Distal Nerve Transfer for Restoring Elbow Extension—Role and Outcome

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J Peripher Nerve Surg 2022–23;6–7:3–9.

Abstract

Background In a patient with good hand function, elbow extension is essential for "reaching out" for the objects especially for overhead activities and its absence drastically reduces the working space of the hand. The choice of the procedure for restoration of elbow extension would be quite case-specific; however, in select situations we performed partial nerve transfer of a fascicle of ulnar nerve to the triceps long head motor branch. We, herein, discuss our indications and selection criteria and present outcome in five cases.

Methods Between 2010 and 2020, five patients underwent the procedure as part of the management of their brachial plexus injury who did not require ulnar nerve as a donor for restoration of elbow flexion. Only the patients who underwent nerve transfer surgery were included in the study. Preoperative and postoperative strength of triceps was noted as per Medical Research Council grading.

Results All the five cases in this series recovered antigravity elbow extension at a minimum follow-up of 14 months (grade 4 in 2 and grade 3 in 3 patients). All the patients felt that the procedure improved their function and were extremely satisfied with the outcome.

Conclusion Though elbow flexion reconstruction still remains a priority, in patients with good hand function we always consider innervating the triceps. Restoration of elbow extension greatly improves the overall limb function and patient satisfaction. Ulnar nerve fascicle transfer to the triceps long head was found to be effective and safe.

Keywords
- restoration of elbow extension
- nerve transfer
- ulnar nerve fascicle transfer
- triceps
- brachial plexus

Introduction

Restoration of elbow flexion is considered as a priority in patients with brachial plexus injuries (BPIs) and there are substantial literature detailing the techniques and their outcomes in various severity of BPI.[1–9] However, there is a paucity of literature dealing with restoration of elbow extension in these patients. Traditionally, gravity-assisted extension of elbow had been deemed sufficient. Nevertheless, in a patient with good hand function elbow extension allows "reaching out" for the objects and is essential for overhead activities. Furthermore, it allows for more precise action of biceps and prevents "overshooting" the targeted flexion

DOI https://doi.org/10.1055/s-0043-1773805.
ISSN XXXX-XXXX.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

range. Hence, restoration of elbow extension must be included in the overall plan of care for these patients as it substantially improves the function of the upper limb.

Restoration of elbow extension could be performed by innervating the triceps by nerve grafting using the proximal functional nerves or by a nerve transfer using a dispensable donor nerve in the vicinity of the triceps motor branches. In delayed presentation, tendon transfers with deltoid or trapezius as donors could be offered. The choice of the procedure would be quite case-specific; however, in select situations we have achieved good outcome with partial nerve transfer of a fascicle of ulnar nerve to the triceps long head motor branch (LHTMB). We, herein, report our indications and outcomes of this relatively uncommon transfer.

Materials and Methods

Between 2010 and 2020, five patients underwent ulnar nerve fascicle transfer to the long head of triceps for the restoration of elbow extension as part of the management of their BPI. Five patients had a follow-up of more than 1 year and were included in the study (►**Table 1**). Each participant signed a written informed consent form, and the research followed the Declaration of Helsinki II guidelines. The study was approved by the institutional ethics committee.

The surgeon-in-charge conducted clinical evaluations to determine the muscle strength prior to the surgery. Medical Research Council (MRC) grading was used to measure muscle strength for elbow extension (►**Table 2**). All the patients had grade 0 triceps function at the time of surgical intervention, and hence were considered for nerve grafting/transfer surgery. Patients were offered this procedure only when they did not require ulnar nerve as a donor for restoration of elbow flexion. Only the patients who underwent nerve transfer surgery were included in the review and patients who underwent nerve grafting to the triceps long head branch were excluded. Outcome of the nerve transfer was assessed by evaluating the muscle strength of the triceps achieved at the end of 1 year from surgery and it was graded as per the MRC scale.

