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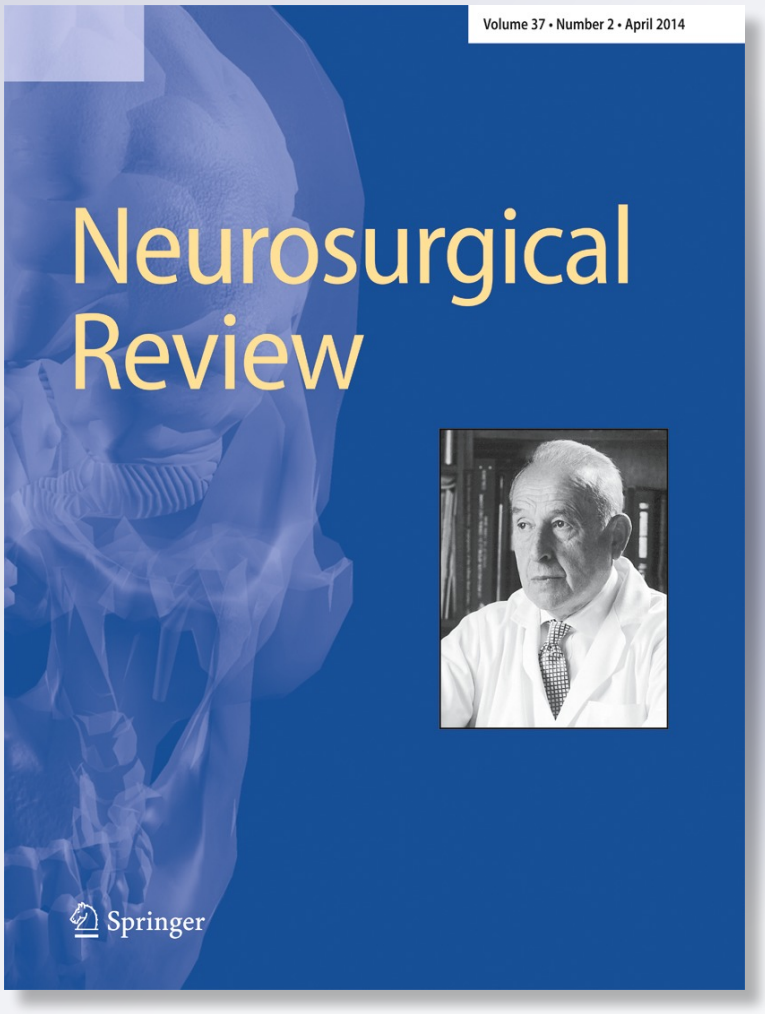

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ORIGINAL ARTICLE

The medial cord to musculocutaneous (MCMc) nerve transfer: a new method to reanimate elbow flexion after C5-C6-C7-(C8) avulsive injuries of the brachial plexus—technique and results

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Abstract The aim of this paper is to report on our ample experience with the medial cord to musculocutaneous (MCMc) nerve transfer. The MCMc technique is a new type of neurotization which is able to reanimate the elbow flexion in multilevel avulsive injuries of the brachial plexus provided that at least the T1 root is intact. A series of 180 consecutive patients, divided into four classes according to the quality of hand function, is available for a long-term follow-up after brachial plexus surgery. The patients enrolled for the study have in common a brachial plexus palsy showing multiple cervical root avulsive injuries at two (C5-C6), three (C5-C6-C7) and four (C5-C6-C7-C8) levels. The reinnervation of the musculocutaneous nerve is obtained via an end-to-end transfer from two donor fascicles located in the medial cord. The selected fascicles are those directed principally to the flexor carpi radialis, ulnaris and, to a lesser degree, the flexor digitorum profundus. Under normal anatomic conditions, they are located in the medial cord, and their site corresponds to the inverted V-shaped bifurcation between the internal contribution of the median nerve and the ulnar nerve. The technique has no failure and no complications when the hand shows a normal wrist and finger flexion and a normal intrinsic function. In case of suboptimal conditions of the hand, the technique has proved technically more challenging, but still with 67 % satisfactory results. In the four-root avulsive injuries, however, this method shows its limitations and an alternative strategy should be preferred when possible. EMG analysis shows a reinnervation in both the biceps and the brachialis muscles, explaining the high quality of the observed results. Moreover, this technique theoretically offers the possibility of a "second attempt" at a more distal level in case of failure of the first surgery. This procedure is quick, safe, extremely effective and easily feasible by an experienced plexus surgeon. The ideal candidate is a patient harbouring a C5-C6 avulsive injury of the upper brachial plexus with a normally functioning hand.

