Nerve reconstruction in patients with obstetric brachial plexus injury results in worsening of glenohumeral deformity

A CASE-CONTROL STUDY OF 75 PATIENTS

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Whereas a general trend in the management of obstetric brachial plexus injuries has been nerve reconstruction in patients without spontaneous recovery of biceps function by three to six months of age, many recent studies suggest this may be unnecessary. In this study, the severity of glenohumeral dysplasia and shoulder function and strength in two groups of matched patients with a C5-6 lesion at a mean age of seven years (2.7 to 13.3) were investigated. One group (23 patients) underwent nerve reconstruction and secondary operations, and the other (52 patients) underwent only secondary operations for similar initial clinical presentations. In the patients with nerve reconstruction shoulder function did not improve and they developed more severe shoulder deformities (posterior subluxation, glenoid version and scapular elevation) and required a mean of 2.4 times as many operations as patients without nerve reconstruction.

This study suggests that less invasive management, addressing the muscle and bone complications, is a more effective approach. Nerve reconstruction should be reserved for those less common cases where the C5 and C6 nerve roots will not recover.

The incidence of obstetric brachial plexus injury is about 0.15% of live births in the United States. Whereas most recover spontaneously, babies with inadequate recovery of biceps function within the first three months of life will have residual functional and anatomical deficits. Clinical studies suggest that shoulder complications of the original nerve injury comprise the major cause of long-term morbidity. The main anatomical changes include glenohumeral dysplasia and posterior subluxation or dislocation, the probable cause of which is muscle imbalance around the shoulder from the asymmetrical injury, the upper plexus (C5-6) being injured more commonly than the lower (C8-T1).

A general trend in the management of obstetric brachial plexus injury, developed particularly in the 1980s and 1990s, has been nerve reconstruction in patients who do not show recovery of biceps function by three to six months of age. However, recent studies suggest that nerve reconstruction may be unnecessary in most of these situations. Moreover, concentration on nerve reconstruction for biceps function ignores those shoulder problems, which ultimately prove to be the major cause of morbidity. This retrospective study compared the effects of nerve reconstruction with no nerve reconstruction on glenohumeral development and shoulder function and strength in matched groups of obstetric brachial plexus injury patients with injuries to the C5 and C6 nerve roots and relative sparing of the C7 to T1 roots.

Patients and Methods
A recent survey showed that 87% of an international group of surgeons who managed children with obstetric brachial plexus injury advocated nerve reconstruction. The senior author (RKN) has operated on several hundred such children each year for over ten years. His criteria for nerve reconstruction were modified in 2004, when the general criterion of clinical assessment of biceps function was replaced by a more perceptive approach which includes a comprehensive clinical examination of the shoulder, arm and forearm, highlighting function and position; glenohumeral joint imaging using CT and/or MRI; and electromyography (EMG) of the shoulder and biceps muscle groups. Nerve reconstruction is performed only on patients with a complete lack of anti-gravity biceps function by six months of age and EMG findings of fibrillation in the paraspinal muscles and no motor units in biceps. This approach has shown that lack of voluntary abduction and flexion of the shoulder and flexion of the elbow in most obstetric
brachial plexus injury patients is the result of secondary musculoskeletal complications, rather than primary paralysis causing ongoing nerve dysfunction. The direct effect of this approach was a marked reduction in the use of nerve reconstruction, relying instead on the reconstruction of secondary deformities to restore limb function. The importance of botulinum toxin in treating the common co-contraction between triceps and biceps is also a central principle of this management protocol.15,16

Earlier studies showed the benefit of a musculoskeletal approach to obstetric brachial plexus injury over a purely nerve-centred philosophy.6,17 The purpose of this study was to evaluate the changes in glenohumeral morphology and shoulder function associated with nerve repair in a matched series of obstetric brachial plexus injury patients.

Between 2005 and 2008, 304 obstetric brachial plexus injury patients with scapular hypoplasia, elevation and rotation18 deformity and fixed medial rotation contracture of the affected shoulder underwent triangle tilt surgery.17 This is a procedure, developed by the senior author, that releases the distal acromioclavicular triangle to its neutral position through osteotomy of the clavicle, acromion and scapula. The scapular deformity is common in obstetric brachial plexus injury patients and is usually associated with a fixed medial rotation contracture of the affected shoulder underwent triangle tilt surgery.17

There were 38 boys and 37 girls with a mean age of 7 years (2.7 to 13.3) at the time of CT and/or MRI examination. They were divided into two groups based on whether they had undergone nerve reconstruction (Table I). Group 1 included 23 patients who had undergone nerve grafting or transfer before or at one year of age. All then had secondary muscle surgery, namely the modified Quad procedure,6 and many had further operations. Group 2 included 52 patients who had only secondary operations.

