evaluation of containment (Figs. 3A-C). Radiographs of the hips were also available.

All patients belonged to Catterall group 3 and 4. For MRI we used 0.5 Tesla scanners (Gyroscan T5 II and Gyrospec ACS-NT; Philips Medical Systems, Eindhoven, The Netherlands). Spin-echo (SE) images were obtained with T1-weighting (TR 406-420 / TE 15-20). T2-weighted images were also acquired. Section thickness was 4 mm.

We relied upon T1-weighted coronal images of the centre of the hip for evaluation. Only in Fig. 3B we selected a T2-weighted image in order to demonstrate the concomitance of extrusion.

In T2-weighted scans fluid and oedema are well depicted by a high signal intensity giving the impression of contrast enhancement. There is, however,

1 Quotation from the original article of Heyman and Herndon (1950): „This is to measure a disproportion of the size of the head in relation to the acetabulum; or lateral displacement of the head from the depth of the acetabulum. Figure ... is ... showing the head in relation to the acetabulum, to illustrate the amount of expansion of the head beyond the supporting roof, or the amount of head coverage. Line A is a horizontal measurement from the innermost surface of the head to a vertical line projected from the outermost margin of the acetabulum; line B is a similar horizontal measurement from the innermost surface of the head to a vertical line projected from the outermost surface of the head. ... From previous studies of roentgenograms in cases of congenital dislocation of the hip, the normal head coverage has been found to be between 70 and 100 per cent, with an average of 90 per cent”.
some distortion by “signal invasion” of the adjacent tissue. Thus in Fig. 3B the femoral head appears smaller than in reality and fluid at the tip of the labrum produces an indentation in the epiphyseal cartilage which does not exist (verified by T1-weighted images and US).

Ultrasonography was carried out with a 7.5-MHz linear transducer (Sonoline Prima, Siemens, Erlangen, Germany). In supine neutral position a longitudinal lateral scan was obtained according to the guidelines of the German Society for Medical Ultrasound.

All images were reviewed by both authors. Evaluation of containment was performed as noted in the preceding section. Changes in the important morphological MR containment features were specified as described previously [2].

RESULTS

Visualisation of the bony roof of the acetabulum, the cartilaginous acetabular rim, the labrum and the epiphysis was successful in all examinations, not only in MRI but also in US (Figs. 1-3A-C).

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Fig. 1. Coronal MR tomogram and longitudinal lateral ultrasound scan. Normal right hip in 4-year-old boy. All the important anatomic landmarks of the lateral hip joint are identified in both images.

Fig. 2. Determination of protrusion/lateralisation. Left hip of a 5-year-old boy in the fragmentation stage, Catterall group 4. Labrum marked with arrows. Calculation of the CAHI and measurement of the LCD are illustrated.
The values of the Acetabulum-Head Index (AHI), Cartilaginous Acetabulum-Head Index (CAHI), and Lateral Cartilage Distance (LCD) in the illustrative cases are presented in Table 1. There was a significant increase in the LCD in all Perthes hips when compared to the unaffected side and also when compared to the published mean normal value of 5.4 ± 0.9 mm (cf. below). Correspondingly, the CAHI values were significantly decreased (75, 69, and 67% versus 87.79, and 81%), also in comparison to published limits of 77,75, and 73% respectively (cf. below). As for the AHI only the value of 71% in the third case represented a definite decrease below published normal limits of 86 and 80.7% respectively (cf. below).

In the 1st case we diagnosed adequate containment. In the 2nd case the AHI of 90% suggested adequate containment whereas considerable protrusion influenced by extrusion was evident in MRI and US. The CAHI was only 69% in comparison to 79% in the unaffected side. The LCD was accordingly elevated (7.4 versus 5.1 mm). Therefore containment had to be considered at risk.

In the 3rd case there was gross deterioration of all parameters. The LCD was particularly increased (11.6 versus 4.1 mm). Loss of containment was evident.

The complementary assessment of the morphological MR containment features supported the diagnosis in all 3 cases (Figs. 3A-C).

**DISCUSSION**

Up to now, only a few investigators have based their analysis of containment on the collection of containment parameter data. Sales de Gauzy et al. [14] concluded from their study of 26 patients with unilateral Perthes’ disease that the femoral head should be considered „subluxated” if the AHI is less than 86% on the plain radiograph and the CAHI less than 77% in MRI. In 8 patients there was a „subluxation” in MRI whereas the plain radiograph was normal. Thus MRI appeared to be more sensitive in determining the „subluxation” of the femoral head during the active phase of Perthes’ disease. Moberg et al. [16] reported that an AHI of < 80.7% indicated early „subluxation” of the femoral head. In a former study we found a lower normal limit of the CAHI of about 75% [17] and more recently a limit of 73% [18].