Keywords Brachial plexus injury · Musculocutaneous nerve · Nerve transfer · Cervical root avulsion · Brachial plexus repair · Biceps muscle · Brachial plexus

Abbreviations

MC	Musculocutaneous
FCU	Flexor carpi ulnaris
FCR	Flexor carpi radialis
EDC	Common extensor of the fingers

Introduction

At the onset of the microsurgical era of brachial plexus repair [36, 39], until the early 1990s [9, 13, 24, 53, 55], the treatment of an avulsive injury of C5-C6 or of C5-C6-C7 was a great challenge for the microsurgeon.

Often, the final function of an otherwise normal hand was left greatly maimed by an unsatisfactory result in the reanimation of the arm. Several techniques were attempted over the years to restore elbow flexion, but none of them [15, 47, 48, 54] with the possible exception of the medial pectoral nerves [4, 6, 19, 43] offered a constant and reliable muscle power. The lower pectoral nerves, however, are available in twos, and when both are used, they entail a remarkable loss of strength in the pectoralis major. Moreover, the feasibility of their use as

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a direct nerve transfer is unpredictable, since from time to time they require short grafts.

The extraplexual donors, namely the phrenic nerve [29, 57], the accessory nerve [1, 2, 21, 25, 42, 45, 49, 58], the intercostal nerves [3, 16, 20, 23, 31–33, 37, 38, 41], the motor cervical rami [8, 61] and the hypoglossal nerve [14, 30], were also variably used to restore elbow flexion with a high variability of results. So, in spite of considerable efforts, this kind of lesions rather often ended with a heavily disabled arm due in part to a poor quality of recovery in the biceps-brachialis complex.

The typical patient had great difficulty in lifting even moderately heavy objects, and he could barely reach a flexion of the elbow against gravity. This condition, in turn, was usually worsened by an unstable shoulder when the denervation of the rhomboids and serratus anterior muscles was marked and complete.

Not infrequently, due to a complete or partial failure of the biceps/brachialis muscles, we had to resort to a Steindler procedure to augment elbow flexion with its inevitable drawback of limitation in elbow extension. Not least, this operation's result is rather complex, with a high risk of failure when the extensors of the wrist and of the fingers were denervated as it may occur in C5-C6-C7 injuries.

In 1993 and 1994, the pioneering work of C. Oberlin [40] announced a true revolution in the treatment of C5-C6 avulsive injuries of the brachial plexus. In the original paper, he described a successful selective reinnervation of the biceps branches via a fascicular neurotization from the ulnar nerve. However, his merit went far beyond the pure technique he described. He opened in various directions the mind of microsurgeons, showing to the world that the neurotization from sound donor nerves, namely the interruption of some of their sound fascicles (fascicular neurotization), was not a sacrilege. Yet, the accurate selection of the donor fascicles allowed to restore new muscle functions without jeopardizing the integrity of the muscles innervated by the donor nerves.

This gave rise to the bypass or nerve transfer era [35], which has been, by far, the recent major advance in the field of brachial plexus reconstructive surgery. Many different ingenious transfers are currently used by microsurgeons [5, 7, 9, 10, 12, 17, 18, 22, 24, 26–28, 44, 50, 52, 56, 59, 60], and the direct reinnervation (without interposition of grafts) of the paralyzed nerves with motor branches coming from an intact part of the brachial plexus has gained worldwide acceptance. Very importantly, it can be done without fear of a significant weakening of the sound part of the plexus.

