Axillary nerve repair by fascicle transfer from the ulnar or median nerve in upper brachial plexus palsy

Clinical article

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Object. Nerve repair using motor fascicles of a different nerve was first described for the repair of elbow flexion (Oberlin technique). In this paper, the authors describe their experience with a similar method for axillary nerve reconstruction in cases of upper brachial plexus palsy.

Methods. Of 791 nerve reconstructions performed by the senior author (P.H.) between 1993 and 2011 in 441 patients with brachial plexus injury, 14 involved axillary nerve repair by fascicle transfer from the ulnar or median nerve. All 14 of these procedures were performed between 2007 and 2010. This technique was used only when there was no deficit of the thoracodorsal or long thoracic nerve, which are normally used as donors.

Results. Nine patients were followed up for 24 months or longer. Good recovery of deltoid muscle strength was seen in 7 (77.8%) of these 9 patients, and in 4 patients with less follow-up (14–23 months), for an overall success rate of 78.6%. The procedure was unsuccessful in 2 of the 9 patients with at least 24 months of follow-up. These patients showed no signs of reinnervation of the axillary nerve by either clinical or electromyographic evaluation in 26 months of follow-up, and the second had Medical Research Council (MRC) Grade 2 strength in the deltoid muscle 36 months after the operation. The last of the group of 14 patients has had 12 months of follow-up and is showing progressive improvement of deltoid muscle function (MRC Grade 2).

Conclusions. The authors conclude that fascicle transfer from the ulnar or median nerve onto the axillary nerve is a safe and effective method for reconstruction of the axillary nerve in patients with upper brachial plexus injury.

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Key Words • neurotization • brachial plexus palsy • axillary nerve repair • neurorrhaphy • peripheral nerve

Neurotization, the transfer of a functional but less important donor nerve to a nonfunctional, more important recipient nerve, remains controversial. The main reason is a lack of large randomized clinical trials. In 1994, Christopher Oberlin introduced a new neurotization technique in which an ulnar nerve fascicle is transferred to the biceps branch of the musculocutaneous nerve, thus restoring elbow flexion in patients with upper brachial plexus injuries without significant motor or sensory deficits of the donor nerve. The advantages of the Oberlin technique include lower level of invasiveness, reduced regeneration distance, and the fact that the nerve transfer is performed in nontraumatized tissue distal to the site of injury. This technique can only be performed in patients in whom the lower brachial plexus is intact. In 2001, Songcharoen described an alternative technique using a median nerve fascicle to repair the musculocutaneous nerve and restore biceps muscle function. Since then, both methods have been used successfully in musculocutaneous nerve reconstruction. Other than some recently published case reports, however, we know of no studies in the literature about using motor fascicle transfer in the reconstruction of nerves other than the musculocutaneous nerve. The aim of this study was to examine the effectiveness of motor fascicle transfer in axillary nerve reconstruction.

Methods

A total of 791 nerve reconstructions were performed by the first author (P.H.) between 1993 and 2011 in 441 patients. (The procedures were performed from 1993 to 1998 at the Department of Neurosurgery, 1st Faculty of Medicine, Central Military Hospital, Prague, and from 1998 to 2011 at the Department of Neurosurgery, 3rd Faculty of Medicine, Charles University, Hospital Kralovske Vinohrady, Prague). A subset of 14 patients (13 male and 1 female) underwent axillary nerve reconstruction using 1 or 2 fascicles from the ulnar or median nerve between...
Fascicle transfer in axillary nerve repair

2007 and 2010 and constitute the patient group for this study. The mean age of these patients was 32.1 years (range 18–61 years). The average time between trauma and reconstructive surgery was 5.4 months (range 2–8 months).

This study was approved by the hospital institutional review board and informed consent was obtained from each patient.

Preoperative Examination

In all patients, the preoperative neurological status was assessed using the British MRC grading scale for muscle strength: Grade 0 (M0), no contraction; Grade 1 (M1), flicker or trace of contraction; Grade 2 (M2), active movement with gravity eliminated; Grade 3 (M3), active movement against gravity; Grade 4 (M4), active movement against resistance; and Grade 5 (M5), normal strength.16 Each clinical assessment was augmented by electrophysiological and radiological evaluations. All patients underwent preoperative electromyographic examination using concentric needle electrodes and nerve conduction studies. Cervical root avulsion was evaluated by means of CT myelography. We did not include MRI in the preoperative evaluation because it is unreliable for the assessment of root avulsion.3 All patients had a high lesion (avulsion or rupture) of some or all C5–7 cervical roots. In 2 cases, a coincident infraclavicular lesion of the ulnar nerve was also present.

