Restoration of Shoulder Function

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KEYWORDS

• Tendon transfer • External rotation • Brachial plexus injury • Lower trapezius
• Global shoulder dysfunction

KEY POINTS

- Surgical management of shoulder paralysis after brachial plexus injury requires multispecialty approach.
- Restoration of external rotation is a priority following paralyzing injury.
- Lower trapezius transfer is a reliable procedure for restoration of external rotation.
- Multiple tendon transfers about the shoulder are utilized to restore global shoulder function provide optimal outcomes.

INTRODUCTION

Brachial plexus injury, although rare, represents a severe and life-altering injury with a variable degree of shoulder and arm dysfunction. Paralysis of the deltoid and rotator cuff muscles results in loss of abduction, external rotation as well as potentially painful inferior glenohumeral subluxation.[1–3] Because of the predominance of upper trunk injuries and innervation pattern through the plexus, the deltoid and rotator cuff are involved in 91% and 100% of palsies, respectively.[4]

Brachial plexus nerve reconstruction, with or without free muscle transfer, has been reported to lead to a good outcome in restoring elbow function in most cases.[2] However, restoration of shoulder motion, namely external rotation, has been disappointing.[3,5] Suzuki and colleagues[1] demonstrated that, at a mean follow-up of 28 months after neurotization of the suprascapular nerve from the spinal accessory nerve, external rotation was only 16.7°. Bertelli and Ghizoni[3] noted no return of external rotation after complete brachial plexus palsy treated with transfer of the spinal accessory to suprascapular nerve.

Historical treatment of shoulder paralysis involved arthrodesis of the glenohumeral joint for stability. However, function was reliant on scapulothoracic motion, which could be compromised in this patient population, especially in those with compromised trapezius muscle after spinal accessory nerve transfer,[6–8] which has led previous investigators to recommend arthrodesis as a salvage procedure for a paralyzed shoulder when alternate attempts at functional restoration have failed.[9–12] The authors advocate for the use of tendon transfers as the preferred treatment modality for patients with shoulder paralysis.

The complex motion of the shoulder in multiple planes requires smooth synergy of primary movers and stabilizers of both the glenohumeral and the scapulothoracic articulations. Knowledge of the anatomy and complex interplay of opposing muscle groups in cooperating joints is necessary to focus reconstructive efforts and identify acceptable tendons to sacrifice for transfer. General principles of transfer include targeting muscles with

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similar excursion and tension, expendability, at least M4 strength, and a similar line of pull to the nonfunctional muscle. The transferred muscle should also be used for a single purpose.[13]

Early attempts at tendon transfers to address shoulder dysfunction following nerve injury emphasized restoration of abduction and flexion. Historically described transfers include the upper trapezius to the proximal humerus, first described in 1891 by Hoffa, later by Lewis in 1910 and Lange in 1911,[11] and ultimately modified by Saha, whose name is now associated with this surgery.[9] However, recovery of abduction and flexion was limited with this transfer, resulting in persistent dysfunction and a largely useless extremity[4,14]; this was partially attributed to the shorter lever arm of the upper trapezius as well as the resection of acromion, which allowed for superior escape of the humeral head. Pedicled latissimus transfer for restoration of the abduction and forward flexion after deltoid paralysis has been described by Itoh and colleagues.[15] Although results were promising in patients with intact rotator cuff musculature, they were less impressive in the setting of paralyzed rotator cuff muscles, leading to the recommendation that rotator cuff muscle reconstruction should be used in conjunction with attempts at restoration of abduction and/or forward flexion.[15] The appreciation of the need to address the stabilizing musculature of the shoulder for improved functional recovery was actually advocated in the earlier recommendations for multiple tendon transfers by Saha, although colloquially associated with the isolated upper trapezius transfer.[9]

Rotator cuff muscle dysfunction contributes to poorer results in flexion and abduction given their contribution to those motions as stabilizers of the joint to maintain appropriate humeral contact with the glenoid. Improved understanding of the need for stability of the joint in addition to primary mobilizers for flexion, abduction, and external rotations guides priorities in secondary repair after global shoulder injury. It should also be appreciated that in addition to the potential for rotator cuff denervation, rotator cuff tears can occur in up to 10% of cases.[16]

Besides to stabilization of the glenohumeral joint, one of the most important functions of the rotator cuff is shoulder external rotation. The significance of external rotation in performing activities of daily living (ADLs) has been identified. In fact, most ADLs are performed with some degree of external rotation with the arm positioned with only 27° of abduction most of the time.[17] Langer and colleagues[18] found that limitation in external rotation significantly impaired ADLs and concluded that even modest improvement in external rotation in the setting of complete paralysis would greatly improve competency and independence in ADLs.

Obligate internal rotation, despite restored elbow flexion, results in a "hand-on-belly" position.[2,19] According to the grading system by Doi and colleagues,[20] the lack of ability to stabilize the shoulder joint and position the hand in space represents an outcome classified as less than poor.

Anatomic, functional, and biomechanical studies have been conducted to determine the relative contributions of individual rotator cuff muscles to shoulder function. Subscapularis contributes 52% to the abduction moment arm as calculated by multiplying cross-sectional area by lever arm.[21] Infraspinatus and teres minor collectively represent 45% of the external rotation moment arm, whereas subscapularis contributes 42% of internal rotation by a similar estimation.[21] These measurements were correlated with clinical evaluation using nerve blocks. Paralysis of the infraspinatus alone led to 70% loss of abduction strength, whereas paralysis of both supraspinatus and infraspinatus led to approximately 75% loss of abduction strength and 80% of external rotation strength.[22] These findings support targeting restoration of the infraspinatus function to maximize external rotation with a single tendon transfer.

Previously described tendon transfers using the latissimus dorsi and/or teres major to restore external rotation in upper plexus palsy should be considered contraindicated in global injury. Because of their line of pull and absent deltoid function, these may in fact lead to worsening inferior subluxation.[9] In addition, these muscles could be affected in the paralytic shoulder, depending on the extent of the injury. On the other hand, the function of the trapezius, levator scapulae, and rhomboids is preserved or recovered in 96% of cases of brachial plexus palsy,[12] representing consistently viable options for tendon transfer in an otherwise limited setting. Herzberg and colleagues[23] demonstrated the potential for division of multipennate muscles into functional subcomponents, further expanding the armamentarium of available transfers. Although these divisions have been demonstrated to be independently significant scapula stabilizers in the athlete,[24] normal function of other scapula stabilizers seems to be protective of dysfunction on harvest of subcomponents.[19]

Elhassan and colleagues[19] described lower trapezius transfer to reconstruct shoulder external rotation in patients with brachial plexus injury and reported successful outcome in most patients.[25]