Shelf acetabuloplasty for children with Perthes’ disease and reducible subluxation of the hip

PROGNOSTIC FACTORS RELATED TO HIP REMODELLING

We evaluated radiological hip remodelling after shelf acetabuloplasty and sought to identify prognostic factors in 25 patients with a mean age of 8.9 years (7.0 to 12.3) who had unilateral Perthes’ disease with reducible subluxation of the hip in the fragmentation stage.

At a mean follow-up of 6.7 years (3.2 to 9.0), satisfactory remodelling was observed in 18 hips (72%). The type of labrum in hip abduction, as determined by intra-operative dynamic arthrography, was found to be a statistically significant prognostic factor (p = 0.012).

Shelf acetabuloplasty as containment surgery seems to be best indicated for hips in which there is not marked collapse of the epiphysis and in which the extruded epiphyseal segment slips easily underneath the labrum on abduction, without imposing undue pressure on the lateral edge of the acetabulum.

Shelf acetabuloplasty has been widely used to treat Perthes’ disease for two different surgical indications. When used as a salvage procedure, it provides relief from pain and better cover of the subluxed femoral head in patients with coxa magna, coxa irregularis or hinge abduction during the late stage of the disease.1,2 It has also been performed for containment of subluxed hips in older children, usually over seven years of age, during the fragmentation stage of the disease.3-6 For this latter indication, it is believed to be beneficial in remodelling the hip by preventing subluxation and stimulating lateral acetabular growth4 in hips with ‘reducible subluxation’, in which the femoral head is centred within the acetabulum in abduction without hinge abduction.3 However, to our knowledge, the factors which predict these beneficial effects of shelf acetabuloplasty have not been investigated.

We have assessed hip remodelling after shelf acetabuloplasty and sought to identify prognostic factors associated with the maintenance of reduction of the hip and the stimulation of acetabular growth, in the expectation that this would clarify the indications for this procedure.

Patients and Methods
The study had institutional review board approval. We reviewed the medical records and radiographs of 25 children (22 boys and three girls) with unilateral Perthes’ disease who had undergone shelf acetabuloplasty between 1999 and 2005. The indications for surgery were age seven years or older, ‘reducible subluxation’ of the hip during the fragmentation stage and abduction of the hip under anaesthesia of more than 45° without hinge abduction. Intra-operative dynamic arthrography was performed in all hips to exclude those with hinge abduction in which the centre of movement was located on the lateral edge of acetabulum and the labrum was deformed upwards in attempted abduction.

Before shelf acetabuloplasty was performed, 23 hips (92%) had been treated either by an abduction cast and soft-tissue release with a simultaneous adductor and psoas tenotomies in 12 and an adductor tenotomy performed in one and a psoas tenotomy in one. In four hips an abduction cast without soft-tissue release and in five skin traction were used. The mean age at surgery was 8.9 years (7.0 to 12.3) and at the final follow-up it was 15.6 years (10.2 to 19.6), giving a mean follow-up of 6.7 years (3.2 to 9.0). All the hips were in the fragmentation stage at the time of operation. Five were in the re-ossification stage and 20 in the residual stage at the final follow-up.

There were ten group-III hips and 15 group-IV hips according to the Catterall classification,7 six group B, ten group B/C border and nine group C according to the lateral pillar classification of Herring, Kim and Browne8 and 25 group B according to the classification of Salter and Thompson.9
eral short-leg casts with a connecting bar are applied for abduction to ensure that there is no impingement between wound, the hip is taken through a full range of flexion and to stabilise the inferior shelf graft. Before closure of the head of rectus femoris is reattached to the direct head to expanded iliac wall and the inferior bone plate. The oblique osteotome just above the capsular margin and the shelf graft), the acetabular depth growth ratio (growth of the true acetabular depth in the affected hip/growth of the acetabular depth in the contralateral normal hip) and the Sharp angle. Remodelling of the femoral head was evaluated using the diameter ratio of the femoral head (diameter of the affected hip/diameter of the contralateral normal hip) and the Stulberg classification. Changes in subluxation were evaluated using the centre-edge angle of Wiberg and the medial joint space ratios (medial joint space in the affected hip/medial joint space in the contralateral normal hip) (Fig. 1).

Satisfactory remodelling after acetabuloplasty was defined as an acetabular depth growth ratio of greater than 100%, an increase in the centre-edge angle and a decrease in the medial joint space ratio (Fig. 2). We investigated the relationship between satisfactory hip remodelling and the following pre-operative clinical and radiological variables, namely, the Catterall group, the lateral pillar group, the height ratio of the lateral pillar versus the contralateral epiphysis (height of lateral pillar/maximal height of the epiphysis on the contralateral normal side), the head sphericity index (distance between the flattened head and the best-fit circle centre of the femoral head/radius of the best-fit circle of the femoral head), the age at the onset of symptoms, the age at the time of operation, the Hilgenreiner-labral angle, the tear-drop thickness, the pre-operative medial joint space ratio and the centre-edge angle. The Hilgenreiner-labral angle was defined as the angle between the line parallel to the Hilgenreiner line and the line connecting the lateral acetabular margin and the labral tip on intra-operative dynamic arthrograms (Fig. 2b). It was measured with the hips in neutral and in abduction between 30° and 45°.

