Results of Distal Nerve Transfers in Restoration of Shoulder Function in C5 and C6 Root Avulsion Injury to the Brachial Plexus

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Abstract

Background The lack of shoulder function following brachial plexus injury is a debilitating condition. Nerve root avulsion injury precludes a direct nerve repair. Under these circumstances, distal nerve transfer is a well-established technique in the restoration of shoulder abduction and external rotation.

Methods Thirty patients with C5 and C6 root avulsion injury were treated with distal nerve transfers in the period between February 2009 and December 2012.The average denervation period was 5.6 months. Shoulder function was restored by posterior transfer of distal part of the spinal accessory nerve into the suprascapular nerve and transfer of the long head triceps branch of radial nerve to the anterior branch of axillary nerve. An additional nerve transfer was performed in four patients with winged scapula by transferring a part of thoracodorsal nerve into the long thoracic nerve.

Results Twenty-seven patients recovered shoulder abduction; 18 scored M4 and 9 scored M3. Range of abduction averaged 118 degrees (range, 90–170 degrees). Nineteen patients restored external rotation with an average of 53 degrees (range: 30–70 degrees). Three patients failed to recover shoulder abduction though the joint regained stability. External rotation remained severely restricted in 11 patients. At final follow-up, winging of scapula improved in three of four patients following reinnervation of the serratus anterior muscle.

Conclusion Nerve transfers, when performed close to the target muscles, restore good range and strength of shoulder abduction in most patients with C5 and C6 root avulsion injuries. However, return in external rotation is not as good as the recovery in abduction.

Keywords
- C5
- C6 root avulsion
- shoulder function
- distal nerve transfers

Introduction

Restoration of shoulder abduction and external rotation are important goals in the rehabilitation of patients with devastating brachial plexus injuries. In C5 and C6 root avulsions, anatomical reconstruction is not possible and nerve transfers offer far superior results over tendon/muscle transfers or shoulder arthrodesis.[1] Suprascapular and axillary are the target nerves in the restoration of shoulder function. Suprascapular neurotization also aims at restoration of external rotation through reinnervation of the infraspinatus muscle. Reinnervation of the deltoid (axillary nerve) allows a greater range of shoulder abduction and also improves the flexion and extension at

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Fig. 1 Upper brachial plexus injury with winged scapula.

the glenohumeral joint. In C5 and C6 root avulsion injury, the serratus anterior muscle is dysfunctional to a variable extent and, at times, presents with considerable winging of scapula. These cases may warrant neurotization of the long thoracic nerve to maximize shoulder abduction.

Patients and Methods

Between February 2009 and December 2012, 30 patients presenting with upper brachial plexus injuries (►**Fig. 1**) were subjected to magnetic resonance myelography and electromyographic studies. Presence of pseudomenigoceles and fibrillation waves supported the evidence of C5 and C6 root avulsions. Patients were operated 3 to 9 months after injury. The average denervation period was 5.6 months (►**Table 1**). Each patient was explored under general anesthesia with a short reverse "C"-shaped incision. Root avulsions were indicated either by an absence of C5 and C6 roots in the scalene triangle or presence of scarred, thinned-out, and flimsy nerve segments that failed to respond to an electrical stimulus. Multiple nerve transfers were performed to reinnervate the prime abductors and external rotators of the shoulder (►**Fig. 2**). In four patients with winged scapula (case numbers 6, 17, 20, and 27 in ►**Table 1**), an additional nerve transfer was performed to restore the serratus anterior muscle function by transferring a part of the thoracodorsal nerve into the long thoracic nerve (►**Fig. 3**).

Transfer of Distal Part of Spinal Accessory Nerve into Suprascapular Nerve

The patient was kept in semilateral position with an assistant holding the arm up in 90-degree abduction. An incision was made parallel to the spine of scapula. After division of the trapezius muscle fibers, the space between it and the supraspinatus muscle was opened.

