

REANIMATION OF ELBOW EXTENSION WITH INTERCOSTAL NERVES TRANSFERS IN TOTAL BRACHIAL PLEXUS PALSIES

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Background: Restoration of flexion in the elbow is the priority in the management of brachial plexus injuries. Current techniques of reconstructions, combining both nerve grafting and nerve transfer, allow more extensive repair, with additional targets: shoulder, elbow extension, hand. The transfer of intercostal nerves onto the nerve of the triceps long head is used to restore elbow extension. The aim of this retrospective study is to evaluate the results of this procedure, in total brachial plexus palsies with uninjured C5 and C6 roots. **Methods:** Eleven patients with total brachial plexus injury were reviewed 24 months in average after intercostal nerves transfer. The average age of the patients was twenty-nine years. The average time to surgery after occurrence of the injury was 5 months. Triceps re-innervation and strength of elbow extension were evaluated. **Results:** The averaged time required for triceps re-innervation after intercostal nerve transfer was 9 months. Seven patients achieved M4 elbow extension according to the Medical Research Council grading system. Two patients achieved M3 elbow extension. Two patients had poor results (M2 and M0). **Discussion and conclusions:** Transfer of intercostal nerves onto the nerve of the triceps long head is a reliable procedure for the restoration of elbow extension in total brachial plexus palsy. © 2010 Wiley-Liss, Inc. *Microsurgery* 31:7–11, 2011.

The use of intercostal nerves in the management of brachial plexus palsies has been reported by many authors.^{1–6} Although in most publications, the intercostal nerves were used to restore elbow flexion,^{1–3,5,7–9} some more recent reports describe its use in the re-innervation of other muscles.^{6,10–12} As a matter of fact, when elbow flexion may be restored by grafting from uninjured C5 or C6 roots, intercostal nerves may be used to restore another function as elbow extension. In line with this, we decided to transfer three intercostal nerves to the nerve of the triceps long head, aiming the restoration of elbow extension in brachial plexus palsies.¹¹ The purpose of the study was to assess the results of this procedure with non avulsed C5 or C6 roots.

PATIENTS AND METHODS

This retrospective study includes 11 patients with total brachial plexus palsy without diaphragmatic palsy. Their average age was 29 years (range 16–52 years). The average time to intercostal nerves transfer after the injury was 5 months (range 2–9 months). In all patients, MRI confirmed the C5 or C6 roots were not avulsed. One patient had associated paraplegia.

Restoring elbow flexion was always the priority. We performed eleven grafts with vascularised ulnar nerve from C5 or C6 root (the whole part of the root) to the musculocutaneous nerve. As regards shoulder function, the long thoracic nerve was stimulated preoperatively.

Provided no serratus muscle contractions were found, the accessory nerve was transferred onto the suprascapular nerve. When serratus muscle contraction was observed, shoulder arthrodesis was scheduled at a later date, so as to preserve the spinal accessory nerve and improve arthrodesis results.¹³ Only three patients underwent shoulder arthrodesis after nerve surgery.

As for elbow extension, all patients had a transfer of three intercostal nerves onto the nerve of the long head of the triceps muscle.

For finger flexion, fascia lata transfer was proposed after elbow flexion recovery and wrist arthrodesis.¹⁴

Operative Technique

Surgical approach was made via a continuous thoraco-brachial incision, with an additional Z-shape plasty at the axillary crease. The thoracic part of the incision was arch shaped beginning at the midline of the sternum 5th intercostal space, arching below the nipple and following the curve of the pectoralis major into the axilla. At the brachial level, the incision lie medially (on the neuro-vascular pedicle) and reached the axilla just beneath the pectoralis major tendon. Intercostal nerve harvesting was performed as described in the literature.¹¹ On the brachial side, the radial nerve was explored and generally found behind the brachial vein. The nerve in the long head of triceps was identified at the level of latissimus dorsi and teres major tendons. Intraneural dissection of this branch within the radial nerve helped maximising its arc of rotation and providing maximum length to facilitate direct suture to the intercostals nerves in the axillary crease, after proximal cutting. The intercostal nerves were glued to each other with fibrin glue and trimmed with sharp scissors or blade. Then, microsurgical coaptation was performed between the intercostal nerves and the triceps long head nerve using 11/0 nylon sutures with the arm in

