Shoulder External Rotation Tendon Transfers For Brachial Plexus Birth Palsy

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■ ABSTRACT

Children with brachial plexus birth palsy may have permanent loss of shoulder external rotation strength. This impairment may result in a difficulty in reaching the face and head with the affected hand for grooming activities, and in reaching overhead for participation in sports or work-related tasks. In addition, the contracture that results from unopposed internal rotation may further restrict range of motion and cause glenohumeral joint deformity and subluxation.

A combination of muscle release and transfers reliably improves the child’s ability to position the hand, and may halt the development of joint deformity. Postoperative rehabilitation is necessary to maximize the strength and range of motion gained from this operation.

Keywords: pediatric, brachial plexus birth palsy, shoulder, tendon transfer

■ HISTORICAL PERSPECTIVE

Brachial plexus birth palsy (BPBP), or obstetric birth palsy, occurs when the brachial plexus is injured during birth. Reports on the incidence of the injury vary, but range from 0.38 to 1.56 per 1,000 live births.\textsuperscript{1,2} The mechanism of injury is forced lateral flexion of the head and the neck which produces traction and injury to the brachial plexus. The primary cause is shoulder dystocia during a cephalic vaginal delivery,\textsuperscript{3} with numerous additional predisposing factors, including macrosomia,\textsuperscript{4} multiparous pregnancies, prolonged labor, assisted and difficult deliveries,\textsuperscript{5} and a history of a previous birth with shoulder dystocia.\textsuperscript{6} During difficult breech or cesarean section deliveries BPBP may also occur.\textsuperscript{7,8}

Although a majority of infants with BPBP have a full or near full neurological recovery,\textsuperscript{9-12} the resulting disability can vary from very mild weakness of shoulder external rotation to complete upper extremity paralysis. The extent of impairment depends upon the location and severity of damage to the plexus. The location of injury is classified as modified from Naraku’s by Smith et al\textsuperscript{13} (Table 1). Type I is the most common; C5 and C6 are most prone to injury where they join to form the superior trunk, which is close to where the suprascapular nerve exits in the plexus (Fig. 1). Injury at this level causes weakness or paralysis of shoulder external rotation and weakness in shoulder abduction and elbow flexion depending on the severity, although elbow flexion strength usually recovers.\textsuperscript{13} Recovery of sensation is typically greater than motor recovery, with the majority of improvement in neurological function seen in the first 12 months of life.\textsuperscript{14}
TABLE 1. Types of brachial plexus birth palsy

<table>
<thead>
<tr>
<th>Type</th>
<th>Roots involved</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>C5 and C6</td>
<td>Erb palsy</td>
</tr>
<tr>
<td>II</td>
<td>C5, C6 and C7</td>
<td>Erb palsy with elbow and/or wrist extension weakness</td>
</tr>
<tr>
<td>III</td>
<td>C5, C6, C7, C8, T1</td>
<td>Global palsy</td>
</tr>
</tbody>
</table>

Treatments options for shoulder weakness associated with BPBP include passive range of motion exercises, goal-directed occupational therapy, surgical plexus exploration and grafting, shoulder soft tissue release with or without muscle transfers, and humerus osteotomy. The indications for surgical intervention follow a clinical continuum based upon the timing of recovery and the motor function lacking in the affected extremity. Most authors agree that the failure of recovery of biceps function by 6 months of age is an indication for plexus exploration, neurolysis, and repair or reconstruction, which may improve function but will not result in full recovery. Infants and children may have difficulty reaching their face and head with the affected extremity, and they may develop shoulder joint adduction and internal rotation contractures due to unopposed or weakly opposed subscapularis, pectoralis major, teres major and latissimus dorsi function. This causes deformity of the glenohumeral joint, and the affected shoulder may eventually subluxate or dislocate posteriorly. Soft tissue release and tendon transfers improve passive and active range of motion in children with muscle imbalance, and may retard the development of glenohumeral joint dysplasia. Older children with a dysplastic and stiff glenohumeral joint may benefit from rotational osteotomy of the humerus.