The nerve transfers available can be generally divided into two categories: extraplexual and intraplexual. Examples of each group are found in Table 1. However, a further division of the intraplexual neurotization may be recognized, namely the "terminal type neurotization" and the "not terminal type (or intraneural fascicular neurotization)". The terminal type neurotization entails a complete loss of function in the muscle

Table 1 Neurotizations variably used to restore elbow flexion

Extraplexual neurotization	Intraplexual (terminal type)	Intraplexual fascicular (not terminal type)
Cervical plexus	Thoracodorsal nerve	Median nerve
Accessory nerve	Subscapularis nerve	Ulnar nerve
Hypoglossal nerve	Medial pectoral nerve	Medial cord
Phrenic nerve	Branch to coracobrachialis	
Intercostal nerves		

denervated after full section of the donor nerve (e.g. in the thoracodorsal to axillary nerve transfer), while the not terminal type retains in great part, if not the whole, the function originally provided by the donor nerve. This can be obtained by using only a portion of the nerve as a donor and therefore is also called a fascicular neurotization.

Currently, intraplexual terminal nerves (such as the medial pectoral nerves or the thoracodorsal nerve) and especially the intraplexual fascicular nerves (the ulnar nerve and the median nerve) are the more commonly used transfers to reanimate elbow flexion [50, 52, 56]. They allow rapid and good results on elbow flexion not only compared to the extraplexual donors formerly described, but even with regard to the classical anatomical graft repair from the root stumps in case of a C5 and C6 rupture, particularly when the gap covered by the grafts exceeds 5–6 cm in length [11, 46]. This is prompting a different attitude in the repair of all the C5-C6 palsies, avulsive and not avulsive, since nerve transfer is far less invasive than sural nerve grafts (Ferraresi S.—III Sino European Meeting on Brachial Plexus Surgery, Milan (Italy), September 2012—oral presentation).

The authors have gained a wide experience with a new personal technique which is able to reinnervate the entire musculocutaneous nerve from two fascicles usually coming from the medial contribution of the median nerve at the level of the infraclavicular plexus. They describe it as *the medial cord transfer*.

Patients and methods

More than 250 patients have been operated with this technique from 1998. All of them were treated within 18 months after the trauma, with a peak incidence of 6 months interval. The vast majority of them are males (only five females). Their age at surgery ranged from the first to the fourth decade. Five patients were over their 50s and one was 75 years old. A 2-year follow-up is available for 180 of them. The patients have been grouped into four classes according to their clinical pictures.

Group A is made up of 127 patients presenting with a completely normal hand function including wrist and finger extensors, wrist and finger flexors and intrinsic muscles.

Group B is composed of 32 patients having a C5-C6-C7 avulsive injury, in whom the flexors and intrinsic muscles were perfectly normal but a wrist drop was present, similar to a high radial nerve palsy.

Group C is represented by 15 patients showing some loss of strength (M3) on wrist and finger flexors. Most of them ultimately will recover an M4 wrist and finger flexion by the end of the follow-up period. Wrist and finger extensors might or might not be functioning but, when present, were generally weaker than normal.

Group D (6 patients) had only one root left, and their hand was capable of some finger flexion and some intrinsic function scored M1-M2. In four patients, weak wrist, thumb and index finger extensions were also retained.

The number of patients forming the last two classes, especially group D which is exceedingly low, is biased by our ongoing experience.

In fact, due to the generally poorer results observed in the meanwhile in some of the patients showing a clinical picture of groups C and D, the medial cord technique was discarded in favour of other neurotizations, namely the intercostals or, rarely, the phrenic nerve.

Yet, in the last 3 years, our policy was to definitely discard the group D patients, while in the patients of group C, for whom we still consider this kind of neurotization in selected cases, we now tend to defer the surgery while waiting for a better recovery of the hand.

Surgical technique The entire plexus is always explored via the combined supraclavicular and infraclavicular approach. Our philosophy is to assess the level and the entity of the damage, to exclude an unexpected integrity of the upper plexus and to avoid missing a distal lesion of the musculocutaneous nerve at the entrance into the coracobrachialis muscle and of the axillary nerve at the quadrilateral space of Velpeau. The musculocutaneous nerve at the lateral cord is then traced back with a gentle fascicular neurolysis and prepared to be cut as proximally as possible (Fig. 1a).

Then, we isolate the medial cord, and an intraneural inspection of the medial part is undertaken. The procedure is painstaking, but it is imperative to repeatedly check at low intensity (0.2 and 0.3 mA) the area of division of the medial cord. Particular attention is focused on the medial contribution of the median nerve at the level of the take-off with the ulnar nerve. Here, finally, we select only the fascicles aimed at the flexor carpi radialis or ulnaris, usually made of one single voluminous fascicle or two smaller fascicles (Fig. 1b). The area to be cut is usually clearly defined and most of the times matches exactly with the section of the receiving MC nerve (video no. 1). The sutures are made of 9-0 nylon and fibrin glue.

