Glenoplasty for complex shoulder subluxation and dislocation in children with obstetric brachial plexus palsy

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We describe the early results of glenoplasty as part of the technique of operative reduction of posterior dislocation of the shoulder in 29 children with obstetric brachial plexus palsy. The mean age at operation was five years (1 to 18) and they were followed up for a mean of 34 months (12 to 67).

The mean Mallet score increased from 8 (5 to 13) to 12 (8 to 15) at final follow-up (p < 0.001). The mean passive forward flexion was increased by 18° (p = 0.017) and the mean passive abduction by 24° (p = 0.001). The mean passive lateral rotation also increased by 54° (p < 0.001), but passive medial rotation was reduced by a mean of only 7°. One patient required two further operations. Glenohumeral stability was achieved in all cases.

In obstetric brachial plexus palsy (OBPP), deformity and disordered development of the shoulder are well recognised,1,4 whereas posterior dislocation of the shoulder is rare5 and often undiagnosed.6,7

The aetiology of posterior dislocation in OBPP is unclear and may include malpositioning during fetal development, birth trauma and a dynamic imbalance of musculature around the shoulder as a result of denervation then reinnervation of the upper trunk of the plexus.7 We also believe that an ischaemic event or vascular anomaly in utero or at birth may lead to reduced growth of the clavicle and fibrosis of local musculature.8

The three steps in the progression of the deformity are internal rotation contracture, posterior subluxation and posterior dislocation.3 Incomplete recovery of the upper trunk causes muscle imbalance with strong internal rotators and weak external rotators leading to an internal rotation contracture. This is detrimental to glenohumeral development,7,9,10 during which it has been noted that there is an alteration in the relationship between the coracoid and glenoid physis leading to retroversion of both in OBPP.11 Also, there is a spectrum of glenoid dysplasia ranging from flattening of its posterior aspect, through biconcavity to the most severe deformity, the so-called pseudoglenoid, in which the humeral head articulates with a distinct, retroverted, posterior articular surface.1,3

In subluxation of the shoulder, the glenoid usually forms a double facet (Fig. 1), with the true glenoid lying above and anterior to the pseudoglenoid. Both are lined with hyaline cartilage and are separated by a ridge. In a true dislocation, the head lies within a distended posterior capsule and articulates with the neck or blade of the scapula. Within the spectrum of glenoid dysplasia it can be difficult to categorise the range of deformities. The terms ‘simple’ and ‘complex’ attempt to describe the secondary change in the growing shoulder after dislocation. The term ‘complex’ suggests the presence of glenoid dysplasia, an elongated coracoid, overgrowth of the acromion and flattening of the head.3

We have earlier reported our experience of complex subluxations and dislocations.3 We were disappointed with the high rate of failure and felt that in these cases the glenoid dysplasia was not fully addressed. We now describe the outcome of the first series of patients treated by a new technique, namely glenoplasty, for the correction of complex shoulder dislocations with glenoid dysplasia, in which anterior release alone was not sufficient.

Patients and Methods

Between 2003 and 2009, 241 patients with OBPP underwent surgery at our institution to obtain and maintain a congruent reduction of their shoulder. Of these, 32 had glenoplasty.

Three patients were excluded because the period of follow-up was less than 12 months. Of the remaining 29, there were 12 girls and 17 boys with 14 right and 15 left shoulders affected and a mean age at the initial consultation of 2.5 years (3 weeks to 14 years).
Following subluxation the upper limb lies in internal rotation with the forearm pronated. The shoulders are asymmetrical with the head of the humerus prominent behind the glenoid. With a frank dislocation, there may be an apparent discrepancy in humeral length and asymmetry in the axillary creases. There is limited active and passive movement of the shoulder, particularly external rotation. Ultrasound was used in an attempt to understand the anatomy further, but was found to be of limited use because of its relative insensitivity as a test for congruency.\(^{16}\) Plain radiography of the shoulder in the anteroposterior and axial planes was also used in children older than 18 months, and CT in older patients with severe deformity to assess the degree of dysplasia.

Of the 29 patients, nine had previous shoulder surgery, involving anterior release and lengthening of subscapularis. In addition, six had a coracoidectomy, one an internal rotational osteotomy of the humerus and one a posterior bone block. The mean age at glenoplasty was 5 years (1 to 18). **Operative technique.** The surgical management of the incongruent shoulder involves four defined steps. These are followed for every shoulder and the more complex the deformity is, the more steps are needed. For example, not every shoulder needs an internal rotational osteotomy or glenoplasty, but the same steps are followed before carrying out these procedures. At the end of each step the passive external rotation and the position of the head of the humerus are re-evaluated.

