Improving Shoulder and Elbow Function in Children With Erb’s Palsy

Andrew Price, Michael Tidwell, and John A.I. Grossman

Many children who sustain birth injuries to the brachial plexus suffer significant functional limitations due to various sequelae affecting the shoulder and elbow or forearm. The maintenance of full passive mobility during the period of neurological recovery is essential for normal joint development. Early surgical correction of shoulder contractures and subluxations reduces permanent deformity. Reconstruction of forearm rotation contractures significantly improves the appearance and use of the extremity for many basic activities. Each child must be carefully evaluated, therapy maximized, and the surgical approach individualized to obtain the best result.

Copyright © 2000 by W.B. Saunders Company

In 1927, Sever1 published an evaluation of 1,100 consecutive patients with brachial plexus birth injuries. He saw no difference in outcome between the operative and nonoperative patients. As a result, treatment of this condition remained largely nonoperative for more than 50 years, with a “wait and see” management philosophy prevailing. Most children with brachial plexus birth injuries were able to adapt to their disability and function in society. Today, our understanding of nerve injury and repair, as well as our refinement of techniques used for musculoskeletal reconstruction in children, has improved our ability to intervene in these sometimes disabling injuries.

Due to the nearly universal involvement of the C5 and C6 nerve roots, many children with brachial plexus injuries at birth usually have some impairment of the function of the shoulder, elbow, and forearm. The purpose of the shoulder is to position the hand in space. A recent study has demonstrated a profound effect of limited shoulder motion on the function and strength of the hand.2 Because the degree of injury and recovery varies from patient to patient, an experienced physician must individually evaluate each child and prescribe a regimen of operative and/or nonoperative treatment to address his or her individual deficits. There are certain nuances to the natural history of this condition that, if ignored, will have significant impact on both the function and appearance of the involved limb.

Timing of treatment is important. Because most children realize neurological recovery over a number of years,3 the delay in normal muscle function and the presence of muscle imbalance across any upper extremity joint can have profound impact on the growing skeleton.4 Thus, if ignored, the child may be left with permanent musculoskeletal abnormalities. Every effort must be made to maintain full passive motion of all joints, primarily through a supervised therapy program and surgical intervention when necessary. It is important to understand that all treatment options have windows of opportunity during which intervention can positively impact the final result. Therefore, patients with brachial plexus injuries must be followed on a monthly basis to monitor recovery and the development of any joint contractures. With knowledge of key orthopedic principles, one can avoid many permanent sequelae and optimize a patient’s function regardless of the ultimate degree of recovery. This article discusses some of these principles and outlines an approach for improving shoulder and elbow function in patients with brachial plexus birth injuries.

EVALUATION OF MUSCULOSKELETAL INJURY

When an infant in the newborn nursery is noted to lack movement of the upper extremity due to a suspected nerve injury, the examination must also determine the presence of a non-neurological injury. Birth trauma may cause fracture of the clavicle, humerus, ribs, and in rare cases, the femur. The extremities and trunk must be examined for swelling, ecchymosis, or crepitus. A fracture in a limb will present as pseudoparalysis. Concomitant brachial plexus injury and fracture is not uncommon. Radiographs of the affected extremity are ordered to rule out a fracture. When suspected, a chest radiograph should also be ordered to determine the presence of rib or clavicle fractures. In the presence

---

From the Division of Pediatric Orthopedic Surgery, St. Luke’s Roosevelt Hospital Center, New York, NY; and the Department of Orthopedic Surgery and the Brachial Plexus and Peripheral Nerve Surgery Program, Miami Children’s Hospital, Miami, FL. Address reprint requests to Andrew Price, MD, St. Luke’s Roosevelt Hospital Center, Roosevelt Division, Center for Neuromuscular Injury, 425 W 59th St, Suite 5C1, New York, NY 10019.

Copyright © 2000 by W.B. Saunders Company

1071-9091/00/0701-0008$10.00/0

Seminars in Pediatric Neurology, Vol 7, No 1 (March), 2000: pp 44-51
of a fracture, the infant needs to be protected by pinning the extremity to the torso by sling and swathe or a Velpeau dressing for about 10 days until enough healing has occurred to begin therapy.

