Improvement in abduction of the shoulder after reconstructive soft-tissue procedures in obstetric brachial plexus palsy

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Residual muscle weakness in obstetric brachial plexus palsy results in soft-tissue contractures which limit the functional range of movement and lead to progressive glenoid dysplasia and joint instability. We describe the results of surgical treatment in 98 patients (mean age 2.5 years, 0.5 to 9.0) for the correction of active abduction of the shoulder. The patients underwent transfer of the latissimus dorsi and teres major muscles, release of contractures of subscapularis pectoralis major and minor, and axillary nerve decompression and neurolysis (the modified Quad procedure). The transferred muscles were sutured to the teres minor muscle, not to a point of bony insertion. The mean pre-operative active abduction was 45˚ (20˚ to 90˚). At a mean follow-up of 4.8 years (2.0 to 8.7), the mean active abduction was 162˚ (100˚ to 180˚) while 77 (78.6%) of the patients had active abduction of 160˚ or more. No decline in abduction was noted among the 29 patients (29.6%) followed up for six years or more. This procedure involving release of the contracted internal rotators of the shoulder combined with decompression and neurolysis of the axillary nerve greatly improves active abduction in young patients with muscle imbalance secondary to obstetric brachial plexus palsy.

The incidence of obstetric brachial plexus injury in the USA is between 0.38 and 1.56 per 1000 live births.1 Perinatal risk factors include infants of increased weight-for-gestational-age, previous deliveries resulting in brachial plexus injuries, multiparous pregnancies, prolonged labour and breech, assisted or difficult deliveries. The upper trunk (C5-C6) is involved most commonly with or without injury to the C7 root. Less often, the entire plexus, including T1, may be involved. The lesion may be a simple stretch injury or varying degrees of rupture and avulsion may be present. The most common form is Erb’s palsy, characterised by lesions of C5-C6 in which there is absence of abduction and external rotation of the shoulder, flexion of the elbow and supination of the forearm in the presence of a relatively intact triceps and function of the forearm and hand.

In obstetric brachial plexus injury, useful function of the affected muscles will return in most cases. For those patients in whom recovery of antigravity function of the biceps and deltoid do not recover by the age of three months, evaluation for operation by neurolysis or nerve reconstruction may be recommended.2-4 Some consider this approach to be overly aggressive, considering that operation should be delayed until the age of nine months if flexion of the elbow is impaired in lesions of the upper trunk.5 Full recovery of strength can be expected by those who have recovered biceps function by the third month,2 but only the infants who recover antigravity biceps strength in the first four to six weeks of life will have no asymmetry of their shoulder girdle in the long-term.6 Recent evidence supports the conservative management of apparent muscle imbalances, using botulinum toxin to treat biceps/triceps co-contraction.7,8

Children with even a mild neurological deficit at the age of three months have a higher risk of long-term dysfunction of the upper limb.6 The most important secondary deformities associated with injury to the upper plexus are related to the resultant weakness of the deltoid and external rotators of the shoulder. This causes apparent shortening of the humeral segment of the arm with deeper anterior and posterior axillary folds associated with adduction of the shoulder and internal rotation of the arm.9 Severe deformity of the joint with posterior subluxation is sometimes associated with less severe neurological injury due to greater muscle imbalance.10,11 The amount of contracture is very variable and not necessarily correlated with the neurological injury or with the extent of recovery.12
tional limitations, posterior dislocation of the glenohumeral joint with the impairment of bone growth and development of the joint can occur.\textsuperscript{13}