**Step 1.** Under general anaesthetic and with the child supine the passive external rotation and position of the head of the humerus are checked. A deltopectoral approach is used to expose the coracoid process. The cephalic vein is preserved and mobilised medially. The coracohumeral and coracoacromial ligaments are divided after elevating the conjoint tendon and the tendon of pectoralis minor subperiosteally through a longitudinal incision over the tip of the coracoid, for later repair. The elongated and dorsally inclined coracoid often presents a mechanical obstruction to the humeral head. For this reason the coracoid is osteotomised at its base, and entirely excised after which passive external rotation is re-evaluated. The rotator interval is then defined and through it, the shoulder joint inspected and subluxation or dislocation confirmed.

**Step 2.** The tendon of subscapularis is released. Release of the upper fibres will sometimes be sufficient to gain congruent reduction of the humeral head and correct the internal rotation contracture. However, a Z-lengthening of this tendon is often necessary, while preserving the shoulder capsule, or at least part of it.

**Step 3.** Excessive retroversion of the humeral head may be present. This can be assessed with reference to the epicondylar axis which can be evaluated easily by flexing the elbow. The retroversion is corrected by extending the deltopectoral approach into the proximal third of the arm and performing an internal rotation osteotomy below the centre of ossification, after which glenohumeral articulation is re-assessed.

Each patient was rated according to the classification of Narakas and Bonnard.\(^{12}\) In group I there were two patients in whom the fifth and sixth cervical nerves were damaged and there was paralysis of deltoid and the biceps. In group II there were 16 patients in whom the fifth, sixth and seventh nerves were damaged and there was paralysis of the elbow, wrist and finger extension. Group III comprised nine patients with virtually complete paralysis of the arm, although there was some flexion of the fingers shortly after birth. In group IV, in which there were two patients, the whole plexus was involved; paralysis was complete and there was a Horner’s syndrome.

A dislocation of the shoulder was diagnosed at the initial consultation in six patients, all of whom presented after the age of four years (4 to 14). In the remaining 23 patients the dislocation occurred in the time between consultations. The mean age at diagnosis of dislocation was five years (1 to 18). In all cases surgery was undertaken within four weeks of diagnosis.

At the initial presentation, each child was assessed clinically and an attempt made to classify their deformity.\(^ {13,14}\) The active and passive ranges of movement were recorded. Measurements were made in forward flexion, abduction, internal rotation with the arm abducted to 90° and external rotation with the arm in neutral abduction and abducted to 90°. The methods for the assessment of function are described elsewhere.\(^ {13,14}\) A modified Mallet scoring system was also used to assess the progress at each visit.\(^ {15}\) This system awards points for five functions of the shoulder. A score of 15 implies good function and a score of five indicates poor function.

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**Fig. 1**
Axial CT scan through the glenohumeral joint showing a biconcave glenoid. Glenoid retroversion can be assessed by measuring the angle subtended by the intersection of the axis of the scapular blade and that of the glenoid joint surface.
Step 4. A glenoplasty is performed if the glenoid is very dysplastic and retroverted (Figs 1 and 2). The assessment for this is largely made at operation, but sometimes glenoid dysplasia is evident from pre-operative CT, especially in older patients. At operation the relationship of the humeral head to the glenoid can be fully appreciated only after steps 1 to 3 have been performed. The articulation of the humeral head and its dynamic relationship to the glenoid during rotation under direct vision are the most sensitive markers of glenoid dysplasia. If the glenoid is considerably retroverted or dysplastic, the wound is closed and the patient turned to the prone position. The inferior margin of deltoid is reflected superiorly and the shoulder capsule and scapula are exposed between infraspinatus and teres minor. The glenohumeral articulation is evaluated through a radial capsulotomy just beyond the glenoid labrum and a biconcave or false glenoid may be seen. An osteotomy is performed with curved osteotomes, parallel to the articular surface. Drill holes are made through the posterior cortex of the neck of the glenoid and connected with osteotomes. The posterior glenoid margin is elevated and the articular surface moulded to the humeral head. The osteotomy is kept in position by impacting corticocancellous graft from the coracoid and correction of glenoid retroversion by glenoplasty. A cortical ring graft can be taken from the spine of the scapula or iliac crest. In one a cortical ring graft was taken from the humerus during rotational osteotomy and in another synthetic hydroxyapatite wedges were used. Four patients had a considerably retroverted proximal humerus and underwent internal rotational osteotomy as well as glenoplasty.

At operation, 18 patients had a flattened retroverted glenoid, six a biconcave glenoid and five a retroverted glenoid with a pseudoglenoid. There was no correlation with the type of glenoid dysplasia, age, Narakas grade or presentation.