Sever first described open subscapularis release in 1925, but because anterior instability can result from this procedure, others have described different approaches to subscapularis release. Carlizon releases the subscapularis origin from the scapula, and Pearl releases the anterior capsule and subscapularis tendon arthroscopically. L’Episcopo first described muscle transfers for this population in 1934; his method was later modified by Hoffer. Transfer of the latissimus dorsi and teres major to the rotator cuff with pectoralis major release has been shown to improve active external rotation and abduction strength, with average gains at 2 to 8 years follow-up of 64-degree active abduction and 45-degree external rotation, and improved ability to bring the hand to the mouth and neck. Improvements in abduction may be owing to stabilization of the glenohumeral joint by the transfer, thereby enhancing deltoid function; external rotation tendon transfers cannot initiate abduction in the absence of deltoid function. There is some indication that the results of these operations may deteriorate with time. If this occurs, humerus rotation osteotomy can improve external rotation, although it does not increase total shoulder joint rotation.

The purpose of this article is to describe a modified version of the Hoffer method of soft tissue release and tendon transfer for children with external rotation weakness due to BPBP.

- INDICATIONS/CONTRAINDICATIONS

Tendon releases can be performed in infancy, but tendon transfers are frequently delayed until the child is old enough to cooperate with postoperative therapy (age 3–4 years). Most surgeons prefer to combine these operations, leading to a trend to perform transfers earlier for those who develop early joint contractures. Subscapularis release augments passive external rotation in adduction, and pectoralis major release augments passive external rotation in abduction. Transfers can successfully improve motion in older children as long as glenohumeral joint dysplasia has not developed, or at least before the glenohumeral joint has dislocated. The status of the glenohumeral joint at the time of soft tissue surgery is more important than the age of the child. Chronic muscle imbalance around the shoulder causes joint dysplasia, which causes joint stiffness, and a muscle transfer will not move a stiff joint. Joint status should be evaluated preoperatively by anteroposterior and axillary radiographs of the shoulder (for children over age 3 years), ultrasonography, computed tomography scan, or magnetic resonance imaging (for children under age 3 years).

FIGURE 1. Drawing of brachial plexus. Roots, trunks and suprascapular nerve are labeled. (Drawing by Denise Waters, Shriners Hospitals for Children Northern California).
Donor muscle function must also be assessed prior to transfer, to assure that the transferred muscle can provide the necessary power. The latissimus dorsi and teres major should have strength against resistance. To test this, the examiner asks the child to hold her arm against her side, and palpates the posterior axilla while trying to passively abduct the arm. In addition, the deltoid must be strong enough to initiate abduction to at least 60 degrees; deltoid paralysis is a contraindication to external rotation tendon transfers. Most children with types I and II palsy (Table 1) will meet these conditions. If additional tendon transfers such as biceps rerouting or flexor carpi radialis to extensor carpi radialis brevis (Green transfer) are indicated, they can be performed at the same anesthetic as shoulder external rotation tendon transfers.

Although not an absolute contraindication, children with type III palsy and very poor hand function will not benefit as much from a tendon transfer that helps their shoulder position their hand in space.

**TECHNIQUE**

Preoperatively, muscle function and joint range of motion may be optimized with intensive occupational therapy focusing on the shoulder and the planned donor muscles. This accustoms the child to participating in therapy, which will be important postoperatively. Active and passive range of motion is measured in a standardized fashion, taking care to measure shoulder motion without including compensatory trunk motion. Standardized active and passive range of motion photographs and a video of range of motion are also obtained, and the occupational therapist interviews the child and parent regarding limitations in age appropriate activities of daily living and other higher level activities. The waist portion of a spica cast is prefabricated with the child standing, then univalved and removed for reapplication at the completion of the operation (Fig. 2).

After administration of a general anesthetic, an interscalene nerve block and/or local administration of bupivacaine and epinephrine is administered (DeVera et al, Journal of Pediatric Orthopaedics, in press). The patient is then positioned in the lateral decubitus position with the affected extremity superior. Because range of motion will be tested intraoperatively, the patient’s position is stabilized with a beanbag and/or kidney rest. Prior to draping, the range of motion is assessed while stabilizing the scapula, with particular attention to passive external rotation in adduction and at 90 degrees abduction. If the shoulder does not reach 30 degrees of external rotation in adduction, the origin of the subscapularis is released. If it does not reach 90 degrees of external rotation in abduction, a fractional lengthening of the pectoralis major is performed. The extremity is draped free, and if release of the subscapularis origin is planned the scapula is in the surgical field.

