

## Nerve Transfer for Elbow Extension in Obstetrical Brachial Plexus Palsy

### Dear Editor,

The aim of this paper is to demonstrate the option of triceps muscle restoration by means of selective neurotisation of the radial nerve in children suffering from obstetrical brachial plexus palsy (OBPP) during their early years of life.

Early nerve surgery, which includes both brachial plexus reconstruction and nerve transfers, is generally accepted as the best option for treating children suffering from severe OBPP in their first months of life. As a matter of fact, nerve surgery is performed in order to achieve a higher potential of sensory and motor recovery in those children who would otherwise be doomed to an unfavourable outcome.<sup>1,2</sup>

Despite the option for early nerve surgery during growth, there is a large group of patients who are still showing signs of unsatisfactory recovery of upper limb function. In the said patients, the muscles are seldom completely denervated due to some regeneration of axons across the neuroma. Consequently, nerve transfers should be considered in these cases, keeping in mind that nerve surgery performed later than the first months of life, especially when nerve transfers are done in the following years, should be considered as a real delayed surgery, because nerve surgery should be performed as early as possible.<sup>3,4</sup>

The restoration of shoulder abduction and external rotation, elbow flexion, and prehension are the main goals of brachial plexus repair in infants, while elbow extension recovery has not been emphasised enough in the literature. However, a strong triceps muscle is fundamental to stabilise the elbow and allow greater reach. Wrist extension is also useful for a better grasp.

We present a case series of 10 patients, who underwent nerve surgery for restoration of elbow extension by means of neurotisation of the radial nerve in different ages after birth palsy (Table 1).

### Materials and Methods

Given that neurotisation in brachial plexus reconstruction is a well-known procedure that has been used for years, Institutional Review Board approval was not required. However, an informed consent was obtained from each patient, particularly supported by clear explanation of the risks and benefits.

Average age at surgery was  $3.3 \pm 1.87$  years (range, 0.8 to 5.5). In all cases, we performed neurotisation: in 5 cases, we transferred the third, fourth and fifth intercostal nerves to the radial nerve; in 4 cases, the fascicles of ulnar nerve for flexor carpi ulnaris were connected to the radial nerve; and in 1 case, either the spinal accessory nerve and the intercostal nerves were transferred, the first to the branches of the radial nerve for the triceps muscle, and the second to branches of the radial nerve for the wrist extensor muscles. Neurotisation by intercostal nerves was for those who presented a plexus palsy involving the inferior roots.

All the patients were evaluated by: clinical examination, triceps muscle sonography, magnetic resonance imaging (MRI) of the brachial plexus and electrophysiological examination to identify possible muscular denervation. A complete denervation of the triceps muscle was considered as a basis for exclusion from surgery.

One of the main goals of the neurotisation procedure is to achieve a functional result, preventing the loss of previous functions, even if those might be minimal. For that reason, during surgery, an accurate stimulation of the nerve trunk is performed, leaving the nerve fascicles untouched, which in turn presents an electrical response. On the other hand, nerve fascicles giving a minimal or an absent contraction of the muscle under electrical stimulation should be neurotised.

Surgery was performed under general anaesthesia without myorelaxation. A curvilinear skin incision was carried out in the anterior part of the axillary folder extended towards the breast in order to elevate intercostal nerves, or downward along the arm when the cubital nerve had to be dissected. The third, fourth and fifth intercostal nerves were isolated along the inferior part of the ribs and after section, the nerves were elevated and pulled backwards to connect them to the radial nerve stump that was already prepared, as a whole or in part.

Conversely, after the identification of the ulnar nerve at a proximal third of the arm, the fascicles of the ulnar nerve assigned to the flexor carpi ulnaris muscle were identified by means of intraoperative electrical stimulation and after resection, were passed through the axillary folder in order to reach the branches of the long head of the triceps muscle directly or with interposition of grafting.