Statistical analysis. The Wilcoxon signed-rank test was performed to evaluate the significance of differences between radiological measurements at the time of operation and those at the final follow-up. The Mann-Whitney U, the chi-squared and the linear logistic regression tests were used to identify prognostic factors related to satisfactory hip remodelling. A p-value of < 0.05 was considered to be significant.

Results
Subluxation of the femoral head decreased significantly after shelf acetabuloplasty. The mean medial joint space ratio of the affected hips versus the contralateral normal hips decreased from 203% (61% to 417%) pre-operatively to 143% (39% to 213%) at the final follow-up (p = 0.00011). The mean centre-edge angle increased from 6.1° (-21° to +20°) pre-operatively to 14.3° (-5° to +28°) at the final follow-up (p = 0.00036). A significant increase in the centre-edge angle occurred despite a mean increase in the diameter ratio of the femoral head of affected hips versus that of the contralateral hips from 111% (96% to 132%) pre-operatively to 122% (104% to 141%) at the final follow-up (p = 0.00014). According to the Stulberg classification at the final follow-up one hip was in group 1, eight in group 2, 13 in group 3 and three in group 4. The
acetabulum also showed marked remodelling after shelf acetabuloplasty. The acetabular depth growth ratio of the affected hips versus the contralateral normal hips was a mean of 138% (58% to 237%). Growth of the lateral acetabular wall resulted in a progressive decrease in the lateral protrusion of the shelf graft and the shelf gap. The mean incorporation rate of the shelf graft into the lateral acetabular wall was 1.4 mm/year (0.2 to 3.9). Deepening of the acetabulum was calculated by subtracting the shelf-graft incorporation (lateral wall growth) value from the increase in acetabular depth. The mean acetabular deepening rate was 0.8 mm/year (0 to 3.5). The mean Sharp angle decreased from 49.1° (41° to 57°) pre-operatively to 45.2° (40° to 57°) at the final follow-up (p = 0.0001) and that of the contralateral hips from 46.4° (40° to 52°) to 41.0° (34° to 52°) (p = 0.000036). The ratio of the Sharp angle of the affected hips versus the contralateral normal hips did not change significantly after shelf acetabuloplasty (p = 0.052; Table I).

When we divided the patients into two groups based on satisfactory or unsatisfactory hip remodelling, satisfactory remodelling was found to have been achieved in 18 hips (72%). In this group, the acetabular depth growth ratio was a mean of 164% (111% to 237%), the mean centre-edge angle increased by 12° (5° to 34°) and the mean medial joint space ratio decreased by 81% (48% to 237%). In the unsatisfactory remodelling group the acetabular depth growth ratio was a mean of 73% (58% to 89%), the mean centre-edge angle increased -0.3° (-8° to +8°), and the decrease in the mean medial joint space ratio was 67% (17% to 98%).

Univariate analysis revealed that the height ratio of the lateral pillar versus the contralateral epiphysis and the Hilgenreiner-labral angle in hip abduction were statistically significant prognostic factors. The mean height ratio of the lateral pillar versus the contralateral epiphysis (SD) was 0.64 (SD 0.14) in hips with satisfactory remodelling, but 0.46 (SD 0.11) in hips with unsatisfactory remodelling (p = 0.0061). The mean Hilgenreiner-labral angle (SD) of
abducted hips with satisfactory hip remodelling was 47° (SD 11), but only 27° (SD 7) in abducted hips with unsatisfactory remodelling (p = 0.0022). For multivariate analysis, we divided the type of labrum into two groups based on the Hilgenreiner-labral angle as follows: ‘a comfortable’ labrum in which the Hilgenreiner-labral angle was > 35° and an ‘uncomfortable’ labrum in which it was ≤ 35°. Multivariate analysis using the linear logistic regression test showed that only the type of labrum in hip abduction correlated significantly with satisfactory hip remodelling (p = 0.012). Specifically, a comfortable labrum (Hilgenreiner-labral angle > 35°) at a hip abduction of between 30° and 45° was found to be correlated with satisfactory hip remodelling with increased acetabular depth growth and the prevention of hip subluxation (Fig. 2).

