IMPROVEMENT IN ACETABULAR INDEX AFTER REDUCTION OF HIPS WITH DEVELOPMENTAL DYSPLASIA

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After late reduction of the hip in children with developmental dysplasia the acetabular contour slowly improves and it is difficult to know if and when acetabular reconstruction is required. We studied the radiographs of 19 patients with unilateral dislocated or subluxated hips which had been reduced between the ages of one and two years. Preoperatively, all the affected hips showed acetabular dysplasia. After reduction they steadily improved for three years by which time none was dysplastic as measured by the acetabular index. After the age of ten years, when assessed by the more sensitive centre-edge angle, two were found to be dysplastic. It was not possible to predict these from early radiographs.

We conclude that the decision to reconstruct an acetabulum should not be taken until three years after reduction, and that a few hips which appear to be developing satisfactorily at that time will, nevertheless, become dysplastic.

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In a patient with developmental dysplasia (DDH) the hip will probably develop normally (Ortolani 1976) if the femoral head is accurately reduced in the neonatal period and the reduction is maintained for a few weeks. If treatment is delayed, secondary adaptive changes in the acetabulum and the femur decrease the likelihood of normal development of the hip. In older children, pelvic or femoral osteotomies are therefore often advised (Salter 1961; Klisic and Jankovic 1976). It is, however, difficult to know in a particular patient if or when acetabular reconstruction should be undertaken. It is seldom advised for children less than 18 months old (Pemberton 1974).

Several years may elapse before the surgeon can confidently predict the quality of acetabular remodelling. Various guidelines have been drawn up to help in this decision (Schwartz 1965; Harris 1976; Lindstrom, Ponseti and Weeger 1979; Tönnis 1987), but they are imprecise. In order to determine the natural history of acetabular remodelling we have studied acetabular development in a group of patients who had late reduction of the femoral head and no pelvic surgery.

PATIENTS AND METHODS

Twenty patients treated at the Nuffield Orthopaedic Centre between 1977 and 1983 for DDH fulfilled the criteria for entry into this study. They had all been between 12 and 24 months old at the time that the hip was reduced and each had had only one unstable hip. None had undergone pelvic reconstructive surgery at the time of reduction or subsequently. Nineteen of the patients had been followed up regularly by standing pelvic radiography; one patient was lost to follow-up when the family emigrated and was therefore excluded from the review.

There were two boys and 17 girls. Six patients presented with residual subluxation after a period of splintage, two presented with subluxating hips at 14 and 18 months respectively, and 11 presented late with established dislocations. The left side was affected in 11 patients, the right in eight.

Hip reduction. All the children had spent two to three weeks in skin traction preoperatively. An arthrogram was performed in them all at the time of operation. Twelve hips were reduced closed and seven open. Percutaneous adductor tenotomy was performed in ten. When open reduction was carried out the ligamentum teres was resected, the inferior acetabular ligament was divided and the capsule was plicated. The limbus was not removed. Derotation and varus femoral osteotomy was performed in all cases. The derotation ranged from 50° to 70° and the varus from 10° to 30°. The hip was then immobilised in a spica cast for six to 12 weeks.

Follow-up was at least once yearly for the first five years, and then at least once every two years. Each child was assessed clinically and also by standing pelvic
radiography. The radiographs were taken with one twelfth of the normal X-ray dose to minimise radiation. The acetabular index (AI) was used as the main measure of acetabular development until the age of ten years. Subsequently, the centre-edge angle (CEA) was used. Methods of measurement were based upon those of Tönnis (1987). For the purpose of this study the postoperative measurements were grouped into time intervals: six-monthly for the first three years; yearly for the next two years; and then two-yearly. If during any interval there was more than one radiograph then the measurements from these were averaged. At each time interval the AI or CEA for the affected hip was compared with that of the unaffected hip and with the normal mean value for that age. The means and standard deviations of the AI in normal children at different ages were obtained from Massie and Howorth (1950) and from Tönnis and Brunken (1968). An AI greater than two standard deviations from the normal mean was considered to indicate definite dysplasia (Tönnis 1987). The normal mean value for the CEA was taken to be 30° for children over the age of ten years and a hip with CEA less than 15° was considered to be definitely dysplastic (Severin 1941; Tönnis 1987).