The spinal accessory nerve coursing on the undersurface of the trapezius muscle was carefully isolated from the thin vessels and dissected further down along the medial border of scapula. Working laterally, supraspinatus muscle was retracted downward to expose the transversally oriented suprascapular ligament along the superior border of scapula. After gaining control over the suprascapular vessels, the ligament was divided and underlying suprascapular nerve was identified in the adipose tissue. The nerve was divided proximally and sutured to the spinal accessory nerve with 10–0 nylon suture or fibrin glue (►**Fig. 2**).

Transfer of Long Head Triceps Branch of Radial Nerve into Anterior Branch of Axillary Nerve

In supine position a curvilinear incision was made along the posterolateral aspect of the arm. The radial nerve was exposed in the triangular space and its branch to the long head of triceps was identified. The axillary nerve with its anterior and posterior branches was identified in the quadrilateral space. The long head triceps branch was sutured to the anterior branch of the axillary nerve with 10–0 nylon suture or fibrin glue (►**Fig. 2**).

Transfer of Lateral Branch of Thoracodorsal Nerve into Long Thoracic Nerve

With a longitudinal incision in semilateral position, the thoracodorsal nerve was identified along the anterior border of the latissimus dorsi muscle in the posterior axillary line. The dominant branch, usually the lateral, was traced distally and sectioned close to the muscle. The long thoracic nerve was identified and divided high in the axilla. The thoracodorsal branch was sutured to the long thoracic nerve with 10–0 nylon suture or fibrin glue (►**Figs. 3**, **4**).

Additional nerve transfers in restoration of elbow flexion consisted of ulnar and median nerve fascicular transfer to biceps and brachialis branches of the musculocutaneous nerve.

Postoperative Care

Postoperatively the operated arm was strapped to the chest for a period of 4 weeks. Mobilizing exercises and electrical stimulation were begun thereafter. The shoulder function was clinically assessed by measuring the abduction and external rotation with a goniometer. Abduction strength was measured on the Medical Research Council (MRC) scale. Clinical evaluations were performed at 3-month intervals for a period of 24 to 48 months (average: 32 months).

Results

The brachial plexus injury was a result of motorcycle accidents in 27 patients, four-wheeler accidents in 2 patients, and a fall from a height in 1 patient. All patients were males. The mean age of the patients was 25.1 years

Table 1 Functional outcomes of distal nerve transfers in shoulder function ($n = 30$)

Case number	Age	Denervation period (mo)	Follow-up (mo)	Abduction (degree)	Abduction strength (MRC grade)	External rotation (degree)
1	19	4	30	170	M4	70
2	21	3	24	150	M3	50
3	28	6	24	Stable shoulder with no active abduction	Nil	Nil
4	21	5	28	160	M3	60
5	18	4	36	170	M4	70
6[a]	29	4	26	160	M3	40
7	20	7	28	110	M3	Nil
8	31	3	24	140	M3	50
9	23	8	28	110	M3	Nil
10	19	4	28	160	M4	70
11	26	7	36	140	M3	40
12	29	9	24	100	M3	Nil
13	27	6	28	130	M3	40
14	24	4	26	140	M3	50
15	19	6	48	150	M3	50
16	35	7	24	90	M3	Nil
17[a]	24	4	28	150	M3	60
18	27	6	24	160	M3	50
19	32	4	30	Stable shoulder with no active abduction	Nil	Nil
20[a]	21	5	28	160	M4	60
21	25	7	26	110	M3	Nil
22	30	6	38	170	M4	70
23	27	5	30	150	M3	40
24	29	8	24	110	M3	Nil
25	32	4	26	Stable shoulder with no active abduction	Nil	Nil
26	21	6	24	140	M3	40
27[a]	19	4	20	170	M4	70
28	32	7	24	90	M3	Nil
29	25	5	26	120	M3	30
30	22	8	24	90	M3	Nil

[a]These patients presenting with winged scapula required an additional nerve transfer, that is, transfer of the lateral branch of thoracodorsal nerve into the long thoracic nerve.