The sonographic assessment of the protrusion of the epiphysis as a reproducible diagnostic method for Perthes’ disease has been reported by Wirth et al. [9,10] and Terjesen [11]. Both measured „the shortest distance between the lateral bony acetabular rim and...
a tangential line along the lateral cartilaginous margin of the femoral head” for which Terjesen coined the term Lateral Cartilage Distance (LCD). In 19 patients he found a significant difference between the mean LCD of the affected hip and the normal hip (6.3 ± 1.3 mm versus 5.4 ± 0.9 mm). Wirth et al. (1992) found in 23 patients that “lateral extrusion” (= LCD) increased from the initial stage onwards until the healing stage (9). They noted values from 0.91 ± 1.22 to 5.44 ± 3.65 mm. The normal value for „lateral extrusion” derived from the normal hip of patients with unilateral disease was 3.1 ± 1.6 mm.

The LCD values presented in Table 1 correspond to Terjesen’s figures. They also comply with own data indicating an LCD < 6.5 mm in joints without loss of containment[18].

Terjesen also introduced the term Lateral Head Distance (LHD) for measurement of protrusion in US (“the distance from the lateral tangent of the ossification centre of the femoral head to the lateral bony acetabular rim”). He found a significant difference between the mean LHD of the affected hip and the normal hip (1.8 ± 1.7 mm versus 0.9 ± 0.9 mm). He concluded that lateral protrusion is visualized by ultrasound as increased LHD and LCD values. There was good correspondence between LHD by ultrasound and radiographic assessment of femoral head coverage, indicating that the degree of uncoverage is determined reliably by ultrasound. Since the lateral outline of the bony femoral head is more easily identified than that of the cartilaginous part, Terjesen believed that LHD is a more reliable parameter than...
LCD. His results showed corresponding side differences in both distances, so he felt that little information was gained by determining the lateral cartilage outline. We think, however, that it is essential to determine the LCD because there is a statistically significant increase in thickness of femoral head (and

Tab. 1. The values of the Acetabulum Head Index (AHI), Cartilaginous Acetabulum Head Index (CAHI), and Lateral Cartilage Distance (LCD) in the selected illustrative cases

<table>
<thead>
<tr>
<th></th>
<th>AHI (%)</th>
<th>CAHI (%)</th>
<th>LCD (mm)</th>
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<tr>
<td></td>
<td>Perthes</td>
<td>Normal</td>
<td>Perthes</td>
</tr>
<tr>
<td>1st case (A)</td>
<td>87</td>
<td>93</td>
<td>75</td>
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<tr>
<td>2nd case (B)</td>
<td>90</td>
<td>92</td>
<td>69</td>
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<tr>
<td>3rd case (C)</td>
<td>71</td>
<td>96</td>
<td>67</td>
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Fig. 3C. Loss of Containment. Hip joints of a 10-year-old boy with Perthes’ disease on the right side in the fragmentation stage, Catterall group 4. Labrum marked with arrows. Vertical lines were positioned for determination of AHI, CAHI, and LCD. The respective values are recorded in Table 1.

Morphological MR containment criteria:
- Labrum lifted beyond horizontal position
- Indentation of the epiphysis by the acetabular rim
- Considerable protrusion influenced by extrusion

The US picture is confusing because the lifted labrum is hypertrophied and distorted. The indentation of the epiphyseal cartilage is not well seen. In such a case MR imaging is mandatory for the diagnosis of loss of containment and in the planning of surgical treatment.

In this situation we would also suggest an intraoperative arthrogram to decide about a combined osteotomy as a salvage procedure (Crutcher and Staheli, 1992) or more recently, a temporary joint distraction (arthrodiasis) by means of an external fixator until the step in Shenton’s Line is well reversed, followed by a 6-week-period of initially fixed and then dynamic retention in a spica cast in wide abduction (≥ 25°).
also acetabular) cartilage in Perthes' disease [3]. The bony epiphysis, on the other side, undergoes considerable variations in size throughout the disease. Measurement of the lateral cartilaginous margin of the head gives a better picture of the true amount of protrusion. Furthermore the quality of imaging by ultrasound has been improved by advances in technology. Identification of the lateral cartilage outline has become more reliable.

In the future we have to establish guidelines regarding the increase in LCD value which signals risk of loss of containment and the need for surgery. Are more than 2 mm significant, as Wirth et al. [10] reported? In cases with doubtful prognosis we suggest repeated exams, in particular in the critical „soft phase“ from the 10th to the 14th month after the beginning of symptoms [2].

We also have to address dynamic ultrasound examination, in particular in hip abduction, but also in adduction, flexion and rotation. A notable flattening of the superior contour of the epiphyseal cartilage and a progressive labrum lift may be indicative of containment at risk. Needless to say that the rare and alarming clinical finding of „hinge abduction“ is very easily confirmed by the dynamic exam.

It may be noted in this context that promising reports have appeared regarding multipositional MR imaging [7,19].

As in ultrasound hip screening of the newborn, practice is necessary to gain expertise. Therefore we encourage the routine use of an ultrasound machine for the examination of Perthes patients.

CONCLUSION

Our findings suggest that US can be helpful for monitoring of containment in Perthes' disease. Ultrasound exams would allow a closer follow-up and a reduction of radiographs or MRI scans every three to six months.

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Received 12.07.2004 r.
Accepted 24.09.2004 r.