Statistical comparisons were made using Student’s \( t \)-tests; these were paired when the operated side was compared with the non-operated, and not paired when comparisons were made with normal values.

At about the age of ten years it becomes difficult to measure the AI, and the CEA is then more reliable. A mathematical model of a hip was developed to compare the AI and CEA based on the assumption that both the acetabulum and the head were roughly spherical and concentric, as is the case in hips in Severin (1941) grades I to III.

**RESULTS**

No patient complained of pain or had limited function or restricted movement. Radiographically, no patient developed avascular necrosis or evidence of osteoarthritis during the limited period of the review. One child who had had an open reduction developed mild coxa magna with no other evidence of ischaemic change. One developed severe bilateral coxa valga and one severe unilateral coxa valga with 5 cm of relative lengthening of the leg. This child was treated by a varus, shortening osteotomy at the age of nine years.

**The affected hip.** The mean preoperative AI of the unstable hips was 38° (SD 6°) (Fig. 1) significantly \( (p < 0.0001) \) greater than the mean AI of the unaffected hips (mean 23°, SD 5°) and of the normal hips (mean 20°, SD 5°). Preoperatively, 18 of the unstable hips were definitely dysplastic (Fig. 2) and one was possibly dysplastic.

![Histogram to show the improvement in the acetabular index (AI) over time in affected and unaffected hips (mean \( \pm \) SEM). The mean AI of normal hips is also plotted as a continuous line.](image1)

![Scattergram of the acetabular indices of the affected hips until the age of ten years. The two hips which became dysplastic are drawn with continuous lines. The mean and the mean \( \pm \) 2 SD for normal hips are plotted as dashed lines. Angles above the mean \( \pm \) 2 SD hips are considered to indicate definitely dysplastic hips.](image2)
During the first three postoperative years the mean AI of the operated hips fell steadily relative to the uninvolved side and to the normal control values (Fig. 1). At three years postoperatively the mean AI of the affected hips was only 3° to 4° greater than that of the unaffected hips and none was considered to be dysplastic.

Between three and ten years postoperatively the mean AI of the affected hips remained 3° to 4° greater than the unaffected hips but during this period none was considered to be definitely dysplastic. At all time intervals the mean AI of the affected hips was significantly greater than the unaffected hips (p < 0.01 at 8 intervals; p < 0.05 at the other three intervals).

After the age of ten years the CEA rather than the AI was measured. At this time the CEA of the affected hips (25°±8°; range 12 to 44) was significantly (p < 0.05) less than that of the unaffected hips (29°±4°; range 22 to 36) and of the normal hips (30°). Two affected hips were now considered to be definitely dysplastic (CEA 12° and 14°). If these two dysplastic hips are excluded then the mean CEA of the affected hips (27°±6°) is not significantly different from that of the unaffected hips or of the normal hips. An attempt was made to identify factors which could have predicted that the two hips would become dysplastic but none was found. The patients' ages at operation were 15 and 18 months; one had an open and the other a closed reduction. For the first three years after operation their AI did not differ from the hips which did not become dysplastic (Fig. 2); between three and ten years postoperatively their AI was near the upper limit of the range for the affected hips, but was no larger than in several hips which ended up normal. The unaffected joints on the opposite side to the dysplastic hips had a CEA of 26° and 27°, slightly less than the average (Figs 3 and 4).

The unaffected hip. Preoperatively, the mean AI for the unaffected hips (23°, SD 5°) was significantly (p < 0.01) greater than that of the normal hips at this age, (20°, SD 5°). At this stage two of the unaffected hips were considered to be definitely dysplastic. During the first five years after operation the mean AI of the unaffected hips remained a few degrees greater than normal (significant, p < 0.05, in only half the time intervals). After five years the mean AI of the unaffected and the normal hips became the same. At the end of the review none of the unaffected hips was dysplastic as assessed by the CEA.

Hip assessment. It had been hoped that the cartilage contour of the acetabulum, as demonstrated arthrographically, would be a prognostic indicator of the quality of acetabular development. In this series it proved to be of no value: there was no correlation between the cartilaginous AI and postoperative hip development.

In normal ten-year-old children the average CEA is about 30° and the average AI is about 10°. Using these figures in the equation which relates a small change in the AI to a small change in the CEA, it was found that a 2° change in AI was equivalent to a 5° change in CEA.