(range: 18–35 years), and the denervation period ranged from 3 to 9 months (mean: 5.5 months). MRC scale was used to assess the preoperative muscle power of the target muscles. Preoperative shoulder abduction and external rotation were graded as 0 degree. Deltoid, supraspinatus, and infraspinatus muscles were assessed as M0. There was M5 power in the trapezius muscle and M4 in the triceps and latissimus dorsi muscles.

Results of Distal Nerve Transfers

Shoulder abduction was restored in 27 (92.86%) patients whereas external rotation could be reinstated in 19 (64.28%). An initial evidence of restoration of shoulder abduction appeared at 30 ± 4 weeks. The degree of restoration of shoulder abduction ranged from 90 to 170 degrees (average 118 degrees); 21 scored M3 and 6 scored M4 on MRC grade. Three patients in whom abduction could

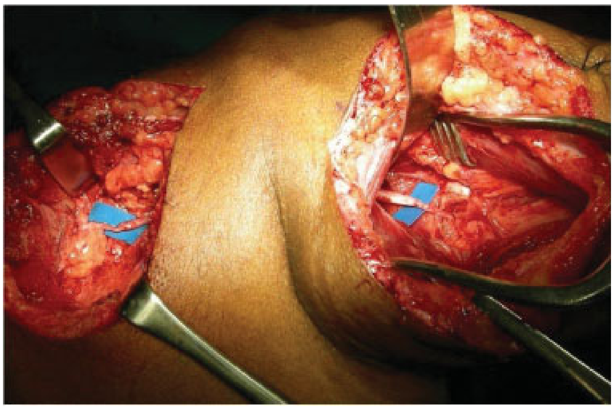

Fig. 2 Distal nerve transfers to suprascapular and axillary nerves (anterior branch).

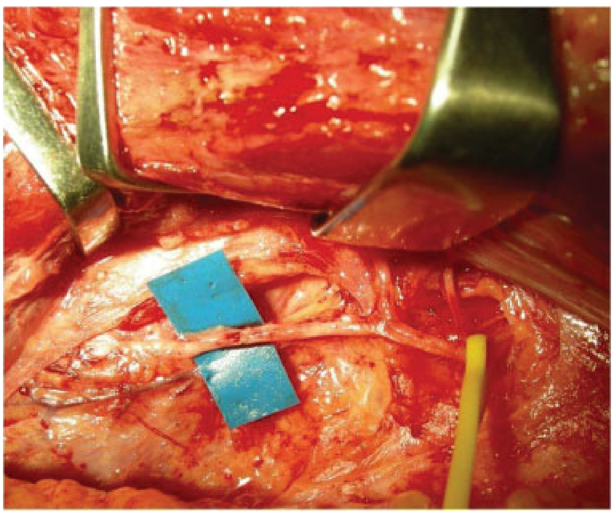

Fig. 3 Transfer of lateral branch of thoracodorsal nerve to long thoracic nerve.

Fig. 4 Surgical incisions.

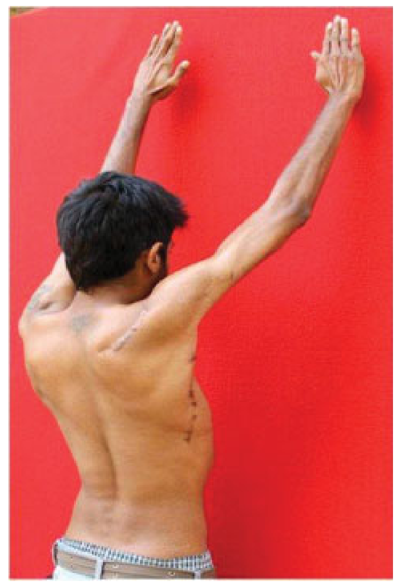

Fig. 5 Restoration of good range of active shoulder abduction and external rotation.

not be elicited on clinical examination were, however, symptomatically better in terms of stability of the shoulder joint and absence of pain.