In eight cases (4 % of the series), this technique had to be modified because of an anatomical variant consisting in a low take-off of the musculocutaneous nerve from the lateral cord (Fig. 2). In these cases, the musculocutaneous nerve was identified at the upper third of the arm, in the bicipital groove, then sectioned and rerouted, performing a direct suture with a donor fascicle located either in the medial portion of the median nerve and directed to radial wrist flexors (FCR), or in the ulnar nerve with one or two fascicles directed to ulnar wrist flexors (FCU). In our experience, shared also by Sungpet [50], the two neurotizations give similar results in spite of the electrical silence in the lateral contribution of the median nerve due to the avulsed upper roots.

In five more cases, the final technique has been carried out incompletely because of a residual function of the biceps seen at the intraoperative stimulation of the MC nerve. Since a contraction of the biceps was clearly visible, we decided not to cut the entire MC nerve, and a side-to-side suture was performed after opening the epi-perineurium between the selected medial cord fascicle and the entire musculocutaneous nerve, which was so left in continuity. The coracobrachialis branch of the MC nerve was freed from its entrance into the muscle, and this allowed the MC nerve to be transposed and anchored to the medial cord with 4-0 epineurial stitches to eliminate any tension at the suture site.

Results

A BMC score of M5 is by definition (normal strength) considered impossible to attain after nerve repair because of fatigue appearing after prolonged and repetitive muscle contraction. Yet, some of our best scores have a power and a volume of the muscle bellies which are practically indistinguishable from the normal side by an external unaware observer (see online video no. 2 and no. 3). Generally speaking, we will refer to as M4 those results from good to excellent. Useful results entail a minimum of a M3 biceps. It allows a flexion of the elbow against gravity with a clearly visible muscle belly. To eliminate the contribution of the epithroclear muscles, the elbow flexion must be obtained without clenching the fist, possibly with the wrist and fingers outstretched and a supinated forearm (Fig. 3 and video no. 3).

The results are summarized in Table 2.

Yet, some aspects of the results deserve a few adjunctive remarks, concerning not only muscle power, but also the timing and type of recovery, the effect on post-avulsive pain and paresthesias. In other words, in the best cases, the overall quality of the final result can well be defined as astonishing (Fig. 4—patient operated in video no. 1).

Group A The best results have been obtained in patients in whom a completely normal hand was present from the onset of the palsy. The outstanding fact is that in this group (excluding one case in which a side-to-side suture was chosen), we had no failures. A powerful biceps/brachialis complex (M4)