Operative Technique

The infraclavicular approach was used in all patients. In cases of supraspinatus muscle denervation, neuritization of the suprascapular nerve was performed using the spinal accessory nerve via the supraclavicular approach.

We used fascicle transfer in patients with a lack of “classic donors,” such as thoracodorsal or long thoracic nerves, which are normally used for neuritization.5 The lack of these donor nerves was confirmed using both EMG and intraoperative neurostimulation.

The axillary nerve was transected 3.5–4 cm cranial to the quadrangular space (foramen of Velpeau) and dorsal to the subscapular vessels (Fig. 1). The flexor carpi ulnaris motor fascicle of the ulnar nerve was carefully selected using electrical stimulation of the proximal part of the arm. After epineuromy, the position of the fascicle was verified through observation of the reaction of the corresponding muscle in response to direct bipolar electrical stimulation. In some cases, the flexor carpi ulnaris muscle was innervated using 2 thin fascicles and it was necessary to use both of them to overlap the whole surface of the recipient nerve. In 2 patients, the fascicle of the median nerve for the flexor carpi radialis muscle was selected due to the absence of muscle activity in the flexor carpi ulnaris muscle. One or 2 fascicles were then transected and detached from the nerve approximately 1 cm proximally. The distal portion of the axillary nerve was transferred ventrally from the subscapular vessels and medially from the radial nerve and sutured to prepared fascicle(s) of the ulnar or median nerve (Figs. 1 and 2).

Postoperative Examination

All patients were hospitalized for 1 week with the upper extremity fixated in shoulder adduction and elbow flexion. The motor and sensory function of the hand was examined in detail. The extremity was fixated for 3 weeks; afterward, daily rehabilitation of the denervated muscles using electrostimulation was recommended. Patients were examined electrophysiologically using EMG and clinically using the MRC muscle strength grading scale every 6 months. A follow-up period of at least 24 months was planned.

Results

Axillary nerve reconstruction using fascicle transfer was performed in 14 patients. In 12 patients the axillary nerve was reconstructed using an end-to-end suture to an ulnar nerve fascicle. In 2 patients with concomitant infraclavicular ulnar nerve injury, the reconstruction was done using a median nerve fascicle. Nine patients completed a minimum follow-up period of 24 months (Table 1). Good recovery of deltoid muscle function and mass was seen in 7 of 9 patients (Figs. 3 and 4), which represents a success rate of 77.8%. A similar outcome was observed in 4 patients with shorter follow-up periods (14–23 months). The success rate for the whole group of patients was 78.6%. Only 1 patient (Case 6, follow-up 26 months) showed no signs of reinnervation of the axillary nerve based on either clinical or EMG evaluation. The patient in Case 4 had electrophysiological signs of reinnervation during EMG examination; however, the deltoid muscle strength was MRC Grade 2. The patient in Case 14 with short follow-up also had muscle strength 2.

In the whole group, the shoulder abduction angle ranges, as of this writing, between 40° (Case 14 with short follow-up) and 120°. The 2 patients with unsuccessful outcomes (Cases 4 and 6) can each abduct the shoulder to 50° with the help of the supraspinatus muscle. In the remaining group of patients with good deltoid muscle function, the minimum abduction angle was 80°.

In 2 patients (Cases 2 and 5), results of the 2-point discrimination test in both the little and ring fingers were worse the day after surgery than before surgery. None of the patients lost motor function in the hand. Three weeks after the surgery, sensory function was no worse than before surgery in any patient.

The function of the suprascapular nerve (supraspinatus muscle strength MRC grade ≥ 3) treated using nerve transfer of the spinal accessory nerve was restored in all 9 patients (100%, evaluated both clinically and electrophysiologically).

Discussion

The Oberlin technique is routinely used to reinnervate the biceps muscle and restore elbow flexion in cases of upper brachial plexus palsy. This technique produces excellent results, with success rates between 90% and 100% when the donor is the ulnar nerve and 64%–80% when the donor is the median nerve. The major benefit of this technique is the option to create a very distal suture close to the recipient muscle.4,7,10,12,17,20,23 We, however, do not use this particular method in musculocutaneous nerve
reconstruction because we have had very positive experiences using the pectoral nerves for neurotization of this nerve (91% success rate). This procedure plus suprascapular nerve neurotization using the spinal accessory nerve are our standard procedures.

