Original Article

Transfer of flexor carpi ulnaris branches to selectively restore AIN function in median nerve sections: Anatomical feasibility study and case report

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Abstract

Background: In recent years, distal nerve transfers have become a valid tool for nerve reconstruction. Though grafts remain the gold standard for proximal median nerve injuries, a new distal transfer of flexor carpi ulnaris branches of the ulnar nerve to selectively restore anterior interosseous nerve function, concomitant with median nerve graft repair, could enhance outcomes. The objective of this paper is to anatomically analyze a technique to selectively reinnervate the thumb and index flexors.

Methods: Both the median and ulnar nerves were dissected in 10 cadavers. First and second branches to the flexor carpi ulnaris (FCU) were measured for length at its emergence from the ulnar nerve, and for width. The emergence of the AIN, just proximal to the arch of the flexor digitorum superficialis, was dissected, and the distance measured from this point to its motor entry at the long flexor pollicis and its branch to the long index flexor. A tensionless repair was performed between one FCU branch and the AIN.

Results: The mean AIN length was 32.3±8.20 mm and width 2.4±0.49 mm. The first branch from the ulnar nerve to the FCU measured 20.8±2.04 mm and 1.52±0.44 mm, while the second, more distal branch measured 24.3±8.71 and 1.9±0.17 mm, respectively. In all dissections, it was possible to contact both the proximal and distal branches of the ulnar nerve to the FCU with the distal stump of the divided AIN, with no tension or need for interposed nerve grafts.

Conclusions: Though proximal reconstruction remains the gold standard, new distal nerve transfer techniques may improve outcomes.

Key Words: Axon donor, distal nerve transfer, flexor carpi ulnaris, median nerve injury, nerve reconstruction
INTRODUCTION

It is a widely accepted principle in peripheral nerve surgery that distal injuries have a better prognosis for recovery than proximal ones, mainly because the growing axons have a shorter distance to reinnervate the target muscle. Due to the pioneering work of Mackinnon and Oberlin in the 1980s and 1990s, numerous procedures have been described over the last decade to augment the peripheral nerve surgeon’s armamentarium and these procedures now successfully compete not only with proximal graft repairs, but also with traditional tendon transfers.

On the other hand, it is well known from the literature that median nerve sections in the arm have an overall favorable prognosis for recovery when timing and surgical technique are respected at the moment of repair. These good results include successful sensory reinnervation of the median side of the forearm and hand, and good functional recovery of forearm flexor muscles. Nevertheless, it is also common to obtain poor results in terms of selective thumb and index flexor muscle recovery, innervated by the anterior interosseous nerve (AIN), the branch of the median nerve emerging at the proximal forearm. Those patients with successful reinnervation of the median nerve exhibit a common scenario: flexion of the thumb and index is only weakly obtained after flexion of the remaining strong forearm flexors, but not independently.

The aim of the present paper is to anatomically analyze a technique by which to selectively reinnervate the thumb and index flexors, by distal transfer of the branches to the flexor carpi ulnaris (FCU) [Figure 1]. This Ulnar to median nerve transfer, was originally employed in the present paper concomitantly with classical reconstruction of the median nerve with grafts, merging good sensory, and motor recovery of the forearm and hand achieved via the latter, with good selective motor reinnervation of the thumb and index fingers via the former technique.

MATERIALS AND METHODS

Ten formalin-fixed forearms were the basis of the present study. A skin incision midway between the passage of the ulnar and median nerves was traced at the level of the elbow. The ulnar nerve was dissected at its entrance through the ulnar tunnel and then distally. The flexor carpi ulnaris muscle was divided proximally and detached from its proximal insertion at the medial epicondyle and reflected anteriorly and ventrally. Branches to the muscle were carefully dissected and identified. The first and second branches to the flexor carpi ulnaris were ascertained for their length from the emergence from the ulnar nerve, and for their width in mm, both using a calliper. Both branches were then divided with a scalpel.