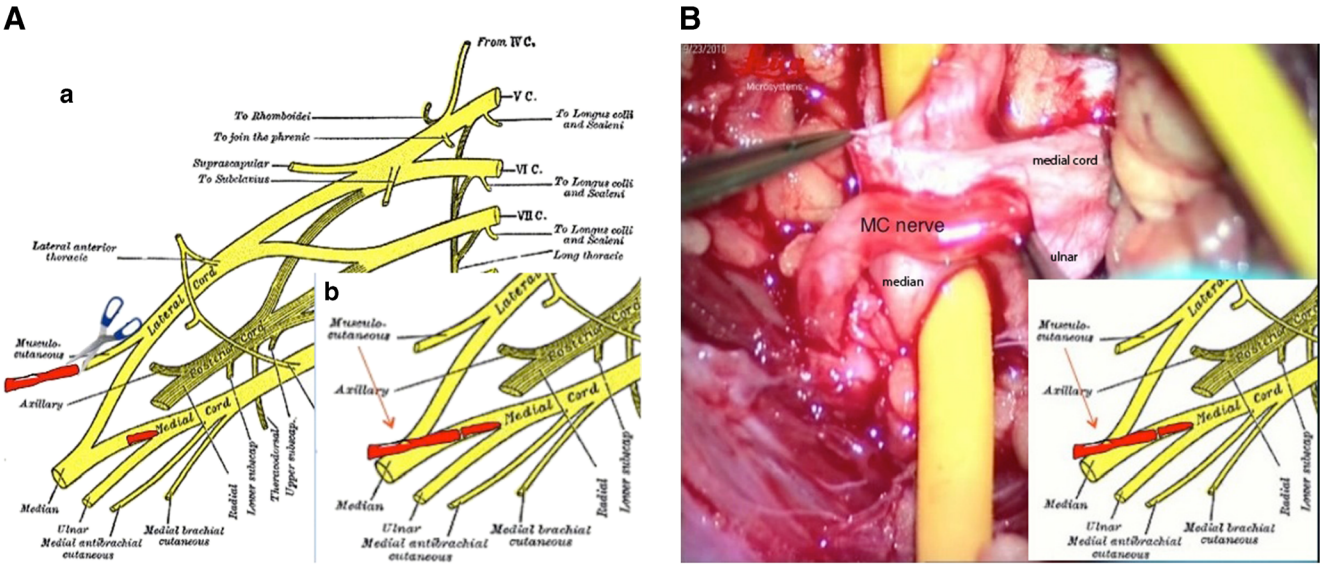

Fig. 1 **a** Main step of the procedure—pre and post. **b** Surgical field: selection of the donor fascicles (scheme in the *insert*)

has been obtained in about 95 % of the cases including the latest referral case (18 months) that scored M4 and in three of the patients older than 50 years. The man aged 75 years scored M3. None of them complained of loss of strength in the donor hand. The eight patients in whom a low take-off of the MC nerve prompted us to modify the original technique also scored constantly an M4 without any loss of the donor part. The technical variant and the preliminary results had been already published by our group in 2004 [12].

Interestingly, some of the worst results in group A come from those patients in whom the MC nerve was left in continuity and received a side-to-side epi-perineurial suture because of some residual function. On the whole, this technique is not rewarding because the reinnervation is either insufficient or very slow and difficult to be reached. Probably, the activity of the musculocutaneous nerve comes from a contribution of C7 which is not capable to increase significantly, and the side-to-side reinnervation is obviously less powerful than the end-to-end.

Among the five patients operated with this technique, four attained a M3 level, and one had to be reoperated 2 years after the first surgery because he was left with a biceps scored M1.

The late reinnervation done at arm level through a motor fascicle coming from the median nerve scored M4 after a 2-year follow-up.

Group B In spite of the lack of wrist and finger dorsiflexion, a powerful elbow flexion (M4) was generally obtained also in this group (70 %), with a slight increase in the number of M3 scores but still no failures (video no. 4). Although not demonstrated, the authors strongly support the hypothesis that the lack of the counteracting extensor forces due to the wrist drop entails a reduced range of movements of wrist flexors which,

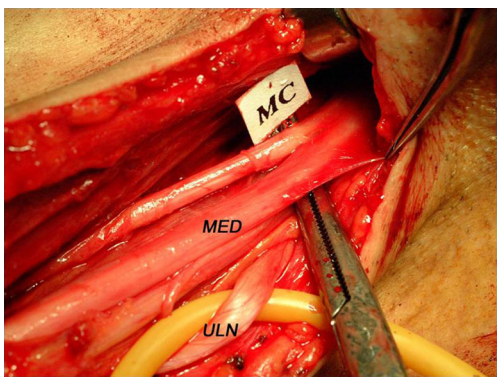

Fig. 2 Anatomical variant: low take-off of the musculocutaneous nerve from the median nerve in the arm

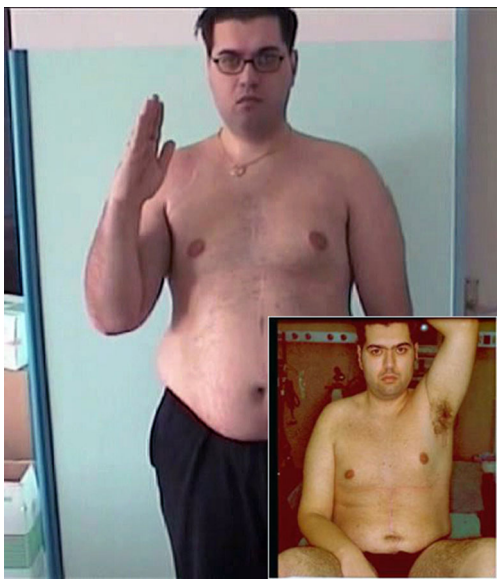

Fig. 3 Result 1 year after the procedure: see how the biceps/brachialis are completely independent by wrist flexors