Many soft-tissue and bony procedures have been described in attempts to treat these secondary deformities. Those most widely used involving soft tissue are adaptations of Sever\textsuperscript{14}'s original release of pectoralis major and subscapularis. The first latissimus dorsi transfer carried out by Schulze-Berge\textsuperscript{13} did not have a satisfactory outcome. L'Episcopo\textsuperscript{16} advocated transfer of the insertion of teres major first and of latissimus dorsi later from the anteromedial to the posterolateral aspect of the humerus, suturing the tendons in their new position under an osteoperiosteal flap. Zachary and Leeds\textsuperscript{17} fixed the tendons of the latissimus dorsi more laterally in order to achieve more external rotation. Phipps and Hoffer\textsuperscript{18} introduced a modification whereby the contracted internal rotators, the pectoralis major, teres major, and latissimus dorsi are released and attached to the part of the rotator cuff where the infraspinatus normally inserts. Improvement is seen in these patients.\textsuperscript{19,21}

More recently, various degrees of success have been obtained with variations in the timing of the muscle release in relation to the transfer and location of insertion of the transfer.\textsuperscript{22-24} Compression neuropathy of the axillary nerve has recently been shown to be a complementary factor leading to persistent muscle weakness. Decompression and neurolysis of the infraclavicular part of the brachial plexus, including the axillary and musculocutaneous nerves, have proved helpful.\textsuperscript{25}

We began to implement a further modification of these procedures in 1996. We believed that release of soft-tissue contractures which limited abduction and neurolysis and decompression of the axillary nerve would improve function in patients with partial recovery from brachial plexus injuries. The primary modification of the previous operations was to untether the contractures of the latissimus dorsi, teres major, subscapularis and pectoralis muscles and to transfer the latissimus dorsi and teres major to a low position in the teres minor muscle, so as not to recreate the initial tethering forces responsible for the loss of abduction in the first place. For the procedure to succeed, anti-gravity recovery of the deltoid must be present although masked by contractures of pro-gravity muscles in the axilla and chest. The procedure, termed modified Quad, is based on the following steps:

1) Transfer of the latissimus dorsi muscle to give external rotation and abduction;
2) Transfer of the teres major muscle to stabilise the scapula;
3) Release of the subscapularis, pectoralis major and minor contractures;
4) Decompression and neurolysis of the axillary nerve.

We have assessed retrospectively the long-term effects of restoration of shoulder abduction by this method.

 Patients and Methods

Patients. There were 98 patients (39 male, 59 female) with obstetric brachial plexus palsy which had not resolved by the age of six months. Of these, 54 had C5-C6 injury, 32 a C5-C7 injury, three a C5-C8 injury, six a C5-T1 injury and three a C5-T1 injury with a positive Horner's sign. Primary operations on nerves had been performed on 13 of the children with a C5-C6 injury, 15 of the children with a C5-C7 injury, one with a C5-C8 injury, three with a C5-T1 injury and one with a C5-T1 injury with a positive Horner's sign. The series consists of consecutive patients for whom complete medical records were available. No cases with adequate follow-up were excluded. The patients were operated upon between 1997 and 2004. The mean age of the children at the time of operation was 2.5 years (0.5 to 9.0). However, all but seven were younger than five years (case 3 was seven years old at the time of surgery). The degree of shoulder abduction was measured in the sitting position for patients unable to stand.

All the patients showed significant adduction deformity with easily palpable contractures of the latissimus dorsi, the teres major and the pectoralis major muscles. Although many patients exhibited significant bony abnormalities such as elevation of the scapula and subluxation of the head of the humerus, these were not a contraindication to operation, since it was felt that they were related more to the internal rotation deformity and were not a cause of loss of abduction. Each patient also had clinical evidence of the ability to rotate the humerus by activity of the deltoid, although this was limited. Patients whose shoulder elevation consisted of shrugging movements without rotation, and who did not have palpable contractures in pro-gravity muscles, were not considered for operation.

Technique of the operation. Under general anaesthesia, an axial incision was made over the lateral margin of the scapula extending from the intersection of the arm and the chest to the junction of the middle and lower thirds of its border. The latissimus dorsi muscle was identified. Dissection proceeded medially across the latissimus dorsi into the subscapularis fossa. The subscapularis muscle was lengthened in a medial to lateral direction using electrocautery and dissection continued down to the periosteum of the medial surface of the scapula (Fig. 1).