The glenohumeral deformity in both groups was posterior subluxation of the humeral head in a retroverted glenoid fossa. These deformities were quantified through MRI and/or transverse CT according to Friedman, Hawthorne and Genez20 and Waters et al3 as follows. A scapular line and a glenoid line were constructed to define the glenoscapular angle (Fig. 1). A total 90° were subtracted from this angle to define the degree of glenoid version (normal value = 0°). The scapular line was also used to determine posterior subluxation, which is the percentage of the greatest diameter of the humeral head anterior to the scapular line, multiplied by 100 (normal value = 50). This was modified from Waters et al3 owing to incomplete ossification of the humeral head.

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Scapular deformity, represented as scapular elevation, was measured from 3D reconstructions of CT images as described by Nath and Paizi (Fig. 2).18 The total area of the scapula and the area visible above the clavicle were measured from anterior views of affected and normal sides. The scapular elevation was calculated by subtracting the ratio of the area above the clavicle to the total area of the scapula for the normal side from that ratio for the affected side, multiplied by 100, with zero as the normal value. Graphic software (Universal Desktop Ruler, AVPSof.com, Voronezh, Russia) was used for all measurements made on CT/MRI images.

### Table I. Patient demographics

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
<td>24</td>
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<tr>
<td>Side of involvement</td>
<td></td>
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</tr>
<tr>
<td>Left</td>
<td>7</td>
<td>14</td>
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<tr>
<td>Right</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Secondary operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Quad6*</td>
<td>23</td>
<td>52</td>
</tr>
<tr>
<td>Posterior glenohumeral capsulorrhaphy</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Biceps tendon lengthening</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Humeral osteotomy</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Forearm osteotomy</td>
<td>1</td>
<td>0</td>
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<td>Total number of secondary operations</td>
<td>48</td>
<td>68</td>
</tr>
<tr>
<td>Mean number of secondary operations per patient</td>
<td>2.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

* this operation includes a series of tendon transfers, release of latissimus dorsi, teres major, subscapularis pectoralis major and minor contractures and neurolysis and decompression of the axillary nerve
Shoulder function was evaluated and scored from video analysis using a modified Mallet scale. Movements include abduction, external rotation, hand-to-mouth, hand-to-neck and hand-to-spine, and are scored from 1 (no movement) to 5 (normal). The total Mallet scores therefore range from 5 to 25 and a total score was calculated for each patient.

The mean and the standard error were determined for each parameter. The Mann-Whitney test was used to compare groups.
compare means of relevant parameters. A p-value of < 0.05 was considered as statistically significant, and all statistical analysis was performed using Analyse-It plugin (Leeds, United Kingdom) for Microsoft Excel 2003 software.

**Results**

The patients were matched for age, level of injury and presence of shoulder deformities requiring operative treatment (Table I). There was no significant difference in age between the groups (p = 0.40). Their deformities and functional scores are shown in Table II.

Posterior subluxation was significantly lower in group 1 than in group 2 (p < 0.05), signifying increased subluxation in the former. There were also significant differences in glenoid version and scapular elevation between the groups, with group 1 having worse deformities in both categories. Patients without nerve reconstruction showed significantly better humeral head congruence and lower scapular elevation than those who had nerve reconstruction (p < 0.05). Representative axial CT images showing the affected shoulders in both groups and 3D-CT images showing elevated scapulae on the affected side are shown in Figures 1 and 2.

There was no significant difference in any individual functional movement or in total modified Mallet score between groups 1 and 2 (p = 0.42). Patients who did not undergo nerve reconstruction had similar shoulder function to those who did.

As an additional indicator of the severity of glenohumeral deformity in group 1, these patients underwent significantly more secondary operations per patient (2.1) than those in group 2 (1.3, Table I). If the original nerve reconstruction is added to the total number of operations, the average number for each group 1 patient is 3.1.