Table 2 Results of the medial cord transfer technique

BMC score system	Class of patients			
	Group A (127[a] pts) Normal hand (pure C5-C6 avulsive injury)	Group B (32 pts) No wrist and finger extensors with normal hand flexors/intrinsic (C5-C6-C7 avulsed)	Group C (15 pts) Flexors/intrinsic M3-M4 (some degree of axonotmesis at C8)	Group D (6 pts) Flexors/intrinsic M1-2 (one-root hand due to C5-C6-C7-C8 avulsive injury)
M4	117 (8[a])	22	2	0
M3	9 (4[b])	10	8	0
M2	0	0	4	2
M0-M1	1 (1[b])	0	1	4
Total 180 pts.	127	32	15	6

[a] Eight cases in which the original technique was not possible because of a low take-off of the MC nerve

[b] (4+1) five cases in which a side-to-side technique was chosen because of some residual activity on the MC nerve

in turn, means weaker stimulus to activate the newly built neural pathway.

The very good news, also in this group, is the possibility to maintain intact wrist flexors and a normal intrinsic muscle function after the medial cord transfer procedure. All the patients in this class, in fact, later received a successful secondary surgery pro-dorsiflexion including the flexor carpi ulnaris (FCU) to extensor digitorum communis (EDC) tendon transfer.

Group C Patients referred to this group show some loss of strength (M3) in wrist and finger flexors. Among them, only a few attained a preoperative level near to M4 in hand function. Wrist and finger extensors might or might not be functioning, but if present, are weaker than normal. A 33 % failure to regain a useful elbow flexion is the outstanding feature in this group.

Fig. 4 Result 2 years after the procedure recorded on video 1: the overall movements are completely natural

Nevertheless, this also means a 67 % success (see video no. 5), but here, the procedure entails some risks for the integrity of the hand, as it happened in two cases (which later scored M3 in the biceps/brachialis) because the surgeon was tempted to cut more than one fascicle from the medial cord, in a crave for ensuring more power to the recipient muscles. This is because the intraoperative electrical stimulation and the selection of the fascicles are more difficult. They require an electrical impulse stronger than 0.3 mA. This brings about a spreading of the muscle response and, consequently, a less precise identification of the donor fascicles due to mass recruitment.

We still adopt the medial cord neurotization procedure for reinnervating the musculocutaneous nerve in selected cases, but considerable prudence and experience are necessary to make this choice. The patients and the physical therapist are asked for an intensive preoperative programme dedicated to improve and stabilize the strength and the resistance of wrist and finger flexors in the affected hand. A late surgery done on a near-normal hand is preferable to an early surgery in the presence of weak flexors of the wrist.

Group D In this group, the results are highly unsatisfactory, and if other possibilities are at hand, we no longer use the medial cord to musculocutaneous (MCMc) procedure in these patients. Only in particular circumstances, i.e. when intercostals or the accessory nerve is not available, will we resort to the medial cord technique. Typical candidates are middle-aged obese patients, with cardiac or pulmonary comorbidity and a hemidiaphragmatic palsy. For them, a further trauma to the breathing apparatus would not be advisable.

Clinical examination and EMG performed in 10 consecutive patients confirmed the recovery in both the biceps and the brachialis muscles.

About 1/10 of the operated patients still complain of pain/discomfort in the radial territory of the thumb and the index finger, but not one of them complained of excruciating pain nor required a major antalgic procedure (DREZ lesion). However, we cannot say if the MCMc technique is able to

soothe C5/C6 deafferentation pain because we lack a consistent control group (not operated or operated with a different procedure).

The timing of recovery is only slightly longer than with the original Oberlin technique.

Most patients start a visible recovery of the biceps muscle from the sixth to the eighth postoperative month, with a clear tendency toward an early recovery among the patients in group A.

The weaker the hand, the longer the period of recovery. Patients in group C never start their recovery before the eighth postoperative month.

The quickest recovery was seen at 3 months after surgery; the slowest started after 12 months.

At 18 months, the patients in group A and B could rely on a well-developed biceps-brachialis complex, while some of the patients in group C needed even 32 months to increase in strength up to the final score.