Dissection then proceeded superiorly along the latissimus dorsi tendon. At the superior extent of the dissection, the tendon was retracted laterally, exposing the underlying tendon of the triceps. The tendon of latissimus dorsi was then detached from its insertion and the tendon of teres major released. Both tendons were now dissected towards the inferior part of the scapula exposing the tendon of triceps as well as its superomedial border. At the superomedial border of the origin of triceps, the axillary nerve was routinely noted to be compressed by a combination of inferior subluxation of the head of the humerus and the dense fascia of the triceps in the quadrangular space. The triceps fascia

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was released, decompressing the axillary nerve (Fig. 1c). A full external neurolysis was performed to remove epineurial scar. Direct electrical stimulation of the axillary nerve confirmed active movement of the deltoid muscle.

At this point, another incision was made in the anterior axillary fold, and the tendon of pectoralis major identified. This was divided by electrocautery. Sufficient lengthening was performed to allow free movement of the arm passively in external rotation. The underlying tendon of pectoralis minor was released under direct vision. Release of the anterior glenohumeral joint capsule was carried out through this incision, to allow improved anterior movement of the head of the humerus.

Teres minor was then mobilised and the arm placed in full abduction and external rotation. An incision was made into the teres minor and the tendons of latissimus dorsi and teres major were individually sutured into this (Fig. 1d). The wound was closed in two layers in absorbable suture over a drain.

The arm was immobilised in an abduction splint for four weeks after which the child was placed in the splint at night only for a further six weeks. Full shoulder
movement was permitted after the initial four-week postoperative period. Rapid improvement in shoulder abduction was noted in all patients. Physiotherapy was prescribed three times a week for at least three months, and swimming was encouraged.

Analysis of outcomes. All children had a comprehensive neurological examination performed by the same brachial plexus specialist prior to surgery and at the latest follow-up visit. Measurements of abduction for the purposes of this study were made by the patient’s local therapist, experienced in managing these patients and independently of the operating surgeon (RKN). These values were confirmed by measurements taken from video recordings.

Results
The mean follow-up was 4.8 years (2.0 to 8.7). All the children had increased active abduction and greater movement of the shoulder. The mean active abduction was 45° (20° to 90°) before and 162° (100° to 180°) after operation (Fig. 2). The increased range of movement allowed the children to...
touch the top of the head, to position the forearm on a tabletop with ease and to place the hand around an object without twisting the trunk. There was no correlation between the range of abduction which was achieved and the age at the time of surgery (r = 0.008), and there was no significant correlation between pre- and post-operative abduction (r = 0.23). The 29 children (29.6%) who were followed up for at least six years had a mean abduction of 158° ± 19°, indicating that the results were stable. No significant difference was found in post-operative abduction between patients who had undergone primary nerve surgery and those who had not (p > 0.05). The power of the deltoid at latest follow-up was recorded according to the modified MRC scale (Table I).

**Table I. Modified Medical Research Council (MRC) grades**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No movement</td>
</tr>
<tr>
<td>1</td>
<td>Muscle contraction without active movement</td>
</tr>
<tr>
<td>2</td>
<td>Active movement</td>
</tr>
<tr>
<td>3</td>
<td>Movement with gravity removed</td>
</tr>
<tr>
<td>3+</td>
<td>Active movement</td>
</tr>
<tr>
<td>4</td>
<td>Anti gravity</td>
</tr>
<tr>
<td>4-</td>
<td>Active movement</td>
</tr>
<tr>
<td>4+</td>
<td>Minimal resistance</td>
</tr>
<tr>
<td>5</td>
<td>Active movement</td>
</tr>
<tr>
<td>5</td>
<td>Weak but with increased resistance</td>
</tr>
<tr>
<td>4+</td>
<td>Overcome with resistance</td>
</tr>
<tr>
<td>5</td>
<td>Slight weakness</td>
</tr>
<tr>
<td>5</td>
<td>Differing from contralateral</td>
</tr>
<tr>
<td>5</td>
<td>Normal function</td>
</tr>
</tbody>
</table>