DISCUSSION

The study confirms that the acetabular shape improves after reduction of a dislocated hip (Fig. 1) and that if the hip is reduced between the age of one and two years, the AI will steadily improve for three years thereafter. At that stage, and in subsequent years, the average AI will be only slightly greater than normal. These findings are similar to but rather more precise than the conclusions of other workers. Schwartz (1965) suggested that maximum acetabular development occurred within two years of

Fig. 3
Serial radiographs (preoperative, three years later and at age ten years) of an affected hip which became nearly normal.
treatment and Harris (1976) proposed that development was greatest during the first four to five years, and continued until the age of eight years. Lindstrom et al (1979) suggested that the acetabular shape continued to improve for up to eight years. We found that most acetabular improvement occurred during the first three postoperative years. We cannot comment on the potential for a dysplastic acetabulum to develop normally if reduction is delayed beyond three years, because we treated such patients by primary acetabuloplasty and so they were excluded from our study.

The main conclusion that we draw is that the decision to carry out acetabular reconstruction should be delayed for three years after reduction because, during that time, there is potential for improvement in the acetabulum. Furthermore, at each interval before three years, some of the acetabula were dysplastic whereas at three years and after none was dysplastic (Fig. 2). Schwartz (1965) suggested that an AI greater than 25° two years after treatment indicated acetabuloplasty but we believe that two years is too soon to make the decision. We found that the majority of patients with an AI greater than 25° at that time ended up with satisfactory hips and never required acetabuloplasty (Fig. 2). Tönnis (1987) advised acetabuloplasty in all patients with definite acetabular dysplasia, that is, with an AI greater than two standard deviations above the normal. We agree with this advice provided that the decision is delayed until three years after reduction. If there is slight dysplasia, that is, between 1 and 2 standard deviations above the normal, surgery may be advisable if other risk factors are present such as a persistently widened medial joint space or eccentric acetabular sclerosis.

In the radiographs taken before reduction we found that the mean AI of the unaffected hips was greater than normal. This observation has been made previously (Weintroub et al 1979; Bolton-Maggs and Crabtree 1983). It is important therefore that the child's dislocated hip should be compared, not just with its fellow, but with an age-matched normal hip. Surprisingly, although we found that two of the opposite hips were dysplastic at presentation, none of them remained dysplastic at the end of the study.

At the end of the review, when the children were over the age of ten years, two of the affected hips were definitely dysplastic as judged by their CEA. A previous study from our unit has shown that these are still likely to be dysplastic at skeletal maturity (Sherlock, Gibson and Benson 1985). It is interesting to speculate why these hips ended up dysplastic. It may be that before reduction the cartilaginous precursor of the os acetabuli was damaged (Ponseti 1978) or that they were congenitally dysplastic, since the contralateral hips had CEAs lower than average. These hips did not have AIs appreciably higher than other affected hips at presentation at earlier stages in the study nor were they dysplastic, as judged by their AI, between three and nine years after reduction. It has to be accepted therefore that even after good reduction some hips thought to be developing normally will become dysplastic and that all patients treated for DDH should be followed radiographically at least until skeletal maturity.

We measured the AI until the age of ten years. It is a widely used and reliable measure of acetabular development in infants and young children (Tönnis 1987) and its normal range at various ages is known (Massie and Howarth 1950; Tönnis 1987). After the age of ten years we used the CEA, as it is simpler to measure and
more sensitive. At this age the site of the triradiate cartilage is poorly defined. Changes in acetabular quality cause larger changes in the CEA than in the AI. For example, at the age of ten years in grade I, II or III hips (Severin 1941) a 5° change in CEA is equivalent to a 2° change in AI (all the hips in this study were grade I to III at this age). There is some controversy in the literature as to what the normal range of the CEA is at the age of ten years. According to Severin (1941) hips with CEA less than 15° are dysplastic, but Massie and Howorth (1950) stated that the upper limit was 20° and Tönnis (1987) chose 25°. We used 15°, as hips with a CEA less than this would be considered to be dysplastic whichever criteria are used. Had we used 20° instead there would have been three rather than two affected hips which became dysplastic but our conclusions would have been the same.

Conclusions. After reduction of a dislocated or subluxated hip the decision whether or not to reconstruct the acetabulum should be delayed for three years. Despite good reduction and careful follow-up a few hips thought to be developing normally will become dysplastic.

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REFERENCES