Discussion

Shelf acetabuloplasty is known to be effective for remodelling subluxed but reducible hips during the early stage of Perthes’ disease in older children, usually over seven years of age. In this group, femoral varus osteotomy carries the risk of limb shortening with coxa vara, and innominate pelvic osteotomy fails to reduce a subluxed femoral head. This surgical indication was described as ‘reducible subluxation’ by Daly et al. They confirmed the reduction of the femoral head by dynamic arthrography and stated that shelf acetabuloplasty was contraindicated in unstable hips with hinge abduction. Domzalski et al also performed intra-operative dynamic arthrography to exclude non-reducible hips in which the epiphysis could not be contained in the acetabulum and the labrum tip moved upwards on attempted abduction. Bursal and Erkula used MRI and physical examination to exclude hips with hinge abduction. We also excluded hips with hinge abduction using intra-operative dynamic arthrography, and our typical indication for shelf acetabuloplasty was hips with ‘impending impingement’, in which the subluxed femoral head could be reduced followed by abduction casting with or without soft-tissue release (18 hips) or traction (5 hips).

Our findings are consistent with those reported by Daly et al in terms of the surgical indications, the age at surgery and favourable results. These authors left the question as to why some patients did badly unanswered. Our study advances their findings by identifying the variables associated with lateral acetabular growth stimulation after shelf acetabuloplasty. These relate to the type of labrum in hip abduction. In hips with reducible subluxation, a ‘comfortable’ labrum in hip abduction implies that the lateral part of cartilaginous femoral head is relatively round and does not impose pressure on the lateral edge of the acetabulum, as long as reduction of the femoral head is maintained by the surgery. On the other hand, an ‘uncomfortable’ labrum in hip abduction may be a manifestation of compression of the lateral acetabular edge by a flattened and hypertrophied lateral part of the cartilaginous femoral head. In these hips, the femoral head may be containable within the acetabulum only in extreme abduction without frank hinge abduction under anaesthesia.

In growing children, acetabular depth increases as a result of growth at the periphery of the acetabular cartilage and the periosseous formation of new bone at the lateral pelvic wall, whereas the acetabular height and width increase because of growth of the triradiate cartilage. Our observation that the growth of acetabular depth of hips with an ‘uncomfortable’ labrum is only 73% of that of the contralateral normal side suggests that femoral heads in these hips may sublux again from the true acetabulum after surgery, despite intra-operative reduction, and that subsequent pressure on the acetabular periphery may lead to the inhibition of growth of the acetabular cartilage and its growth plate. Based on our observations, shelf acetabuloplasty appears to be inadequate in terms of stimulating lateral acetabular growth in hips with an ‘uncomfortable’ labrum. In this situation, a redirectional osteotomy which enables the lateral acetabular margin, including the labrum, to rotate to achieve containment of the femoral head may be more beneficial for hip remodelling and, furthermore, it may also substantially reduce the risk of labral tear.

Our operative technique has some advantages compared with those previously described. First, immediate stability of the shelf graft can be expected, because it is supported firmly by the expanded lateral acetabular wall under which cancellous bone and calcium sulphate tablets are packed tightly. In addition, the abductor muscles are not damaged during the operation, because graft is harvested from the inner wall of the ilium. Therefore, post-operative immobilisation is limited to the use of bilateral short-leg casts with a connecting bar for three to six weeks, allowing patients to sit comfortably. In previous studies hip spica casts have been used for longer periods of time.

The limitations of our study require consideration. First, it is a cohort study without a control group. However, in subluxed Perthes’ hips with impending impingement in older children, it is, in our experience difficult to maintain...
the reduced position after abduction casting, soft-tissue release or skin traction without a subsequent containment bony procedure. This is why we could not set up a control group in our study. Secondly, the number of patients recruited was not large enough to achieve strong statistical power, and thus a larger study may reveal that prognostic factors found to be insignificant in our study are in fact relevant. For example, the height ratio of the lateral pillar versus the contralateral epiphysis was found to be a statistically significant prognostic factor by univariate analysis, but this significance was lost during the multivariate analysis. It may be proved to be significant in a larger study. Thirdly, the radiological indices of hip remodelling, including the acetabular depth ratio, were measured using antero-posterior plain radiographs. Although we assumed that the increase in the acetabular depth may reflect lateral acetabular growth stimulation, two-dimensional assessment is inadequate to determine the real configuration of the remodelled acetabulum. In future, it may be possible to elucidate the mechanism of lateral acetabular growth stimulation after a labral support procedure by advanced three-dimensional MRI techniques which can detect macro-molecular changes during cartilage growth or degeneration.

In summary, shelf acetabuloplasty for hips with reducible subluxation was found to produce favourable hip remodelling in older children with early Perthes’ disease. In addition, we were able to identify a prognostic factor associated with increased acetabular wall growth and the prevention of hip subluxation. Shelf acetabuloplasty as a containment procedure seems to be best indicated for subluxed hips in which epiphyseal collapse is not advanced and the extruded epiphyseal segment can slip easily underneath the labrum on attempted abduction without imposing undue pressure on the lateral edge of the acetabulum.

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References