Though rare, an acute shoulder or elbow dislocation can occur at birth in association with brachial plexus palsy. If the former is suspected, magnetic resonance imaging (MRI) of the shoulders is the preferred method of evaluation. Depending on the extent of neurological recovery, muscle imbalance around the shoulder may develop and cause an internal rotation contracture of the shoulder and eventual deformity or permanent shoulder dislocation. Therefore, the humeral head must be periodically checked to ensure that it is well located in the anatomic glenoid, and full passive external rotation confirmed by MRI (Fig 1). If a dislocation is suspected at any time and then documented on MRI, surgical open reduction with subscapularis muscle release from the scapula and posterior capsular reefing is performed. This procedure is often performed in conjunction with microsurgical reconstruction of the plexus.

When a brachial plexus injury occurs without concomitant fracture or dislocation, traditionally the affected arm has been pinned empirically to protect the recently injured plexus. There are no data supporting the need for prolonged immobilization. We believe that immediate gentle restricted motion should be instituted, and no pinning or immobilization is routinely done.

There are critical times in the natural history of musculoskeletal development of the affected limb in these children that affect the approach to management. The phase of neurological recovery is the period of time it takes for the initial neurological injury or the reconstructed plexus to recover or plateau in recovery. This phase usually lasts at least 5 or 6 years. During this time, our goal is to maintain full passive motion of all joints, primarily through an ongoing intense rehabilitation program.

ORTHOPEDIC MANAGEMENT OF THE SHOULDER

Joints require full motion to develop normal anatomic shape and function. The growth and development of the joint surface is an ongoing process that involves active epiphyseal growth on each side of the joint. The shoulder joint has the most motion of any joint in the body. Elevation of the shoulder is a complex motion involving a coordinated combination of glenohumeral and scapulothoracic motion. Many researchers have attempted to determine the minimal requisites for shoulder elevation and the role and relative importance of specific muscles. One essential condition for elevation is agreed on: active external rotation of the shoulder is an essential requirement for normal shoulder elevation and the ability to bring the hand to the face. External rotation of the shoulder relaxes the inferior capsule and clears the greater tuberosity from impinging on the coracoacromial arch, thereby allowing unimpeded elevation. Without external rotation, raising the hand to the face requires the clarion position (Fig 2). If an internal rotation contracture of the shoulder develops and persists, pathological changes in the glenohumeral joint follow, with possible subluxation or dislocation resulting in restricted motion and a permanent loss of function. In our experience, a significant internal rotation contracture before 4 or 5 months of age is strongly suggestive of a shoulder dislocation. Passive motion must be maintained to ensure the development of a congruent glenohumeral joint. With the progression of ossification of the humeral head and glenoid, the shoulder joint begins to take on its permanent shape at about 3 years of age. Therefore, if our therapy is unable to maintain external rotation and a concentrically located joint, surgical intervention is necessary before age 3 years to avoid joint incongruence and permanent loss of motion. We initiate a carefully supervised physical therapy program by trained
Fig 2. Clarion posture due to weakness or paralysis of external rotators or a contracture in internal rotation.

therapists knowledgeable about the special needs of these patients. They educate parents and caregivers in the proper techniques for joint motion preservation. To maintain external rotation, the therapist or caregiver must perform this exercise with the arm adducted and the elbow against the torso. External rotation with the arm abducted 90° does not get the maximum stretch out of the anterior shoulder capsule and subscapularis muscle. Furthermore, all motions of the upper extremity are attended to with special care taken to isolate glenohumeral motion from scapulothoracic motion. It is important to maintain a continuous physical therapy program at home and with a therapist; interruption of this program will lead to rapid loss of function and contracture. We also incorporate functional electrical stimulation into our therapy program, both with the therapist and at home, to minimize muscle atrophy.

The experience and creativity of the therapist is critical when attempting to cajole a young patient in the noncompliant phase of development to perform therapeutic exercises designed to maintain motion and gain strength. Play activities are designed to incorporate the desired motion and exercises.