Figure 1: This schematic draw is intended to describe the proposed technique to ameliorate results of grafting proximal lesions of the median nerve. Top: a proximal section of the median nerve. The flexor carpi ulnaris branches and anterior interosseous nerve are shown. Bottom: the median nerve is grafted with sural nerve, and concomitantly a distal nerve transfer from one of the flexor carpi ulnaris branches to the anterior interosseous nerve nerve is performed

A classical incision described to expose the median nerve in the distal third of the arm was employed, after entering the cubital fossa posterior to the bicipital aponeurosis and passing between both heads of the pronator teres. Even though this zone has many variations, the nerve passes almost invariably between the flexor digitorum superficialis and the flexor digitalis profundus, which is where we identified it in our study. The emergence of the AIN, just proximal to the arch of the flexor digitorum superficialis and 5–8 cm distal to the medial epicondyle, was dissected. The point of emergence of the AIN from the median nerve is the section point of the former nerve. The distance was measured from the emergence of the anterior interosseous nerve to its motor entry point at the long flexor pollicis, and near its branch to the long-index flexor. The nerve was then transected at the aforementioned point, and the width of the nerve was measured. Figure 2 describes the anatomical description herein.

Both branches of the FCU were sectioned as distally as possible, immediately proximal to their entry point at the FCU. Finally, an attempt was made to bring into contact both branches of the flexor carpi ulnaris with the anterior interosseous nerve; both whether this was achievable, and whether or not it could be achieved without tension, were recorded.

RESULTS

The FCU and the AIN were exposed by the approach described herein. There were always at least two FCU branches: the first and second branched from the
ulnar nerve after it enters the cubital tunnel. Table 1 summarizes the results of our dissections. The mean AIN length was 32.3 ± 8.20 mm, and its mean width 2.4 ± 0.49 mm. The first (proximal) branch from the ulnar nerve to the FCU had a mean length of 20.8 ± 2.04 mm and width 1.52 ± 0.44 mm, while the second, more distal branch measured 24.3 ± 6.71 mm and 1.9 ± 0.17 mm, respectively.

In all anatomical dissections, it was possible to contact both the first and second branches of the ulnar nerve to the FCU with the distal stump of the divided AIN, without tension and, therefore, without the need to use any interposed nerve grafts.

The mean widths of the proximal and distal branches to the FCU were 68% and 72% the width of the receptor nerve (AIN), respectively.

**CASE REPORT**

A 28-year-old man sustained a lacerating injury in the proximal medial aspect of the left arm during a fight. He was initially treated in the emergency department with simple wound closure, and no more medical attention was sought for 10 months, at which time he presented to our department. A complete median nerve deficit had been observed immediately after the trauma, and this had persisted without change since that time. Ulnar, radial, and musculocutaneous nerve function were intact, as for the brachial and antebrachial medial cutaneous nerves. Preoperative evaluation included a Doppler ultrasound of the axillary artery and vein confirming that both vessels were intact and an electromyogram that correlated well with the afore-mentioned neurological deficit.

Immediate surgical exploration was indicated. At surgery, a classical axillary approach to the median nerve revealed a complete section, which required reconstruction with four grafts, each 8 cm long extracted from the left sural nerve. After this, a “lazy s” incision was created along the medial aspect of the distal arm, continuing toward the anterior aspect of the proximal forearm [Figure 3]. Surgical exposure of the ulnar nerve at the elbow, opening the ulnar tunnel and exposing the branches to the FCU, and of the median nerve from the medial bicipital groove up to the origin of the AIN nerve was performed, employing this incision. Then, sectioning of the AIN at its origin from the median nerve and of just the more distal of the two branches of the ulnar nerve to the FCU was performed. Good coaptation was obtained and the FCU branch was transferred to the AIN, employing three 10.0 nylon stitches and fibrin glue outside the suture. No tension was observed at the time of neurorrhaphy, and both wounds were closed. No FCU deficit was observed after surgery, and the patient had no such complaint.

Four months after surgery, the patient started to flex his index finger isolatedly [Figures 4a and b]. The thumb long flexor exhibited reinnervation 3 months later [Figures 5a and b]. One year after reconstructive surgery, sensation in the distribution of the median nerve and weak median flexor strength was evident at examination, M4 for index flexion and M3 for thumb flexion in the British Medical Research Council Scale was achieved, and thumb opposition remained absent. At 2 years of