Surgical Procedure

Standard exploration of the brachial plexus, arm, and axilla (and infra clavicular region when required) was performed to identify the median, ulnar, radial nerve, and its branch to the long head of triceps. The final nerve reconstruction plan was decided based on the preoperative findings, intraoperative findings, and nerve stimulation response (►**Table 2** details the nerve reconstruction plan in the five cases). The ulnar nerve was identified in the plane between the biceps and triceps muscles and behind the basilic vein. Ulnar nerve was chosen for donating a fascicle to the long head of triceps because of its vicinity, experience available on its safety, and

Table 1 Patient demographics

Patient	Age	Sex	Mechanism of injury	Type of brachial plexus injury
1	46	Male	RTA	Infraclavicular
2	23	Male	RTA	Upper extended
3	34	Male	RTA	Infraclavicular
4	23	Male	RTA	Posterior cord
5	25	Male	RTA	Upper extended

Abbreviation: RTA, road traffic accident.

Table 2 Nerve reconstruction plan and results

Patient	Time to surgery (months)	Preoperative triceps power (MRC grade)	Donor nerve	Concomitant transfers	Recipient nerve	Follow-up (months)	Postoperative triceps power (MRC grade)
1	4	0	Ulnar	SAN to SSN; median nerve fascicle to brachialis	LHTMB	16	3
2	1	0	Ulnar	SAN to SSN; median nerve fascicle to brachialis	LHTMB	28	4
3	2	0	Ulnar	Neuroma resection and reconstruction with sural nerve grafts of axillary nerve	LHTMB	96	4
4	3	0	Ulnar	Neurotization of axillary nerve with thoracodorsal nerve	LHTMB	14	3
5	2	0	Ulnar	Median nerve fascicle to biceps	LHTMB	132	3

Abbreviations: LHTMB, triceps long head motor branch; MRC, Medical Research Council; SAN, spinal accessory nerve; SSN, suprascapular nerve.

observation that a longer fascicle length could be harvested from ulnar nerve with relatively more ease than the median nerve in order to reach the long head branch of triceps. The anteromedial or anterolateral fascicle of the ulnar nerve, destined for the flexor carpi ulnaris, whichever had the better size match with the motor branch to the long head of triceps, was chosen as the donor. Epineurium of the ulnar nerve was longitudinally incised under magnification, and low-frequency (0.2-0.4 mA) electrical stimulation was utilized to identify the fascicles that caused substantial wrist flexion but little intrinsic function. The fascicle that was dissectible for a length of about 2 cm and had a better size match (with LHTMB) was taken so as to allow an easy reach and coaptation with the LHTMB. The radial nerve was identified posterior and deeper to the ulnar nerve. Long head of triceps motor branch was identified at the lower border of teres major as the first branch arising from the radial nerve (►**Figs. 1** and **2**). Electric stimulation of the radial nerve and the LHTMB was used to confirm any functional activity in the triceps. The LHTMB was transected as proximal as possible to have a sufficient length to reach the ulnar nerve fascicle. A tension-free coaptation with the motor fascicle of the ulnar nerve was done using epineural suturing technique using 10-0 nonabsorbable sutures (►**Fig. 3**). The coaptation site is then augmented with nerve glue. In patients, where tissue scarring is encountered with the anterior approach, all the branches to the triceps from the radial nerve and ulnar nerve could be approached from the posterior aspect of the proximal arm. We have performed the transfer using posterior approach in one patient of this series. The other nerve transfers/repair required to address other deficits were completed concurrently. The limb was then immobilized in a sling for 1 month and thereafter they were advised passive mobilization and electrical stimulation of the triceps muscle. They were assessed at 1 month and then every 3 months for the rest of the 1 year of follow-up period.

Results

Five patients with traumatic BPIs underwent surgery between 2010 and 2020 with a minimum follow-up of 1 year. The average period of follow-up was 57.2 months (ranging from 14 to 132 months). At the last follow-up, two patients regained M4 strength and remaining three patients regained M3 strength with the isolated recovery of long head of the triceps. There were no complications observed.