In the absence of shoulder dislocation, if external rotation cannot be achieved through the physical therapy program, surgical release through a subscapularis slide is performed between the ages of 18 and 24 months. This is augmented by 6 weeks of cast immobilization. The use of botulinum toxin a to weaken the internal rotators is currently under trial. After cast removal, the patient realizes immediate improvement of function and limb appearance. Over the course of the ensuing year, if the contracture begins to recur because the external rotators have not been reinnervated and adequately recovered, the latissimus dorsi and/or teres major are transferred around to the back of the humerus to become external rotators (Fig 3). Although occasionally a rerouting of the latissimus dorsi tendon works well, we agree with Hentz that, in many cases, there is greater improvement of elevation if only the teres major is transferred without the latissimus dorsi (V.R. Hentz, personal communication, June 1999).

For patients who are seen late, when permanent bony incongruence has developed in the glenohumeral joint, an external rotation osteotomy of the humerus is the only option to salvage a better arc of motion and improve limb condition (Fig 4).

It is only over the last 2 decades that these early soft-tissue contractures and shoulder deformities have been recognized as a major contributing factor in the chronic shoulder adduction-internal rotation deformity classically associated with the Erb’s palsy child. Although the previously described musculoskeletal operations and many other variations are useful in obtaining some improvement, early appreciation of correctable nerve and soft-tissue abnormality may avoid more severe permanent deformities.

Other less frequent chronic shoulder deformities include persistent deltoid paralysis and external rotation contractures, which can be improved by various muscle transfers, releases, and lengthenings. The best results in these cases are obtained
when surgery is coupled with extensive preoperative and postoperative physical therapy. Thus, delaying surgery until after 6 or more years of age when children are more compliant is recommended.

The trapezius transfer leaves the patient with limited abduction, a webbed neck, and a poor cosmetic appearance. In the face of profound abduction weakness, we prefer to perform a bipolar transfer of the latissimus dorsi, which, in addition to gaining abduction power, also gives some bulk to the deltoid area and improves the cosmetic appearance of the shoulder. These procedures require patient compliance with an extensive postoperative rehabilitation and thus are performed after the age of 8 years.

ELBOW AND FOREARM

In many children with classic Erb’s palsy, a paradoxical elbow flexion contracture often develops, causing a functional as well as cosmetic disability, especially in view of the limb length discrepancy seen. Given the normal triceps power in the face of weak or absent biceps function, it is difficult to reconcile. Aitken investigated this phenomenon by reviewing elbow radiographs in these patients. He demonstrated the presence of proximal ulnar bowing, radial neck clubbing, and posterior subluxation of the radial head. To date, there is no definitive treatment for this condition. We have used a spring-loaded extension splint for evening or nighttime use that may partially decrease the elbow contracture. Occasionally, release of the contracted antecubital fascial structures in conjunction with release of an associated pronation contraction improves the elbow flexion contracture as well.

When the biceps lacks the ability to flex the elbow against gravity at least 90° to 100°, the child cannot raise the hand to eat, button a shirt, or comb their hair. The muscle transfer of choice is the triceps to biceps when the former is of normal strength. Other muscles that can be transferred to gain elbow flexion include the pectoralis major and latissimus dorsi.

When a significant imbalance in either the pronators or supinators of the forearm is present early in recovery, a pronation or supination contracture may develop, which limits function and sometimes gives an unsightly cosmetic appearance to the limb. Even if the opposing muscles recover sufficient
power, they alone are not capable of reversing a fixed contracture. It is important to release these contractures before fixed bony changes occur in the radius and ulna. If these subtle changes occur, the rotation of the forearm can be permanently constricted.

In addition to being an elbow flexor, the biceps muscle is the most powerful supinator of the forearm. With major weakness of the biceps, a pronation contracture may develop. Although largely ignored in the literature, we have observed that the pronation contracture leads to well-defined functional loss in hygiene, toileting, and sports activities. Additionally, it tends to exaggerate the somewhat unsightly internal rotation posture of the extremity. If the biceps then recovers at least 80%
power, we have demonstrated lasting improvement in function by releasing a variety of soft tissues in the forearm (Table 1).