External rotation was restored in 19 cases and the range of external rotation varied from 30 to 70 degrees (average 53 degrees).

At the final follow-up, winging of scapula had improved in three of four patients following reinnervation of serratus anterior muscle. Surgical outcomes are depicted in ►**Table 1** and ►**Fig. 5**.

Postoperative Follow-up

All patients were evaluated at 3-month intervals for a period of 24 to 48 months (average: 27.8 months). At 6-month follow-up, the trapezius muscle power was assessed as M4 in 27 cases and M3 in 3 cases. Muscle power in triceps was downgraded to M3 in all cases. In four cases in which lateral branch of the thoracodorsal nerve was used to reinnervate the serratus anterior muscle (case numbers 6, 17, 20, and 27 in ►**Table 1**), latissimus dorsi muscle power was assessed as M3.

Discussion

Restoration of shoulder function is an important goal in the management of devastating brachial plexus injuries. In C5 and C6 root avulsion injury, anatomical reconstruction of the plexus is not feasible and nerve transfer to the suprascapular and axillary nerves is a viable option in restoration of shoulder function.

A direct nerve transfer between the spinal accessory nerve and suprascapular nerve produces an average of 45 degrees of shoulder abduction (range from < 20 to 80 degrees).[1] The recovery in external rotation is variable depending on the number of axons ultimately reaching to the infraspinatus muscle. Conventionally the spinal accessory nerve is transferred to the suprascapular nerve by an anterior supraclavicular approach. An anterior coaptation has certain limitations: in severe traction injuries suprascapular nerve may be retracted retro/

infraclavicularly and its coaptation with spinal accessory nerve may necessitate a nerve graft; proximal transfer may denervate a significant part of the trapezius muscle; and distal injury to the suprascapular nerve, though rare, may be overlooked. A posterior transfer near the suprascapular notch is in close proximity to the target muscles. This possibly facilitates an early reinnervation, as suggested in one of the study.[2] In the series reported, clinically active shoulder abduction was restored in 27 patients. Three patients lacked active abduction, but shoulder was stable and free from pain.

A simultaneous nerve transfer to the axillary nerve yields much better results when adequate donors are available.[1,3–5] In anterior neurotization of axillary nerve, a considerable mismatch in the sizes of donor and recipient nerves results in dilution of nerve fibers entering the deltoid muscle.[5] A posterior transfer of the long head triceps branch into the anterior branch of axillary nerve in the quadrilateral space selectively maximizes the donor axonal input into a single muscle (deltoid).[6,7]

C5 and C6 root avulsion injury at times presents with considerable weakness of serratus anterior muscle. The serratus anterior muscle, innervated by the long thoracic nerve, originates from the external surfaces of the first eight ribs and is inserted to the costal surface of the scapula. This muscle stabilizes the scapula against the chest wall and is an important complement to deltoid function in shoulder abduction. In the serratus anterior muscle palsy arm can no longer be lifted higher than 90 degrees. With significant denervation, the scapula is tilted superiorly and medially and its inferior pole rotated medially. In cadaveric studies in 38 dissections, Wang et al[9] have reported different derivations of the long thoracic nerve: C4–7, C5–7, C5 and C7, C5–7, C5–C8, C6, and C7, and branch from C6. This may explain the varying extent of winging observed with different grades of injury. The anatomic study of the thoracodorsal and long thoracic nerves have shown that the lateral branch of the thoracodorsal nerve has an adequate length and sufficient number of axons for a direct transfer to the long thoracic nerve.[10] In the present series, four patients with winged scapulae underwent simultaneous neurotization of the serratus anterior muscle with a branch of the thoracodorsal nerve. In three of four patients, winging of the scapula improved with restoration of shoulder function.

In this study, patients with C5 and C6 root avulsion injury underwent distal nerve transfers close to the target muscles and exhibited a good outcome in shoulder function.

Conflict of Interest
None.

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