The average age of the patients in the study was 30.2 years (range: 23–46 years). All patients were male. In terms of the mechanism of nerve injury, all of the patients suffered a traumatic injury in the form of road traffic accident. Two patients had upper extended type of brachial plexus palsy, two patients had infraclavicular BPI and one other patient had posterior cord injury (►**Table 1**). Preoperatively, the triceps muscle strength for elbow extension was MRC grade 0 in all these patients. Surgical procedures were performed at an average of 2.4 months after the injury (The minimum interval between injury and surgery was 1 month, and the maximum interval was 4 months). There were no intraoperative complication and none of the patients had any post-surgery motor or sensory deficit related to the fascicle transfer from the ulnar nerve. The independent recovery of the reinnervated long head of the triceps muscle rules out spontaneous recovery, which has been observed in upper root plexus injuries on rare occasions. In the present series, the patient age ranged from 23 to 46 years and the injury to surgery interval ranged from 6 weeks to 4 months. None to these two factors remarkably influenced the final outcome. All the five patients were functionally improved and were satisfied with the outcome of surgery (►**Fig. 4**).

Discussion

Restoration of elbow extension in BPIs has attracted much less attention in the literature and a gravity-assisted "fall"

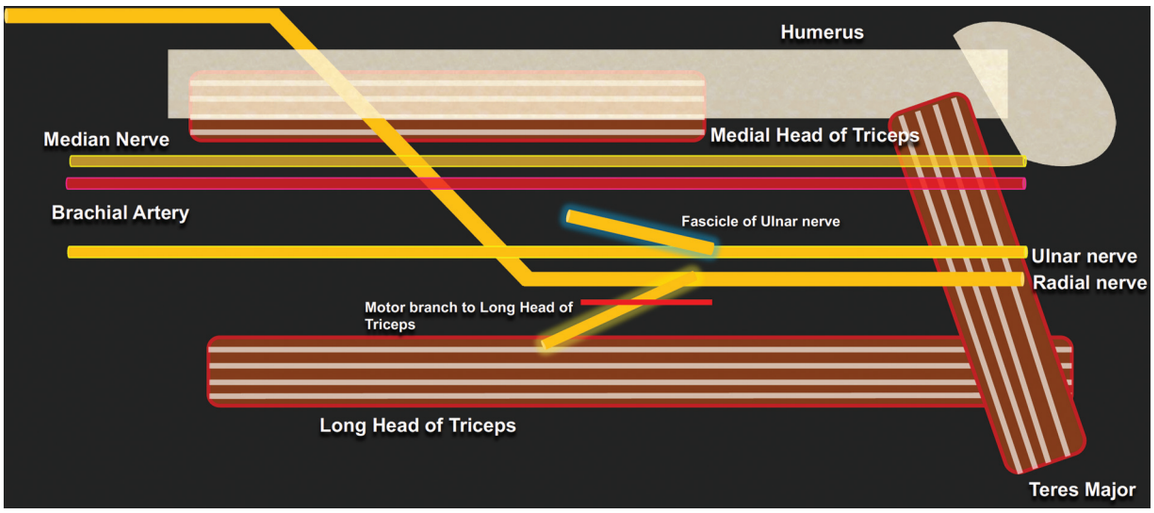

Fig. 1 Schematic illustration of the anatomy of the proposed transfer of ulnar nerve fascicle to long head of triceps motor branch.