Conversely, if the biceps recovers without recovery in the forearm flexor/pronator muscles in a patient with complete plexus injury, the imbalance will cause a supination contracture of the forearm. Supination deformities of the forearm are particularly bothersome to children. The contracture is unsightly and impairs performance of many tasks, including use of a keyboard, which is quite problematic in today's world of computers. The approach popularized by Zancolli is generally successful. It involves release of any interosseous membrane power.

<table>
<thead>
<tr>
<th>Age/Sex</th>
<th>Passive</th>
<th>Active</th>
<th>Operation</th>
<th>Postoperative</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/M</td>
<td>80-20</td>
<td>80-0</td>
<td>PT/lacertus lengthening</td>
<td>80-80 80-80</td>
<td>Satisfied</td>
</tr>
<tr>
<td>5/M</td>
<td>80-20</td>
<td>80-10</td>
<td>PT/lacertus/brachialis/biceps/flexor lengthening and elbow capsular release</td>
<td>80-60 80-50</td>
<td>Satisfied</td>
</tr>
<tr>
<td>6/M</td>
<td>80-45</td>
<td>80-0</td>
<td>PT/lacertus lengthening</td>
<td>80-80 80-45</td>
<td>Satisfied</td>
</tr>
<tr>
<td>4/F</td>
<td>80-45</td>
<td>80-10</td>
<td>PT/lacertus/flexor lengthening</td>
<td>80-80 80-45</td>
<td>Satisfied</td>
</tr>
<tr>
<td>12/F</td>
<td>80-80</td>
<td>80-0</td>
<td>PT/lacertus lengthening</td>
<td>80-80 80-45</td>
<td>Satisfied</td>
</tr>
<tr>
<td>3/M</td>
<td>80-10</td>
<td>80-0</td>
<td>PT/lacertus/brachioradialis/flexor lengthening/subscapularis slide</td>
<td>80-80 80-45</td>
<td>Satisfied</td>
</tr>
<tr>
<td>15/M</td>
<td>80-10</td>
<td>80-0</td>
<td>PT/lacertus/transfer to joined ECRL and ECRB</td>
<td>80-75 80-10</td>
<td>Satisfied</td>
</tr>
<tr>
<td>13/M</td>
<td>80-20</td>
<td>80-10</td>
<td>PT/lacertus/flexor lengthening</td>
<td>80-80 80-50</td>
<td>Satisfied</td>
</tr>
<tr>
<td>17/M</td>
<td>80-15</td>
<td>80-0</td>
<td>PT/lacertus/flexor lengthening</td>
<td>80-80 80-40</td>
<td>Satisfied</td>
</tr>
</tbody>
</table>
contracture and use of the biceps as a dynamic transfer, changing its supination function to one of pronation by a tendon rerouting (Fig 5). This procedure requires a stable wrist. In patients with extensive paralysis of wrist flexion and extension, we will stabilize the radial carpal joint with internal fixation until skeletal growth is complete. Occasionally, neglected deformities with a marked interosseous membrane contracture and bony deformity are best treated by osteotomies of the forearm bones.

Whatever technique is selected to correct forearm rotation contracture, the results are almost uniformly satisfactory. In our review of 21 children with either supination or pronation deformities

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did your child realize improvement in function following surgery?</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Did your child realize improvement in the appearance of the extremity following surgery?</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Would you recommend this surgery to other parents for their children?</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Pronation (N = 9), Supination (N = 12)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
treated over a 5-year period, only 1 child realized no significant improvement (Table 2).

In all children with musculoskeletal sequelae following an obstetrical brachial plexus injury, careful and complete evaluation of the disabilities and deformities must be performed jointly by the surgeon and therapist. The use of advanced imaging and neurophysiologic techniques is often a valuable supplement. In most children with shoulder and elbow-forearm deformities, a properly selected surgical procedure(s) significantly improves the form and function of the injured extremity.

REFERENCES