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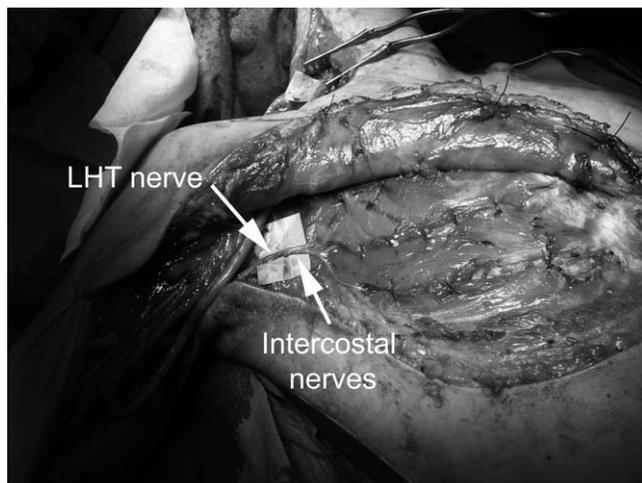


Figure 1. A continuous thoraco-brachial incision to harvest intercostal nerves and expose the long head of the triceps nerve (LHT nerve). Nerves are sutured in the axilla.

full abduction (Fig. 1). Only three sutures were performed under microscope. We never used any interposition nerve graft for this neurotisation; consequently, after defatting, the intercostal nerves cable provided a perfect size to match the nerve of the triceps long head (Fig. 2).

Postoperatively, the entire upper extremity was immobilised for 3 weeks in a thoraco-brachial splint with the elbow in 90° flexion. Passive elbow extension exercises were then encouraged to prevent joint contractures. As soon as the first contraction of the long head of the triceps muscle was seen, intercostal nerve stimulation was undertaken by asking the patient to breathe deeply. After active extension of the elbow against gravity was recovered, strength exercises against resistance were added.

RESULTS

The average duration of follow-up was 24 months (range, 18–28 months). No complications were noted. Nine patients recovered elbow flexion (one patient M3 and eight patients M4). Shoulder elevation was restored in two patients out of three with spinal accessory nerve transfer, and in the three patients who had shoulder arthrodesis.

The average time for the first triceps contraction was 9 months (range 5–11 months). Among the nine patients, who recovered M3/M4 elbow extension, the average time required to achieve extension against gravity was 16 months (range 13–20 months). Of the three patients with poor or fair results, two patients had this surgery more than 6 months after the injury.

M4 elbow extension was obtained in seven patients (Fig. 3) with average strength against 2.6 kg (1–3 kg).



Figure 2. Direct end-to-end suture between three intercostal nerves and the nerve of the LHT. The nerves match in size.

Two patients recovered active M3 elbow extension. Two had poor results (M2 or worse). All patients who recovered strong elbow extension were satisfied. The details of outcomes are shown in Table 1.

DISCUSSION

In our preliminary study,¹¹ we assessed intercostal nerves transfers to radial nerve in partial and total brachial plexus palsies. In the seven patients with total brachial plexus palsy, only four recovered M4 elbow extension. All patients with partial palsies recovered active elbow extension. In these cases, it may be difficult to make clinically the difference between the long head of the triceps re-innervation and spontaneous recovery of the lateral head of the triceps, from the C8 uninjured root.¹⁵ Consequently, we decided to study this transfer in an homogenous group of patient with total brachial palsies with non avulsed C5 or C6 roots.

When C5 and C6 are not avulsed, we prefer using a graft from C5 to the musculocutaneous nerve to recover elbow flexion than nerve transfer using an interpositional nerve graft from the intercostal nerves or spinal accessory nerve.¹⁶ We use vascularized ulnar nerves for long graft as described by Doi et al.^{17,18} As a matter of fact, the diameter of ulnar nerve match perfectly for musculocutaneous nerve and the suture is easier than with three fascicles from a sural nerve.