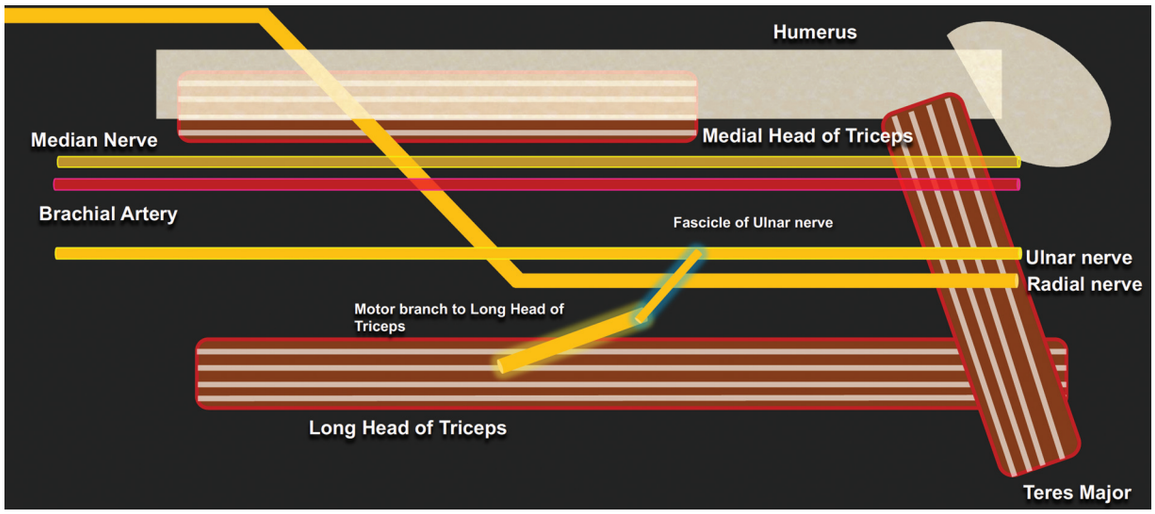

Fig. 2 Schematic illustration of the transfer of the ulnar nerve fascicle to long head of triceps motor branch. The transferred fascicle of ulnar nerve (blue) and the motor branch to long head of triceps (yellow) have been highlighted.

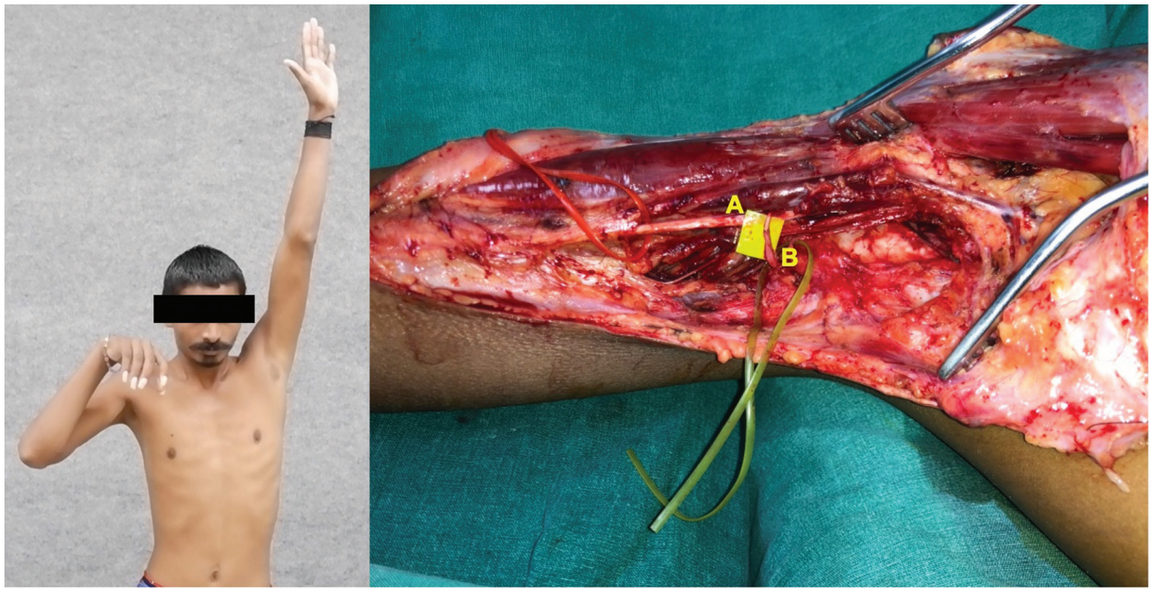

Fig. 3 A patient with paralysis of muscles supplied by the posterior cord of brachial plexus—lack of shoulder abduction, elbow extension, and wrist extension with intact elbow flexion; Intraoperative photograph showing fascicle of ulnar nerve (**A**) transferred to long head of triceps motor branch (**B**).

into extension is often considered sufficient. However, in a patient with good hand function the "reach" of the hand for various activities, especially the overhead activities, needs elbow extension and its absence would drastically limit hand function. Also, in the absence of an antagonist the biceps muscle function lacks precision and there is "overshooting" of the targeted flexion range. Furthermore, in cases where primary surgery fails to restore elbow flexion (M0 to M2), the reinnervated triceps could be used to provide this function.[10]