A transverse skin incision is made in the axillary fold along a Langer cleavage line, extending anteriorly to the pectoralis major and posteriorly to the deltoid-triceps interval (Fig. 3A). If indicated, pectoralis major fractional lengthening is performed first. While protecting the axillary vessels and plexus, the tendinous portion of the pectoralis major, located on the posterior aspect of the muscle, is transected near its insertion on the humerus, leaving the muscle fibers, located anteriorly, intact. Transection of the entire pectoralis muscle is not necessary. If indicated, subscapularis lengthening is then performed through a separate 4-cm incision over the inferolateral scapula, and the inferior aspect of the origin of the teres major is reflected from a 3-cm portion of the scapular border. This is easier if the inferior tip of the scapula is stabilized by grasping it with a tenaculum through the incision. A small Cobb elevator is then used

**FIGURE 2.** Shoulder spica cast. The waist portion is prefabricated with the child standing, then univalved and removed. It is reapplied immediately after the operation while the child remains under general anesthesia, overwrapped, and connected to a long arm cast by anterior and posterior dowels, holding the arm in 90 degrees abduction and the position of external rotation selected intraoperatively (see text).
to thoroughly scrape the subscapularis origin off the thoracic aspect of the scapula.\textsuperscript{24}

The teres major and latissimus dorsi muscles and their tendons, which are usually conjoined,\textsuperscript{31} are then isolated in the posterior part of the axillary incision using blunt dissection (Fig. 3B). The axillary nerve and posterior circumflex humeral artery are visualized as they enter the quadrangular space and protected; they are easier to see after the latissimus dorsi and teres major tendons are detached.

The latissimus dorsi and teres major tendons are detached from their insertion on the humerus (this is easier if the shoulder is positioned in maximum internal rotation), and tagged with #0 nonabsorbable sutures with a figure 8 stitch that is secured by tying (Fig. 3C). Their muscle bellies are freed from surrounding tissue to improve excursion, taking care to avoid damaging the circumflex scapular vessels.

In the posterior aspect of the incision, the interval between the triceps and deltoid is developed, proximal to where the axillary nerve passes deep to the deltoid posteriorly. The tendons of the supraspinatus and infraspinatus (rotator cuff) are identified (this is easier if the shoulder is positioned in maximum external rotation). With the shoulder in 90 degrees of abduction and 60 to 80 degrees of external rotation, the latissimus dorsi and teres major tendons are passed posterior to the triceps muscle, and sutured into the rotator cuff tendons and, if
necessary, periosteum of the humerus, as firmly and superiorly as possible using the tag sutures. The needle is cut off for each tag suture, and the suture rethreaded on a smaller needle (Anchor stainless steel surgical needle, Orthopaedic 9/16 circle taper point #1869-8D); the strength of the "bite" should be secure, and as the donor tendon is attached it will be pulled up against the cuff tendon because the suture was tied to the donor tendon (Fig. 3D). With the surgeon’s finger on the tendon attachment, the shoulder is gently ranged to determine the position of rotation that best relaxes the attachment; this position (usually maximum passive external rotation and 60–80 degrees of abduction) is used for immobilization.

After wound closure and while the child is still under general anesthesia, she is placed in a supine position and the prefabricated waist portion of the spica cast is applied, followed by a long arm cast, which is then attached to the waist portion with 2 wooden dowels.

### COMPLICATIONS

The axillary nerve is at risk during exposure of the latissimus dorsi and teres major, and again during development of the deltoid-triceps interval; damage to this nerve would increase shoulder impairment by causing deltoid weakness.

Most problems from this operation result from poor patient selection. If the child’s deltid is too weak to initiate abduction, external rotation tendon transfers will not improve range of motion, and if hand function is poor, improving shoulder motion will not reduce the associated disability. Glenohumeral joint dysplasia will probably not be improved by tendon release and transfer, but these operations may halt its progression. If the child and/or parent cannot cooperate with postoperative rehabilitation, the outcome may suffer.