**Discussion**

These patients had suffered a brachial plexus injury at birth. Although their overall passive range of movement of the shoulder was initially good, progressive muscle imbalance developed within the first year of life. This was due to weakness of the deltoid, infraspinatus, supraspinatus and teres minor in combination with the strength of the relatively spared large internal rotator and adductor muscles, resulting in loss of abduction and external rotation. This muscle imbalance resulted in tethery in anti-gravity abduction of the arm by the much stronger pro-gravity adductor muscles, which eventually developed contractures. This caused a typical movement pattern of inhibited active abduction and compensation by truncal bending (Fig. 2). These imbalances and contractures led to glenohumeral subluxation and an elevated hypoplastic scapula, with fixed internal rotation of the humerus.

All children had the procedures described, with the aim of improving overhead function. The transfer of latissimus dorsi and teres major to teres minor enhances the stabilising effect of the rotator cuff, enabling the deltoid to act more effectively. Although there was no gain in active supination of the forearm, there was impressive improvement in active abduction of the shoulder. While external rotation and supination often improved, we did not include these results in our study, as we consider these to relate to bony deformities and to require appropriate surgery for correction whilst simultaneously maximising gains in abduction. External rotation has been improved by placing the tendon transfers higher in the shoulder and more laterally than ours (Table II). Although the shoulder gains external rotation, it appears to lose the maximum achievable abduction and flexion.

In addition to the effect on function, rebalancing tendon transfers delay, but do not reverse, progressive retroversion of the glenoid and instability of the glenohumeral joint.21 Posterior subluxation of the shoulder can have an early onset.27 Therefore, we do not advocate delaying the transfer of muscles as advised by Hoffer and Phipps26 and Pearl et al,27 who recommend waiting until the child is three or four years of age when no further spontaneous recovery is expected.

Secondary compression of the axillary nerve in the quadrangular space has been demonstrated to be a separate and common reason for impairment in children with brachial plexus injury.23 The weakened axillary nerve is compressed in the deformed shoulder beneath the superomedial border of the triceps fascia. Hence, we routinely perform decompression of the axillary nerve and further address the periartricular tightness by releasing the long head of the triceps.

Sometimes release and transfer procedures are staged27,28 in order to ensure adequate passive external rotation of the shoulder prior to transfer of the muscles. The modified Quad procedure bears a closer resemblance to that of Hoffer and Phipps.19,21,26 Transfers of the insertions of latissimus dorsi and pectoralis major are performed at the same time as the release of the contracture. However, while they transfer the insertions to the rotator cuff, we suture the transferred muscles closer to the origin of the teres minor, ensuring full passive abduction of the arm. This is similar to the technique employed by Narakas in a small series of patients, as analysed by his colleagues.29 We insert the muscle transfers as low as possible and add the axillary nerve decompression as described by Adelson et al.23 Inserting the already contracted muscles to the rotator cuff would further tether the joint. Instead, it is now possible for the weakened abductors to function without the tethering effect of the stronger muscles which have been released. Of the 98 children, 77 (78.6%) had active abduction of 160° or more. This would not have been possible if the released muscles had been inserted into the rotator cuff. Our improvements in active abduction of the shoulder are superior to those presented in Table II, where we have tried to summarise the results of relatively recent comparable studies. Also, our follow-up time is greater than all but one of these studies.

In order to achieve a successful lasting outcome, there must be adequate strength of the deltoid in the presence of easily palpable contractures of pro-gravity muscles.
Although unusual, early contractures may occur and progress. Therefore, early intervention is appropriate.