Restoration of elbow extension can be done by a nerve surgery (grafting or nerve transfer) or by performing tendon transfers. Nerve surgery is always preferred as it restores more "natural" movement and when successful, is much stronger than a tendon transfer surgery. Traditional nerve grafting remains an option when proximal functional nerve tissue is available. However, the modern distal nerve transfer techniques provide an opportunity for early restoration of function provided a suitable expendable donor option is available.[11] Moreover, nerve transfer would be a preferred option in cases where proximal nerve is not available for repair (avulsion) or is of doubtful quality for nerve grafting and in patients presenting late. Proximity of the nerve coaptation to the target muscle and it being away from the zone of injury results in an earlier recovery and a better success rate with nerve transfer surgery. Tendon transfer, though useful, is reserved for late presentations or after failed nerve surgery.

Fig. 4 Outcomes of the nerve transfer at 1 year of follow-up: visible contraction of the long head of triceps noted (arrowhead).

Various nerve surgeries have been used to restore elbow extension with varying outcomes. Apart from the available roots, contralateral C7 root, spinal accessory nerve, cervical plexus, phrenic nerve, and various intraplexal nerves have all been tried for reinnervating the proximal radial nerve.[12–16] All these options need nerve grafts of variable length resulting in two repair sites and a longer distance to the target muscle and hence are associated with modest outcome. Direct nerve transfer to the triceps motor branches is often possible from the donors like medial pectoral nerve (MPN), intercostal nerves (ICN), thoracodorsal nerve obviating the need for a nerve graft.[1] Furthermore, partial nerve transfer (fascicular transfer) from the ulnar or median nerve provides an excellent option for reinnervating the triceps with no obvious donor deficit. However, this is possible only when ulnar/median nerve fascicle transfer is not required for restoration of elbow flexion, which surely is a priority. Ulnar nerve is preferred over the median nerve because of its proximity to the triceps motor branches and its fascicular anatomy that allows harvest of a longer length of fascicle to allow tension-free coaptation with the triceps motor branch.

Flores used MPN for triceps reinnervation in patients with C5-7 brachial plexus palsies and found it to restore elbow extension in all the 12 patients, with seven attaining M4 motor power (58%) and remaining five attaining M3 power.[17] Soldado et al used the thoracodorsal nerve transfer to triceps motor branch to find MRC grade 4 triceps recovery in 7 of their 8 patients and MRC 3 in one. The (partial) denervation of the latissimus dorsi muscle had no significant effect in any of the patients.[18] Despite the positive outcomes obtained with ICN to triceps motor branch transfer, the procedure's utility is limited by the extensive and precise dissection necessary for ICN exposure, as well as their tiny diameter and lesser motor axonal count.[12] Flores found that transferring a healthy motor fascicle from the radial nerve of the affected side to one of its nonfunctional motor branches to the triceps is also an effective and safe procedure for restoring elbow extension in patients sustaining partial injuries of the brachial plexus.[19]

Flores used ulnar nerve motor fascicle transfer to the nerve to the long head of triceps to restore elbow extension function in two patients (injury to surgery time: 4 and 5 months) and achieved M4 muscle strength for the triceps at 7 and 8 months after surgery.[20] In a series by Emamhadi et al,[21] seven patients with partial BPI or posterior cord injury involving the triceps muscle were managed with transfer of a motor fascicle of ulnar nerve to the nerve to the LHTMB for elbow extension restoration. Six patients (85.71%) achieved M4 functional muscular strength. Electromyography- Nerve conduction velocity studies (EMG-NCV) were used to confirm reinnervation in all of the patients. We have used ulnar nerve motor fascicle to LHTM branch in five cases of partial plexus injury wherein the ulnar nerve fascicle was not needed for biceps/brachialis innervation. All five patients recovered elbow extension with two achieving MRC grade 4 and three MRC grade 3 motor power at a minimum follow-up period of 1 year. All the patients showed triceps recovery within 6 months with earliest clinical recovery noted at 3 months in a patient. Two of the patients with grade 3 recovery were of shorter follow-up duration (14 and 16 months) and were likely to progress to grade 4 with more rehabilitation as we had observed in other cases (►**Figs. 5** and **6**). However, a grade 3 power itself was observed to improve reach and overhead activities in all the patients and was associated with improved function and high patient satisfaction. No distal deficit was noted in the ulnar nerve in any of the cases. The number of cases in this series is small to derive reliable conclusions regarding the influence of age and injury to surgery interval on the outcome following this nerve transfer. However, consistent results noted in our series and the previous publications indicate that this nerve transfer is effective and safe.