**Discussion**

It is well established that shoulder problems are the most common long-term complication of the initial nerve injury and the major cause of morbidity in obstetric brachial plexus injury.2-6 The general trend in the management of the condition is based on the assumption that lack of biceps function by the age of three to six months implies a complete nerve rupture, and the child should therefore undergo nerve grafting or transfer. However, more recent reports suggest that nerve reconstruction may not be necessary in many or most such cases11-13 and that less invasive management, such as the use of botulinum toxin in conjunction with surgery for secondary musculoskeletal complications, is more effective, less expensive, and carries less morbidity.

This study shows that patients who have undergone nerve reconstruction not only develop more severe shoulder deformities, but also require more operations to address them. The most likely cause for this difference is that the neuroma resection (in nerve grafting) or nerve transection (in nerve transfer) interrupts pathways that include nerve fibres misdiagnosed as nonviable. Possible mechanisms for misdiagnosis are:

a) relying solely on the physical examination of biceps flexion;22,23

b) failing to appreciate the frequent presence of co-contraction between biceps and triceps in which the overly strong and early triceps recovery will mask effective biceps recovery;24,25

c) assuming that intra-operative nerve conduction studies at the site of the neuroma results in a valid evaluation of the amount of viable nerve within the neuroma. It may be that the common presence of dense epineural scarring insulates recovering and uninjured axons from the current produced by the stimulating electrode, thereby resulting in a false-negative impression of viable nerve status.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean (SE)</th>
<th>Group 1</th>
<th>Group 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at examination</td>
<td>7.2 (0.5)</td>
<td>6.9 (0.4)</td>
<td>0.40</td>
<td></td>
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<tr>
<td>Bony deformity parameters</td>
<td></td>
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<tr>
<td>Posterior subluxation (%)</td>
<td>9 (4)</td>
<td>23 (2)</td>
<td>0.008</td>
<td></td>
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<tr>
<td>Glenoid version (*°)</td>
<td>-37 (3)</td>
<td>-28 (2)</td>
<td>0.002</td>
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<tr>
<td>Scapular elevation (%)</td>
<td>29 (3)</td>
<td>19 (2)</td>
<td>0.01</td>
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<tr>
<td>Modified Mallet functions (1 to 5)</td>
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<tr>
<td>Abduction</td>
<td>4.6 (0.1)</td>
<td>4.5 (0.1)</td>
<td>0.14</td>
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<tr>
<td>External rotation</td>
<td>2.6 (0.1)</td>
<td>2.4 (0.1)</td>
<td>0.78</td>
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<tr>
<td>Hand to mouth</td>
<td>2.0 (0.1)</td>
<td>2.1 (0.1)</td>
<td>0.34</td>
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<tr>
<td>Hand to neck</td>
<td>3.0 (0.1)</td>
<td>3.0 (0.1)</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Hand to spine</td>
<td>2.2 (0.1)</td>
<td>2.4 (0.1)</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Total modified Mallet score</td>
<td>15.0 (0.3)</td>
<td>15.5 (0.3)</td>
<td>0.42</td>
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</tbody>
</table>
d) operating on these children between three and six months of age is too early to allow effective assessment of the recovery potential of the injured brachial plexus nerves.12,26

In C5-6 injuries, once upper root pathways have been surgically interrupted, any growth imbalances between upper- and lower-root innervated muscle groups are accentuated because of the need for regeneration across the graft or transfer. Spontaneously recovering upper root injuries, albeit delayed compared to the uninjured lower roots, apparently do not create imbalances as severe as those in patients who have undergone nerve reconstruction. These patients did not show improved outcomes in the present study.

Patients undergoing nerve reconstruction on the basis of biceps function alone suffer from more significant shoulder dysplasia than matched patients in whom a more conservative approach is followed. Shoulder movement scores are similar in nerve-reconstructed and non-nerve-reconstructed patients at an average age of seven years, indicating the lack of useful effect of nerve reconstruction on shoulder anatomy and function. Because functional biceps strength was present in all patients at the time of examination (age 2.7 to 13.3 years), the necessity for nerve grafting/transfer as primary treatment in patients with a C5-6 injury is questionable. Protocols for nerve reconstruction should therefore include the understanding that shoulder contracture and co-contraction between the biceps and triceps mimic a complete nerve injury but the recovery potential of the injured brachial plexus nerves.12,26

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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.

References


NERVE RECONSTRUCTION IN PATIENTS WITH BRACHIAL PLEXUS INJURY RESULTS IN WORSENING OF GLENOHUMERAL DEFORMITY 653