A total of 17 patients required a buttress plate to augment the osteotomy. In the remaining 12, the construct was considered to be stable after impaction of the bone graft. The mean operating time was 189 minutes (105 to 330). The patients who required internal rotational osteotomy of the humerus and glenoplasty had the longest times.

The mean follow-up was 34 months (12 to 67). The mean Mallet score increased from eight (5 to 13) pre-operatively to 12 (8 to 15) at the last follow-up (Wilcoxon signed-rank test, p = 0.0001, Table I). The mean passive forward flexion increased from 143° (30° to 180°) pre-operatively to 161° (90° to 180°, Student’s t-test p = 0.017). The mean passive abduction increased from 132° (30° to 180°) to 156° (70° to 180°) (Student’s t-test, p = 0.001, Table II). The mean passive external rotation increased from -1° (-45° to +60°) to 53° (0° to 100°) (Student’s t-test, p < 0.0001).

The mean passive internal rotation was 90° (90° to 100°) pre-operatively and 83° (0° to 90°) at final follow-up. This reduction was not significant (Student’s t-test, p = 0.06). There was a reduction in active and passive internal rotation in nine of the 29 patients post-operatively with a mean reduction of 24° (0° to -90°). One patient lost 90° of active and passive internal rotation and will be discussed later.
There was a significant increase in the mean active forward flexion by $25^\circ$ (-10° to +90°) (Student’s t-test, $p < 0.0001$) and in the mean abduction by $31^\circ$ (-30° to 140°) (Student’s t-test, $p = 0.005$).

No patient had a recurrent dislocation. There were no peri-operative infections and all patients tolerated the surgery and immobilisation well. One patient (case 6) fell one year after operation and sustained a fracture beneath the plate used to augment the osteotomy. She developed palsy of the radial nerve after the fracture which required physiotherapy, and have the most severe muscle imbalance because of incomplete recovery of the upper trunk.

Another patient (case 27) developed a considerable limitation in internal rotation. It was thought that the 2.7 mm plate used to augment the osteotomy might be creating a mechanical block and it was removed at two years post-operatively. This did not improve matters and therefore she underwent an open posterior capsular release four years post-operatively.

### Discussion

Glenoplasty was first reported by Scott in 1967\(^1\) for the treatment of recurrent post-traumatic posterior instability in adults. He described the technique as an alternative to the established posterior bone-block method\(^1\) in which there was difficulty in fixing the block on to the neck of the glenoid. The concept was to create a buttress at the posterior glenoid margin, similar to the acetabuloplasty in developing unstable hips, as described by Gill.\(^1\)

In our initial experience with posteriorly dislocated shoulders in patients with OBPP, we found that 25% of such patients developed posterior subluxation or dislocation even after neurological recovery.\(^3\) Secondary bone deformities become significant with a postural deformity of the resting scapula in the transverse plane because of weakness of serratus anterior, overgrowth of the outer clavicle and acromion due to traction of the deltoid and overgrowth of the coracoid secondary to traction from its attached muscles after paralysis of the supporting structures of the humerus.\(^3\) The nature of the deformity of the glenoid may determine its evolution.\(^7,20\)

A surprisingly high number of patients in our series developed subluxation or dislocation during outpatient review. This may well reflect the aetiology of the deformity. It is likely that these patients with an internal rotation contracture develop progressive subluxation or dislocation despite physiotherapy, and have the most severe muscle imbalance because of incomplete recovery of the upper trunk.

The diagnosis of glenohumeral incongruity is mainly clinical. Difficulty in imaging has been a confounding factor in appreciating deformity and retroversion of the glenoid in the skeletally immature patient. Plain radiography is of some use after the age of 18 months, before which the ossific nucleus of the humeral head is usually small enough to enable the glenohumeral joint to be imaged by ultrasound by an experienced radiologist.\(^2,16\) It was noted, however, by Saifuddin et al\(^16\) that ultrasound did not have high sensitivity for detecting an incongruent joint. They found that the clinical impression had a greater sensitivity. Pearl and Edgerton\(^1\) used axial arthrography to assess glenohumeral morphology. This technique, like ultrasound, has the advantage of offering dynamic assessment of the shoulder, but it requires general anaesthesia and is invasive. CT allows good assessment of glenoid version and dysplasia but also requires general anaesthesia in young patients and carries a relatively high exposure to ionising radiation. MRI also requires general anaesthesia.