Only 2 of the patients evaluated in the present study had partial short-term sensory loss after surgery. None of the patients lost motor function of the hand. This is in concordance with previously reported data.

The axillary nerve can be successfully reinnervated by neurotization using the spinal accessory nerve in 60% of patients, the phrenic nerve in 66%, intercostal nerves in 33%–67%, thoracodorsal nerve in 36%–93%, and the contralateral C-7 root in 52%. Recently, neurotization of the triceps branch of the radial nerve with the axillary nerve was performed to restore triceps muscle function. To date, however, there are no reports in the literature describing the use of ulnar or median nerve fascicle(s) for axillary nerve reconstruction.

Typically, the ulnar nerve is intact in an upper plexus injury due to its formation from the C-8 and T-1 roots.
The radial nerve, however, which arises from the C5–T1 roots, can be severely damaged in certain cases. Therefore, our method of using one or more fascicles from the ulnar nerve can be an alternative in patients with radial nerve weakness. The median nerve also arises from the C5–T1 roots. In patients with a combined supra- and infraclavicular injury, the median nerve is often the best of the 3 possible donors, in which case its fascicle should be used for axillary nerve repair, as described in 2 of our patients.

The success rate of fascicle transfer in axillary nerve reconstruction evaluated in our study (78.6%) is very similar to the success rates in the studies that used the Oberlin technique to restore elbow flexion. Only 2 of our cases (Cases 4 and 6) were unsuccessfully treated. The patient in Case 14 (with short follow-up) had MRC Grade 2 muscle strength, but function of the deltoid muscle appeared only a few weeks before the last examination. Therefore, progressive improvement is expected in this case.

Although the single nerve transfer of the spinal accessory nerve to the suprascapular nerve could yield a similar result, reconstruction of both the suprascapular

### Table 1: Group of 14 patients with axillary nerve sutured onto the fascicle from the ulnar or median nerve

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Avulsion Level</th>
<th>Latency (mos)†</th>
<th>Donor</th>
<th>Follow-Up (mos)</th>
<th>MRC Grade</th>
<th>Angle (“”)‡</th>
<th>SSN</th>
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<tr>
<td>1</td>
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<td>40, M</td>
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<td>UN–</td>
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<td>3</td>
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*MN = median nerve; SSN = suprascapular nerve–cranial nerve XI neurotization; UN = ulnar nerve; UN– = UN, partial sensory loss after surgery; + = done; – = not done.
† Period from injury to surgery.
‡ Angle of shoulder abduction.

The radial nerve, however, which arises from the C5–T1 roots, can be severely damaged in certain cases. Therefore, our method of using one or more fascicles from the ulnar nerve can be an alternative in patients with radial nerve weakness. The median nerve also arises from the C5–T1 roots. In patients with a combined supra- and infraclavicular injury, the median nerve is often the best of the 3 possible donors, in which case its fascicle should be used for axillary nerve repair, as described in 2 of our patients.

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**Fig. 3.** Case 3. Photograph obtained 24 months postoperatively showing success of fascicle transfer on the left side.

**Fig. 4.** Case 12. Photograph obtained 14 months postoperatively showing success of fascicle transfer on the left side.
and axillary nerves is usually performed to strengthen shoulder abduction.\textsuperscript{10,17} Even if it might be difficult to attribute improvement to neurotization of the axillary nerve in such cases, we demonstrated deltoid muscle function electrophysiologically using EMG and clinically using the MRC muscle strength grading system and by evaluation of muscle mass increase.

Conclusions

The overall results of motor fascicle transfer in axillary nerve repair were very good. This method provides an effective alternative for treatment of axillary nerve injury in an upper brachial plexus palsy, especially with concomitant radial nerve injury.

Disclosure

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Author contributions to the study and manuscript preparation include the following. Conception and design: Haninec. Analysis and interpretation of data: Kaiser. Critically revising the article: both authors. Reviewed submitted version of manuscript: both authors. Approved the final version of the manuscript on behalf of both authors: Haninec. Statistical analysis: Kaiser. Administrative/technical/material support: Haninec. Study supervision: Haninec.

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