### REHABILITATION

The shoulder spica cast is left in place for 6 weeks. After cast removal the child is fitted with a shoulder abduction splint and begins an intensive occupational therapy program (IOTP; 2 sessions of therapy per day, 5 days per week, for 2 weeks). On-going occupational therapy in the child’s community is arranged to begin after IOTP. If any other transfers were performed at the same anesthetic, rehabilitation protocols for those operations are combined with the ERTT protocol.

Training the child and family regarding precautions, splint schedule, and exercise program is initiated during the first day of therapy as well, including handouts with this information to aid in the follow-through.

Active shoulder range of motion and passive external rotation in adduction and abduction are measured initially and at discharge from the IOTP. Active shoulder range of motion is encouraged, but passive range of motion other than external rotation is avoided, to limit stretching of the transfer attachment site while scars are maturing. Precautions include no passive shoulder internal rotation, and no passive shoulder flexion, horizontal adduction, or abduction greater than 90 degrees for 6 months. Isometric resistance against a static surface is allowed, but dynamic resistance is delayed until 4 months after surgery.

The shoulder abduction splint is worn at all times except during therapy, supervised exercises, hygiene, and skin inspection for 1 week after cast removal. Beginning the second week of therapy, a tapering schedule is initiated with a gradual decrease in daytime wear until wearing at night only by the final day of the 2 week therapy program. Night wear of the airplane splint continues until 6 months after the surgery.

Treatment sessions begin with active range of motion exercises for shoulder flexion, abduction, and external rotation in 90 degrees of abduction. Gentle passive stretching for external rotation is also included.

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1. Leeman Pediatric Shoulder Abduction Rotation Orthosis, Model 190 (Becker Orthopedic, Troy, MI).

![FIGURE 4. Occupational therapy includes activities that appeal to children, including playing ball.](image-url)
if necessary. Active and passive range of motion is also addressed in the elbow, forearm, wrist, and hand; limitations in these areas may be present initially due to the period of immobility in the cast. The exercises are followed by a wide variety of functional activities that encourage overhead reach incorporating shoulder active range of motion.

Creativity and variety is important in these sessions to achieve maximum participation and cooperation with these young patients. Examples of activities that incorporate the newly acquired overhead reaching skills include throwing and catching balls, lightweight Frisbees, Velcro catch and toss toys, small beanbags, foam toys, or any other light weight toy that can be raised overhead (Fig. 4). Other engaging activities for preschoolers include reaching up to paint or draw on papers mounted on a wall, smearing shaving cream on a wall-mounted mirror, washing a window, and answering a wall mounted phone. Games and toys can also be placed on a raised tabletop to encourage raising the arm to reach for play without resting the arm on the table. Younger children enjoy songs with hand motions that incorporate reaching.
up or imitating overhead arm positions. Daily living skills also encourage active motion. Reaching can be encouraged by donning a shirt, brushing or washing hair, reaching items on a shelf, or washing hands at a sink. During the second week, aquatic therapy is initiated. Activities in the pool are gauged to the child’s capabilities, ranging from raising the arm and splashing down on top of the water to front or backstroke swimming. Overall, activities vary depending on the age, cooperation, and attention level of the patient.

Caregivers are encouraged to participate and are given suggestions of activities that can be used as part of the home program. Before discharge from the IOTP, the occupational therapist ensures that the patient and family are able to demonstrate use of the shoulder abduction splint, take the necessary precautions, and follow the home program. Upon completion of the 2 weeks of IOTP, the child is referred back to their community therapist to continue therapy 2–3 times per week for 6 months. Further therapy at a decreased frequency may continue for a longer period of time and is assessed individually. The child is reassessed in clinic at 4, 6 and 12 months postoperatively, then on an annual basis, using a standardized evaluation that includes active and passive shoulder range of motion, an evaluation of performance of age-appropriate activities of daily living, and shoulder range of motion photographs (Figs. 5, 6).

REFERENCES