Table 1. Case Series of Patients

Patients	Original Injury	Previous Surgery	Residual Funzional Deficit	Goal of Surgery	Age at the Time of Nerve Transfer	Donor Nerve	Recipient Nerve	Outcome*
Case 1	C5-C6-C7	No	Elbow extension	Triceps and extensor carpi radialis recovery	5 months	3-4-5 intercostal nerves	Radial nerve branch for long head of triceps	Fair
Case 2	C5-C6-C7	No	Elbow and wrist extension	Triceps recovery	8 months	3-4-5 intercostal nerves	Radial nerve branches for long head of triceps and estensor carpi radiali	Good
Case 3	C5-C6-C7	No	Elbow extension	Triceps recovery	4 years and 11 months	Branch of ulnar nerve to flexor carpi ulnari	Radial nerve branch for long head of triceps	Good
Case 4	C5-C6-C7	No	Elbow extension	Triceps recovery	5 years and 5 months	3-4-5 intercostal nerves	Radial nerve branch for long head of triceps	Good
Case 5	C5-C6-C7-C8-T1	No	Elbow extension	Triceps and extensor carpi radialis recovery	3 years and 7 months	3-4-5 intercostal nerves and accessory spinal nerve	Radial nerve branches for long head of triceps and estensor carpi radiali	Good
Case 6	C5-C6-C7	No	Elbow extension	Triceps recovery	2 years and 6 months	Branch of ulnar nerve to flexor carpi ulnari	Radial nerve branch for long head of triceps	Good
Case 7	C5-C6-C7	No	Elbow extension	Triceps recovery	4 years and 11 months	Branch of ulnar nerve to flexor carpi ulnari	Radial nerve branch for long head of triceps	Good
Case 8	C5-C6-C7	No	Elbow extension	Triceps recovery	4 years and 7 months	Branch of ulnar nerve to flexor carpi ulnari	Radial nerve branch for long head of triceps	Good
Case 9	C5-C6-C7	No	Elbow and wrist extension	Triceps recovery	8 months	3-4-5 intercostal nerves	Whole radial nerve	Fair
Case 10	C5-C6	No	Elbow extension	Triceps recovery	3 years and 2 months	3-4-5 intercostal nerves	Radial nerve branch for long head of triceps	Good

\*Outcome has been evaluated by means of the Medical Research Council Scale (Good >M4, Fair M4-/M3+ and Bad <M3).

A single patient underwent surgery using a posterior approach and by means of sural nerve grafting. In the remaining 3 cases, a simultaneous exposure of the ulnar and radial nerves in the axillary folder was carried out, obtaining a direct nerve suture without grafting. All the nerve coaptations were constantly performed by means of 10/0 stitches and fibrin glue.

## Results

We reevaluated all the patients by the Scale of Medical Research Council. Average follow-up was  $3.2 \pm 0.85$  years

(range, 2.5 to 4.6). The results were considered: good for functional outcome >M4, 8 cases; fair for functional outcome M4-/M3+, 2 cases; and bad for functional outcome <M3, no one. The 2 fair cases were total brachial plexus palsy treated by intercostal neurotisation.

## Discussion

Elbow extension recovery can be obtained with the repair of 2 specific branches leading to the long head of the triceps muscle. Some publications have illustrated satisfactory results in radial nerve repair using the intercostal nerves,

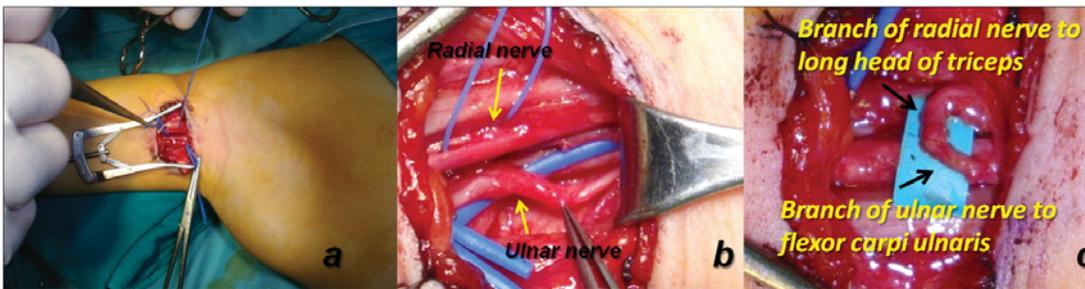


Fig. 1. At a and b, Microsurgical exposure of radial and ulnar nerves at the axillary fold. At c, two branches of the ulnar nerve leading to flexor carpi ulnaris muscle were directed to the branches of the radial nerve leading to the triceps muscle by means of direct nerve suture, without grafting.

despite the fact that the musculo-cutaneous nerve constantly demonstrates a higher level of recovery.<sup>5-7</sup> In our experience of radial nerve neurotisation (5 cases treated to date) by means of intercostal nerves, we have always achieved good results (>M3+).