Discussion

Intraplexual nerve transfers of the "terminal type" such as the medial pectoral nerves, subscapular nerve and thoracodorsal nerve are, in our opinion, a second choice to restore elbow flexion.

This is mainly because their use implies a subtotal or a complete loss of function in their target muscles. The only exception is the accessory nerve, normally harvested after a distal intramuscular dissection in the anterior trapezius, which maintains the integrity of its target muscle. However, it should be used as a direct transfer to the suprascapular nerve, which is the technique of choice to restore good shoulder abduction, as confirmed by Merrell et al. reporting on a meta-analysis of the literature related to nerve transfers [34].

The thoracodorsal nerve also has a one-to-one effect, and its section paralyzes the latissimus dorsi, a powerful muscle which can be transferred monopolar to stabilize and reinforce the shoulder muscles or bipolar as a support to elbow flexion or as an elbow or wrist extensor. In addition, like the weaker subscapularis nerve, it is almost always affected in C5-C6-C7 avulsive injuries. We use it to neurotize the axillary nerve as part of the triad of microreconstruction in C5-C6 avulsive injuries (XI to suprascapular, medial cord (MCMc), thoracodorsal to axillary nerve transfer).

Although we do not ignore the immense value of the nerve transfer by means of the inferior pectoral nerves (by far the most reliable procedure in C5-C6 avulsive injuries before the appearance of the technique described by Oberlin), similar considerations apply to the medial pectoral nerves. Their harvest can weaken the lower pectoralis muscle, which has a powerful action in the thoraco-brachial pinch (such as carrying a book under the axilla) and could eventually be used as a monopolar or a bipolar transfer to reinforce a weak elbow flexion. In adjunct, from time to time and accordingly to the anatomical environment, a short interpositional graft is required to reach the MC nerve.

Due to all of these reasons, an intraplexual fascicular neurotization from the medial cord (MCMc), which leaves a normal hand function and spares the latissimus dorsi or the pectoralis major, appears to be the technique of choice.

Although the source of donor axons is ultimately similar or amenable to the Oberlin technique, specifically, the more proximal position of the MCMc technique offers distinct advantages, some of them exceeding all the other intrafascicular techniques of nerve transfer, namely the following:

- The medial cord technique MCMc is very effective, and its results are constant and reproducible in patients in whom the hand function, or at least its flexor and intrinsic power, is completely retained. The absence of wrist and finger dorsiflexion never had an impact on the final result.
- The technical procedure is delicate but does not require a special skill nor a particular learning curve for an experienced plexus surgeon.
- The procedure is straightforward in the course of a standard exploration of the plexus and does not require additional incisions in the arm.
- In case of failure, it leaves a "second occasion". An Oberlin type operation at the arm level still remains feasible since the function in the ulnar-innervated muscles is not significantly weakened after the first procedure.
- The reinnervation of the entire MC nerve theoretically could restore sensitivity in the cutaneous territory of C6, but this does not seem to be a distinctive advantage of the technique.

Table 3 Characteristics of other neurotizers of the musculocutaneous nerve

Intercostal nerves T3-T4-T5	Functional M3 result in 60 % of the cases
Accessory nerve	Excellent donor for the suprascapular nerve but unsuitable for a direct transfer to the MC: may require a fairly long graft (11–13 cm)
Phrenic nerve	Functional M3 result in 50–70 % of the cases with direct suture to the upper trunk. Requires graft if used for the MC nerve unless harvested from the thorax. Long-term effect of a diaphragmatic palsy unpredictable, especially on the right side
Thoracodorsalis nerve	Good result (but sacrifice of the latissimus dorsi) with direct coaptation to the MC nerve in most cases. However, it is usually unavailable in C5-C6-C7 avulsive injuries (patients of group B)
Medial pectoral nerves	Good result. Almost always a direct suture is possible (not in case of anatomical variant of the MC nerve). Severe loss of strength in the pectoralis major muscle

Instead, in three cases, we succeeded in a late (6 months after the MCMc procedure) selective reinnervation of the brachioradialis muscle using a nerve transfer between the cutaneous branch of the MC nerve (which in the meanwhile had also gained a motor attitude) and the nerve to the brachioradialis muscle.

The description of this procedure is clearly beyond the scope of the present paper, but this preliminary experience indirectly confirms the prevalence of the motor reinnervation over the sensory recovery.