We reserve intercostal nerves to restore elbow extension, with a transfer to the nerve of the long head of the triceps. Intercostobrachial coaptation was the first procedure performed to re-innervate an avulsed brachial plexus.¹⁹ The imperfections of this method include the distance between the site of nerve suture and the de-

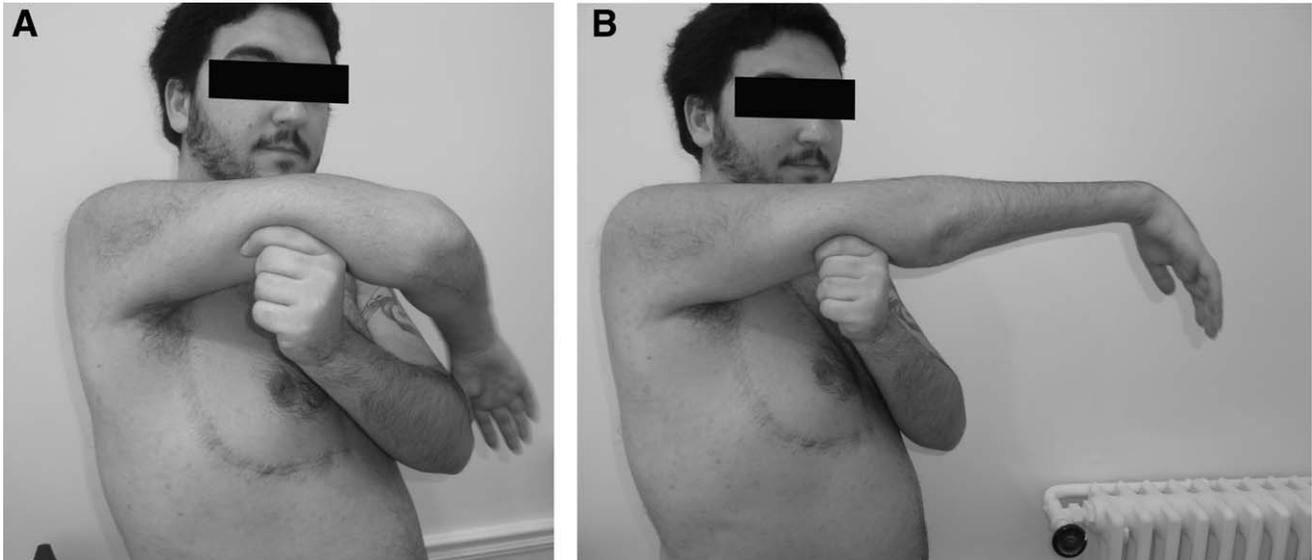


Figure 3. Active elbow extension has been restored. However, shoulder arthrodesis in this patient has not been performed yet.

nervated muscles, the use of nerve grafts, the mixing of motor and sensory axons at the suture line, and the relatively small number (500–700) of motor fibres.^{20,21} This explains why the first results reported in the literature concerning this technique were not always excellent (good results between 33% and 50%).^{4,20,22} Nevertheless, direct intercostal nerves transfer without interposition nerve graft is a valuable reconstructive procedure. Malessy⁸ achieved 64% functional elbow flexion in twenty-five cases of direct transfer of intercostal nerve transfer to the musculocutaneous nerve. El-Gammal reported 89.5% good and excellent results in intercostal nerve neurotisation to the musculocutaneous nerve.²³

Recovery of elbow extension has not been considered of much importance regarding functional outcome in brachial plexus injuries. The aim of restoring elbow extension is to achieve spontaneous and natural stabilization of the elbow, without the help of the contralateral normal hand. Thus, optimal prehension can be achieved, as has been described by Doi et al.²⁴ Moreover, locking the elbow is particularly important in bicycle riding, pushing objects, or performing transfers from the wheelchair in case of associated paraplegia.

Doi et al.²⁴ has attempted to restore elbow extension in brachial plexus palsies by intercostal nerve transfer in adults; 65% patients recovered active elbow extension but active elbow extension was limited by elbow contracture. In addition, Doi transferred only two intercostal nerves to the whole triceps branch.²⁴ These technical points could explain the difference with recent publications.^{6,15} As a matter of fact, restoration of elbow extension necessitated

the re-innervation of only one of the three heads of triceps muscle. We preferred using the nerve of the long head of the triceps, because it is the first branch from the radial nerve seen in the axillary, and the anatomic situation is perfect for suturing to the intercostal nerves. Moreover, this nerve can be divided very far into the radial nerve, increasing its length. Finally, the diameter of this branch matches perfectly the three intercostal nerves.