CT studies have shown that there is retroversion of the glenoid in posteriorly subluxated or dislocated shoulders in patients with OBPP.\(^2,21\) Waters et al\(^7\) found progressive deformity of the glenoid with increasing age. The mean retroversion on the affected side was 25.7°, compared with 5.5° on the normal side. Sibinski et al\(^22\) also showed that

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### Table I. The mean pre-operative and final follow-up Mallet scores, with the incidence of complications by Narakas group\(^12\) in the 29 patients

<table>
<thead>
<tr>
<th>Narakas group</th>
<th>Cases</th>
<th>Complications</th>
<th>Mallet score</th>
<th>Pre-operative (range)</th>
<th>Final (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2</td>
<td>0</td>
<td>9 (6 to 12)</td>
<td>13 (11 to 15)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>16</td>
<td>0</td>
<td>9 (5 to 13)</td>
<td>12 (10 to 15)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>9</td>
<td>0</td>
<td>8 (5 to 10)</td>
<td>12 (8 to 15)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>2</td>
<td>2</td>
<td>7 (6 to 7)</td>
<td>10 (8 to 12)</td>
<td></td>
</tr>
</tbody>
</table>

### Table II. The mean pre-operative and final passive range of movement by Narakas group\(^12\) in the 29 patients (range)

<table>
<thead>
<tr>
<th>Narakas group</th>
<th>Cases</th>
<th>Passive forward flexion (°)</th>
<th>Passive lateral rotation (°)</th>
<th>Passive abduction (°)</th>
<th>Passive medial rotation (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2</td>
<td>150 (120 to 180)</td>
<td>15 (0 to 60)</td>
<td>65 (40 to 90)</td>
<td>145 (110 to 180)</td>
</tr>
<tr>
<td>II</td>
<td>16</td>
<td>159 (90 to 180)</td>
<td>170 (120 to 180)</td>
<td>144 (10 to 90)</td>
<td>166 (110 to 180)</td>
</tr>
<tr>
<td>III</td>
<td>9</td>
<td>114 (30 to 180)</td>
<td>145 (90 to 180)</td>
<td>109 (30 to 170)</td>
<td>142 (70 to 180)</td>
</tr>
<tr>
<td>IV</td>
<td>2</td>
<td>135 (110 to 160)</td>
<td>145 (130 to 160)</td>
<td>135 (110 to 160)</td>
<td>145 (120 to 170)</td>
</tr>
</tbody>
</table>

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shoulder function was directly related to the degree of glenoid dysplasia and congruency. Hui and Torode suggested that glenoid dysplasia improves with time after satisfactory open reduction. This may be due to the re-establishment of more normal joint mechanics but is limited by the age of the patient and the ability to remodel. In their study the mean age of the patients was two years and five months at operation. Older children may not have the capacity to correct retroversion without surgery. It also does not resolve the issue of containment of an unstable humeral head by a retroverted glenoid.

Based on the current literature, muscle or tendon transfer with or without release of subscapularis and open reduction, is successful in younger patients with a normal or mildly deformed glenohumeral joint. Patients with complex subluxation or dislocation of the shoulder remain untreatable by soft-tissue procedures alone. The complex associated bony abnormality, notably coracoid overgrowth and glenoid dysplasia and retroversion, are not addressed.

Before we used glenoplasty for a complex shoulder dislocation we placed a posterior bone block and augmented lateral rotation by muscle transfer. This technique unfortunately had a high rate of failure (30%) since it did not address the glenoid version.

In some patients the limitation of internal rotation post-operatively, although not statistically significant, is of concern. This occurred in nine patients, in six of whom a plate operatively, although not statistically significant, is of concern. It was noted post-operatively that not only did passive movement improve, reflecting articular congruency, but also active movement. This is likely because of the re-establishment of a more effective and stable lever arm for the forces acting across the shoulder. Although not the primary objective of the procedure, which was to establish articular congruency to aid normal development of the shoulder, it is nevertheless advantageous.

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It should be noted that the scapula is ossified from seven or more centres: one for the body, two for the coracoid process, two for the acromion, one for the vertebral border and one for the inferior angle. Much of the ossification is intramembranous. The upper third of the glenoid cavity is ossified from a separate subcoracoid centre, which appears between the tenth and 11th years and unites between the 16th and the 18th years. Also, an epiphysial plate appears for the lower part of the glenoid cavity, while the tip of the coracoid process often has a separate centre. These various epiphyses are joined to the scapula by the 25th year. In the same way as development of the hip is reliant on a congruent femoral head within the acetabulum, the humeral head and glenoid also rely on a congruent reduction. Osteotomy to achieve this would appear to be beneficial and there is no evidence to suggest that it will have a negative effect on future development.

Although our follow-up is limited, we have shown that this new technique in the treatment of complex shoulder dislocations in patients with OBPP is effective and safe. The main objectives of establishing congruency and stability of the glenohumeral joint can be achieved and the absence of recurrent instability, compared with a previous failure rate of 25%, is encouraging.

**Supplementary material**

A table showing the clinical details and relevant findings at glenoplasty in the 29 patients is available with the electronic version of this article on our website at www.jbjs.org.uk

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**References**