Despite the fact that deformities of the chest and the spine in using intercostal nerves are often claimed, we have not observed those shortcomings. In fact, the surgeon should be aware of the risk of damaging the growing structures, which might lead to spine or thoracic deformities as sometimes has happened in thoracic surgery. The potential damage of the vertebral or costal physis would be caused by the vast ribs wide opening or by the extensive denervation of intercostal nerves. Actually, while elevating the intercostal nerves, we should always try to spare the surrounding tissues, avoiding extensive dissection. Thoroughly dissecting intercostal nerves with minimal incision, especially avoiding excessive stretching apart of the ribs, would be a solution to avoiding skeletal deformities during growth.

In patients without any involvement of the lower roots, we consider the ulnar nerve fascicles to be the number one choice for delayed repair of the radial nerve (Fig. 1). Conversely, when the ulnar nerve is impaired, the intercostal nerves always represent a good option for restoring elbow extension (Fig. 2).

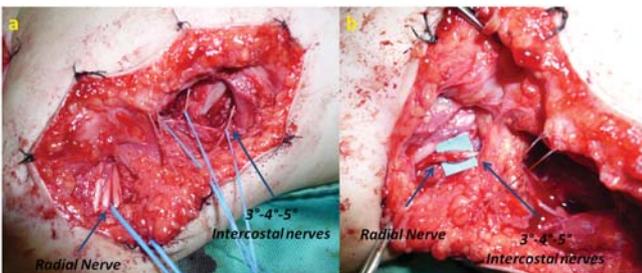


Fig. 2. When the ulnar nerve is impaired, the intercostal nerves always represent a good option for restoring elbow extension. In a), surgical exposure of radial nerve at the axillary folder and 3° and 4° intercostal nerves dissection is shown and in b), neurotisation of the intercostal nerves into the radial nerve is shown.

Objections deriving from the selective neurotisation procedure are the exhaustion of a prolonged denervated muscle and the time limit in which the nerve transfers should be performed. Actually, electromyographic studies may offer further indications, but the point to be considered in OBPP is that a complete denervation of the muscles rarely occurs. More often, in-continuity neuroma allows for recording some neurogenic potentials (i.e. late fibrillation potentials). Those are expressions of the muscle vitality.<sup>8,9</sup>

Through analysing our case studies, good average outcome has been reached, despite the amount of time elapsed since the nerve lesion. In fact, 8 in 10 cases have achieved a functional muscle strength (M4) of the triceps muscle. The explanation of the discrepancy between the results in children and in adults might stem from both prolonged nerve regeneration in childhood, in which residual muscle vitality is maintained despite the absence of functional motion, and the augmentation of residual triceps function, otherwise too weak for motion.

Another factor might be the short distance from the site of nerve coaptation to the target organ. Thus, the most critical point is the age at which such nerve surgery is indicated, particularly because it is difficult to hypothesise the time limit for performing a delayed neurotisation procedure of triceps muscle. Our data has also demonstrated that the percentage of negative outcomes did not increase in the event of a child being older. As a matter of fact, some positive outcomes have been recorded, regardless of the child's age at the time of surgery.

We are aware of the short follow-up of patients treated by means of nerve transfer for triceps recovery. However, those children have not demonstrated significant deformities, even if they are not fully grown. Considering the time elapsed since the obstetrical lesion and the prolonged muscular denervation, it is difficult to define a timeline beyond which surgery should be excluded. Having successfully treated children up to about 6 years of life, we do state that up until 6 years of age, late nerve surgery could be deemed acceptable. However, this does not rule out the possibility of surgery

on children of an older age. On the other hand, in general, for the upper limb but also specifically for elbow function restoration, the onset of elbow joint deformity and anterior soft tissue retraction may add further functional limitation.

## Conclusion

Patients with a lack of recovery of elbow extension, due to the palsy of muscles innervated by the posterior cord of the brachial plexus, are in need of selective repair of deficient muscular function.

To restore elbow extension, one possible solution is to reinnervate motor branches of radial nerve to the triceps muscle, in the hope of obtaining good functional results. Depending on the severity and extension of brachial plexus lesion, the radial nerve can be neurotised by means of intercostal nerves when the palsy involves the whole brachial plexus (thus inferior roots are damaged), while in upper or three radicular palsy, the use of fascicles of the ulnar nerve (modified Oberlin's procedure) is advisable.<sup>10</sup>

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