| Nerve                | Sp#1 | Sp#2 | Sp#3 | Sp#4 | Sp#5 | Sp#6 | Sp#7 | Sp#8 | Sp#9 | Sp#10 | Mean | SD  |
|----------------------|------|------|------|------|------|------|------|------|------|-------|------|-----|
| AIN length           | 30   | 45   | 20   | 40   | 30   | 33   | 40   | 30   | 20   | 35    | 32.3 | 8.20|
| AIN width            | 3    | 2    | 2    | 3    | 2    | 3    | 2    | 2    | 2    | 2     | 2.4  | 0.49|
| FCU proximal length  | 17   | 20   | 20   | 20   | 22   | 21   | 20   | 22   | 25   | 21    | 20.8 | 2.04|
| FCU proximal width   | 1    | 2    | 1.5  | 2    | 1    | 1.5  | 2    | 1    | 1.5  | 1.5   | 1.5  | 0.41|
| FCU distal length    | 35   | 20   | 17   | 20   | 21   | 23   | 31   | 35   | 21   | 20    | 24.3 | 6.71|
| FCU distal width     | 2    | 1.5  | 2    | 2    | 2    | 2    | 2    | 2    | 2    | 2     | 2.2  | 1.9 |

FCU: Flexor carpi ulnaris, Sp: Specimen

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**Figure 2: Anatomical study. The white arrow pointing upward shows the median nerve, while the black arrow pointing upward shows the anterior interosseous nerve at its origin from the median nerve. The white star shows the ulnar nerve; and the black arrows pointing left show both ulnar nerve branches to the flexor carpi ulnaris. The bars show the section point of the anterior interosseous nerve and the second branch to flexor carpi ulnaris to achieve the nerve transfer.**

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**Table 1: Results in millimeters obtained after dissections of the donor branches (proximal and distal branches to the FCU) and receptor nerve (AIN), in length and width**
follow-up, the patient displayed no opposition and good sensation in the median nerve distribution including appropriate two-point discrimination. An EMG made at that time confirmed the successful reinnervation of the AIN-dependent muscles.

DISCUSSION

In our dissections, two main branches, one proximal and another immediately distal, were identified regularly emerging from the ulnar nerve to innervate the FCU. More branches could be present. The existence of these two branches made one expendable as axon donor. The match between one of these branches and the AIN was variable from one specimen to another (68--72%, considering only the mean nerve width), but relative to other distal transfers, this proportion is very adequate.\(^1\)

According to our findings, when transferring FCU branches to the AIN, individual situations should be considered. For instance, as depicted in Table 1, in specimen #1, the 2 mm width distal FCU branch adequately covered the 3 mm AIN; while, in specimen #2, the proximal FCU branch precisely matched the 2 mm AIN. The pure motor nature of both the AIN and FCU branches ensures no fiber misdirection to sensory targets.

Since the early work carried out by Seddon and others, and especially after the standardization of the method by Millessi in the 1960s and 1970s, reconstruction of a nerve gap with nerve grafts and microsurgical techniques has become the gold standard. The results of these techniques have been well established in many large series. It has become clear, therefore, that the more distal a nerve lesion is, the greater the opportunity for good motor and sensory recovery. This largely is due to the speed of the growing nerve toward its target, being 1 mm per day.\(^10\) In order to avoid irreversible atrophy, muscles must be reinnervated within 12--18 months of trauma, with empirical evidence absolutely clear that the sooner the repair, the better the clinical result. The time limit for sensory reinnervation is less clear than for motor reconstruction.

Nevertheless, even though overall motor results for primary repair with grafts are good, selective reinnervation of certain muscles is not the rule with complete nerve sections, this being especially true for small and distal muscles of the forearm and hand. In the case of the median nerve, due to its complex mix of sensory and motor fibers, recovery of anterior interosseous-dependent muscles (i.e., long thumb and index flexors) is difficult to achieve. Some authors\(^2\) even insist that nerve grafting presents certain obstacles to nerve regeneration, related to nutrition and structural factors that are not issues with nerve transfers.
In this scenario, a selective distal nerve transfer, like the one described in the present paper, could be of great help. Moreover, it could be combined with more proximal complete reconstruction with grafts, combining acceptable sensory reinnervation of the hand, gross motor reinnervation of the forearm (due to the proximal repair with grafts), and hyper-selective amelioration of thumb and index finger flexion due to the distal transfer described herein.

It could be argued that tendon transfers may overcome the same problem addressed in this paper. Nevertheless, according to Mackinnon[4] and Guelinckx,[5] the functional results of transferring a nerve are better than transferring a tendon, when the former is performed at an appropriate time. The sacrifice of one of the branches to the FCU, as described, is not associated with any deficit.

On the other hand, the usual tendon transfer for an AIN deficit (i.e., tenodesis of the flexor digitorum profundus long and index fingers to the flexor digitorum profundus (FDP) tendon of the ring and little fingers innervated by the ulnar nerve, and of the brachioradialis tendon to the flexor pollicis longus for recovery of thumb flexion) implies partial sacrifice of the afore-mentioned tendons, immobilization for 4 weeks, and the probable loss of independent movement of these fingers. Moreover, if the nerve transfer described in the present paper fails, there will be no contraindication to a later tendon transfer.