Table II. Summary of papers describing modifications of muscle release and transfer for restoration of abduction in obstetric brachial plexus palsy

<table>
<thead>
<tr>
<th>Author/s</th>
<th>Number of patients</th>
<th>Years of follow-up</th>
<th>Concomitant release</th>
<th>Tendon transfer†</th>
<th>Inserted to</th>
<th>Abduction pre-operative</th>
<th>Abduction post-operative</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoffer and Phipps26</td>
<td>8</td>
<td>2 to 5</td>
<td>Pectoralis major LD + TM</td>
<td>Infraspinatus</td>
<td>Active 74˚</td>
<td>Passive 84˚</td>
<td>Passive 164˚</td>
<td>Strength improved in 13 of the 35 patients</td>
</tr>
<tr>
<td>Phipps and Hoffer18</td>
<td>56</td>
<td>5</td>
<td>(6 patients C5 to C6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pagnotta et al20</td>
<td>203</td>
<td>1, 3, 6, 10, 15</td>
<td>± teres major</td>
<td>LD (+ TM)</td>
<td>Supraspinatus</td>
<td>~90˚</td>
<td>~115˚</td>
<td>In 45˚ to 90˚ abduction, pre-operative group at 6 yrs post-operatively</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>[C5 to C6 at 6 years]</td>
<td></td>
<td></td>
<td></td>
<td>~30˚</td>
<td>~90˚</td>
<td>In ≤ 45˚ abduction, pre-operative group at 6 yrs post-operatively</td>
</tr>
<tr>
<td>Waters and Bone21</td>
<td>25</td>
<td>3.6 (2 to 10)</td>
<td>±</td>
<td>LD + TM</td>
<td>Infraspinatus</td>
<td>Abd. Mallet⁴</td>
<td>Abd. Mallet⁴</td>
<td>4.0</td>
</tr>
<tr>
<td>Waters and Peljovich³¹</td>
<td>32</td>
<td>1.6 (0.3 to 5.3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safoory³⁹</td>
<td>32</td>
<td>2.3 (1.5 to 3.5)</td>
<td>± subscapularis</td>
<td>LD + TM</td>
<td>Infraspinatus</td>
<td>Gilbert§ 1-2</td>
<td>Gilbert§ 4-5</td>
<td>Six older patients had recurring internal rotation, no functional problems</td>
</tr>
<tr>
<td>Al-Qattan³²</td>
<td>12</td>
<td>4 (3 to 5)</td>
<td>(release of other muscles is performed in stages)</td>
<td>LD</td>
<td>rotator cuff (older), humeral head (younger)</td>
<td>Active 100˚</td>
<td>Active 140˚</td>
<td></td>
</tr>
<tr>
<td>Aydin et al³⁰</td>
<td>46</td>
<td>3.4 (2 to 5)</td>
<td>± subscapularis</td>
<td>LD + TM</td>
<td>Infraspinatus</td>
<td>62.5˚</td>
<td>131.4˚</td>
<td>In group ≤ 90˚ abduction pre-operative</td>
</tr>
<tr>
<td>Present work</td>
<td>72</td>
<td>5.1 (2 to 8)</td>
<td>Subscapularis, pectoralis major and minor</td>
<td>LD + TM</td>
<td>Teres minor</td>
<td>41˚</td>
<td>158˚</td>
<td></td>
</tr>
</tbody>
</table>

*±: as deemed appropriate  
† LD: latissimus dorsi, TM: teres major  
‡ abduction according to Mallet: 2: < 30˚, 3: 30˚ to -90˚, 4: > 90˚  
§ abduction according to Gilbert: 1: = 45˚, 2: < 90˚, 3: =90˚, 4: < 120˚, 5: > 120˚, 6: > 150˚

We have achieved excellent results, even in patients with very poor pre-operative function. All our patients had pre-operative abduction of less than 90˚, which is considered adverse by some, although others have also had good results in those groups. We believe that our results are primarily a consequence of the lack of tethering by our tendon transfers and of the decompression of the axillary nerve, both of which will tend to enhance abduction.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Supplementary Material

A table showing the patient demographics and clinical assessment is available with the electronic version of this article on our website at www.bjs.org.uk

References