Active free muscles transfers may be proposed to recover elbow extension. However, vascular microsurgical failure is possible and tension of the free muscle is not easy to adjust. The results of active extension after free muscle transfers was achieved in six patients out of 24 transfers in Doi's experience.²⁵ Therefore, we prefer restricting this technique for late plexus palsies.

Finally, in case of a biceps recovery less than M3, we can transfer the re-innervated triceps so as to enhance elbow flexion strength. Furthermore, in case of C5-6-7 palsy, transferring the intercostal nerve onto the nerve of the triceps long head allows sparing the radial nerve and gives a chance for spontaneous triceps recovery by the re-innervation from C8 root.

Our results are similar to recent reports in the literature^{6,15} (81% of M3 or M4 elbow extension achieved). Several technical points could explain these results. We transferred three intercostal nerves, with good size match. Direct suture was always possible. Furthermore, because the nerve of the long head of the triceps is purely a motor nerve, no axons were wasted on a sensory component, and every motor fibres of the intercostal nerve were connected to motor fibres of the long head of the triceps branch.

Table 1. Patients and Results

	Age	Gender	Cause of injury	Time before surgery (months)	Follow-up (months)	Elbow flexion	Elbow extension	Shoulder elevation	Fascia lata transfer
Patient 1	17	M	Motorcycle accident	6	26	M4 (C5 to MC)	M4 (ICT to LHT)	Shoulder arthrodesis scheduled	No
Patient 2	25	M	Motorcycle accident	5	26	M4 (C5 to MC)	M4 (ICT to LHT)	M4 (Shoulder arthrodesis)	No
Patient 3	52	M	Motorcycle accident	9	21	M1 (C6 to MC)	M0 (ICT to LHT)	M0 (X1 to SS)	No
Patient 4	43	M	Motorcycle accident	9	27	M1 (C6 to MC)	M1 (ICT to LHT)	M3 (X1 to SS)	No
Patient 5	19	M	Motorcycle accident	5	26	M4 (C5 to MC)	M4 (ICT to LHT)	Shoulder arthrodesis scheduled	No
Patient 6	26	M	Motorcycle accident	6	24	M4 (C5 to MC)	M4 (ICT to LHT)	M4 (Shoulder arthrodesis)	No
Patient 7	47	M	Motorcycle accident	3	19	M3 (C6 to MC)	M3 (ICT to LHT)	Shoulder arthrodesis scheduled	No
Patient 8	26	M	Motorcycle accident	5	23	M4 (C5 to MC)	M3 (ICT to LHT)	M3 (X1 to SS)	No
Patient 9	25	M	Motorcycle accident	6	25	M4 (C5 to MC)	M4 (ICT to LHT)	Shoulder arthrodesis scheduled	Scheduled
Patient 10	28	M	Motorcycle accident	4	28	M4 (C5 to MC)	M4 (ICT to LHT)	M4 (Shoulder arthrodesis)	Active fingers flexion
Patient 11	16	M	Motorcycle accident	2	18	M4 (C5 to MC)	M4 (ICT to LHT)	Shoulder arthrodesis scheduled	Scheduled

MC, musculocutaneous nerve; ICT, intercostal nerves; LHT, nerve of the long head of the triceps; X1, spinal nerve; SS, suprascapular nerve.

Adequate surgery scheduling influence final outcomes.¹⁵ In our series, two patients who underwent surgery after 6 months, had poor results. In the series of Ruch et al.,⁹ six of the eight patients with successful results had a transfer performed within 5 months after injury. Nagano et al.² found that 75% of patients who underwent transfer 4 to 6 months after injury had fair or good results. This number decreased to 40% when surgery was delayed for over 7 months.

We did not test the pulmonary function in our series. Two studies^{26,27} had demonstrated a mild decline in pulmonary function without any subjective change in the respiratory status.

CONCLUSIONS

Intercostal nerves transfer to the nerve of the triceps long head is a reliable procedure that allows restoration of functional elbow extension. However, a larger series is needed to confirm these results. Besides, a functional and quality of life study is necessary to evaluate the interest of elbow extension in patients with brachial plexus palsy.

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