- Denervation pain in the territory of the median of ulnar nerve has never been observed. We had, on the contrary, one case of long-lasting pain in the ulnar territory with denervation and reflex sympathetic dystrophy after a double Oberlin operation (one fascicle from the ulnar nerve to biceps motor branches and one motor fascicle of the median nerve to brachialis motor branches).
- In case of a weaker ulnar nerve function (M3 hand of Group C), the medial cord technique offers more choice (a selection of proximal mixed fascicles for FCR or FCU) than the Oberlin type procedure which, in the arm, can select only one nerve at a time (either the median or the ulnar).
- Although our experience ultimately demonstrates that the side-to-side procedure is not so rewarding as expected (see Table 2—patients), the medial cord technique can be applied even in the presence of a residual function of the musculocutaneous nerve. At infraclavicular level, a side-to-side suture with a reasonable expectancy of a further reinnervation is still possible without definite interruption of the MC nerve. The Oberlin type of nerve transfer, on the opposite, forces a definitive decision requiring the section of the receiving branches of the musculocutaneous nerve in the arm.
- The frequency and the power of reinnervation, thanks to the participation of the biceps and the brachialis, are stronger than with other techniques (see Table 3).

Drawbacks of the MCMc technique

- The technique cannot be performed in case of an anatomical variant of the lateral cord, namely a low sited take-off of the musculocutaneous nerve coming directly from the median nerve at the upper arm level. In this case, an additional incision below the axilla is required.
- There is uncertainty about the final strategy of reconstruction when some contraction is visible in the biceps after electrical stimulation of the entire MC nerve. A straightforward exposure of the MC nerve at the arm level [51] allows a direct stimulation of the individual branches directed to the biceps and to the brachialis muscles. This might permit a selective reinnervation of the terminal branches of the MC nerve.

Conclusions

We are enthusiastic about this technique, and in the presence of a normal function of the hand, we can anticipate for the patient a good outcome without fear of being contradicted by the facts. This also applies even in the presence of a wrist drop due to a C7 root avulsion.

If the hand function is good enough (M3/M4), although not normal, the technique can also be carried on with greater attention but with final results, on the whole, at least comparable to a neurotization with intercostal nerves. Yet, the procedure does not require an additional exposure and is quicker and more straightforward.

In case of a weak wrist and finger flexors ("T1-hand"), this procedure is not recommended, and doing intercostals (or an alternative technique) should be strongly considered.

The drawbacks are exquisitely technical and do not jeopardize the final result. They only eventually require additional incisions at the arm level to arrange for the best strategy.

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Comments

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Nerve transfers are very selective microsurgical procedures on peripheral nerves, allowing specific sensitive or motor reinnervation of selected important functional targets. In a recent review, we also looked at the indications, the important technical steps and the possible anatomic variety of these procedures, applied to severe proximal nerve damages like in severe brachial plexus lesions (1). There are a lot of potential motor donors and targets, according to the extent of the lesion and the reconstructive priorities.

The team in Rovigo has a large and sound experience with severe brachial plexus lesions and comes up with an interesting rather proximal nerve donor, choosing selective motor fascicles out of the medial branch contributing to the median nerve, arising from the medial cord. Compared to Oberlin's procedure, it is obvious that the origin of the donor fascicles out of the lower trunk allows a surgical indication even if the avulsion injury extends beyond the roots C5 and C6 to C7. This is a clear advantage.

On the recipient site, the authors show encouraging good results in functional recovery of the biceps-brachialis group, although the musculocutaneous nerve is targeted as a whole and not as selectively as compared to a single or double Oberlin type transfer. One even could imagine using the "motorized" initial sensitive branch of the musculocutaneous nerve for a specific motor nerve transfer more distally.

Ferraresi's paper is thus not only interesting from a conceptual point of view, but also shows, based on a large patient group, how the results are affected by a growing extent of the lesion to the lower brachial plexus roots.

The donor morbidity is slow, as this is mandatory for all selective transfers harvesting functional capacity out of still working networks.

I want to express my congratulations to the authors for their creative, well-documented, and properly written work, adding a worthful procedure to the armament of functional nerve transfers in the upper limb.

(1) Bahm J, Elkazzi W, Schuind F.: les transferts nerveux. Rev Med Brux 2011 32: 54–7.