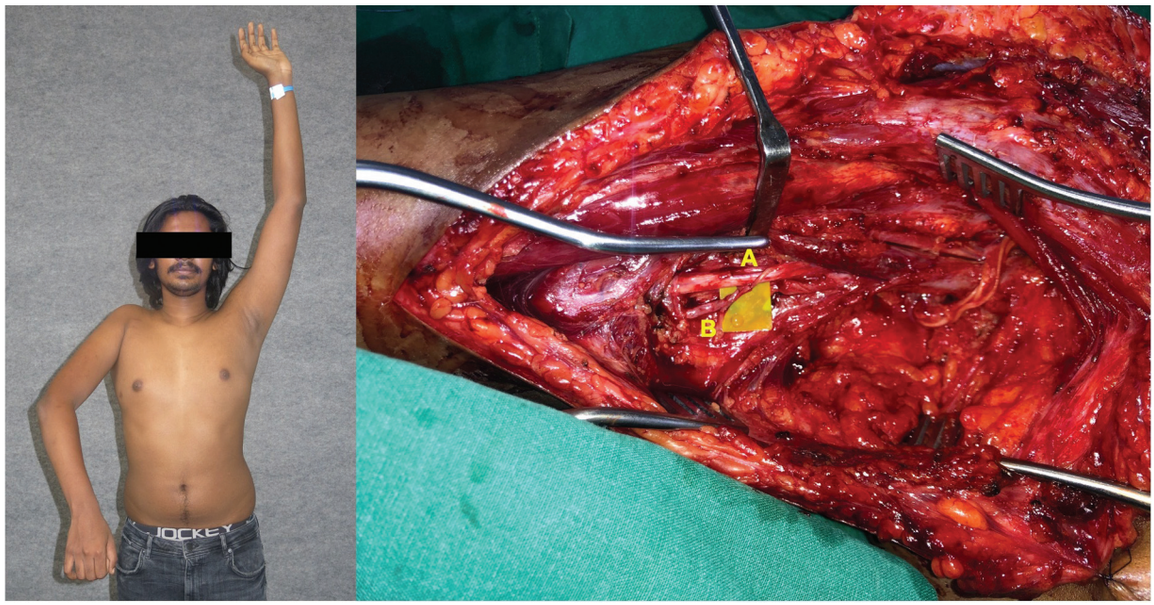

Fig. 5 A patient with partial brachial plexus palsy with paralysis of shoulder and elbow extension; Intraoperative photograph showing fascicle of ulnar nerve (**A**) transferred to long head of triceps motor branch (**B**).

Fig. 6 Outcome of the nerve transfer at 6 months follow-up.

Conclusion

The present series reports the outcome of ulnar nerve fascicle transfer to LHTMB. However, it is a select group of patients wherein the ulnar nerve fascicle was expendable for triceps reanimation and the proximal nerve was not available for grafting. Based on the favorable outcomes in these cases, we now prefer ulnar nerve fascicle transfer over nerve grafting using the proximal functional roots/nerve as it is more reliable, avoids nerve graft with two repair sites, and provides early recovery. Yet, it is possible only when the ulnar nerve is functioning normally and is not needed for innervating the elbow flexors.

Ethical Approval

Institutional research ethical committee approval was obtained for the study.

Informed Consent Declaration

Written informed consent was obtained from all subjects before the study. There is no information (names, initials, hospital identification numbers or photographs) in the submitted manuscript that can be used to identify patients.

Funding

None.

Conflict of Interest
None declared.

Acknowledgement
The authors wish to thank to Dr. Eitan Melamed and Dr. Madhusudhan NC for great help in interpreting the results and compiling the final article.

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