Another criticism of this technique is that some motor fascicles coming from the grafts of the restored median nerve could be wasted, because those fascicles originally heading to the AIN would not find a viable distal end to reinnervate. The poor results obtained using AIN-mediated muscles to reinnervate after primary reconstruction; the low morbidity of our technique in terms of FCU strength; and the relatively low percentage of fibers in the main trunk of the median nerve that actually go to the AIN justify employing a distal nerve transfer in association with a primary proximal repair. Combining these two techniques should generate better results than either procedure used alone, but this conjecture awaits larger series for confirmation.

The results of our anatomical studies clearly show that all principle criteria for transfer of donor nerves are met with the technique we have described: the donor nerve is near the target motor end-plates; its branches are expendable; it is a purely motor nerve; there is a good donor--recipient size match; and the donor and recipient nerves are not antagonistic against each other.

The fact that, in our case, thumb opposition was not restored in our patient is explained by the aforementioned poor general results for distal muscles that very proximal median nerve reconstructions with grafts exhibit. A third procedure, destined to selectively and distally reconstruct this function—an opponensplasty—is needed to ameliorate this deficit.

The technique presented in the current paper is the converse to the AIN to deep motor branch of the ulnar nerve transfer performed to improve intrinsic hand function in patients with isolated ulnar nerve injury.[2,3,11] Larger series still remains to be done in order to determine the exact rate of success of this new technique.

CONCLUSIONS

In the present paper, we anatomically describe a selective technique by which to reinnervate distal muscles after a proximal nerve injury, so as to restore function that is not usually recovered after classical reconstruction with grafts. Our anatomical study probes the feasibility of this procedure, in terms of axon-donor/receptor size and the need of an interposed graft to coapt both nerve stumps. We conclude that (1) the procedure is feasible; (2) interposed grafts are not necessary; (3) and the constant presence of two branches to the FCU does not imply theoretically a functional deficit if one of them is sacrificed. The surgical case presented in this study illustrates our anatomical findings. We ultimately conclude that, even though proximal reconstruction remains the gold standard for distal median nerve injuries, patient outcomes can clearly be ameliorated also using new distal nerve transfer techniques.

REFERENCES

1. Bertelli JA, Kechele PR, Santos MA, Maccagana BA, Duarte H. Anatomical feasibility of transferring supinator motor branches to the posterior interosseous nerve in C7-T1 brachial plexus palsies. J Neurosurg 2009;111:326-31.
2. Brown JM, Mackinnon SE. Nerve transfers in the forearm and hand. Hand Clin 2008;24:319-40.
3. Brown JM, Shah MN, Mackinnon SE. Distal nerve transfers: A biology-based rationale. Neurosurg Focus 2009;26:E12.
4. Dellow AL, Mackinnon SE. Musculopaoneurotic variations along the course of the median nerve in the proximal forearm. J Hand Surg Br 1987;12:359-63.
5. Guelinckx PJ, Carlson BM, Faulkner JA. Morphologic characteristics of muscles grafted in rabbits with neurovascular repair. J Reconstr Microsurg 1992;8:481-9.
6. Kim DH, Kim AC, Changda PK, Tiel RL, Kline DG. Surgical management and outcomes in patients with median nerve lesions. J Neurosurg 2001;95:584-94.
7. Millesi H, Meissl G, Berger A. The interfascicular nerve-grafting of the median and ulnar nerves. J Bone Joint Surg Am 1972;54:727-30.
8. Oberlin C, Beal D, Leechavengvongs S, Salon A, Dauge MC, Sarcy JL. Nerve transfer to biceps muscle using a part of ulnar nerve for C5-C6 avulsion of the brachial plexus: Anatomical study and report of four cases. J Hand Surg Am 1994;19:232-7.
9. Roganovic Z, Pavlichev G. Difference in recovery potential of peripheral nerves after graft repairs. Neurosurgery 2006;59:621-33.
10. Seddon HJ, Medawar PB, Smith HR. Rate of regeneration of peripheral nerves in man. J Physiol 1943;102:191-215.
11. Tung TH, Mackinnon SE. Nerve transfers: Indications, techniques, and outcomes. J Hand Surg Am 2010;35:332-41.