*Received: September 11, 2024*
*Accepted: November 24, 2024*

*Acad Med J 2024;4(3):108-117*
UDC: 616.833.35-089.844
https://www.doi.org/10.53582/AMJ2443108p
*Case report*

# A UNIQUE DISTAL NERVE TRANSFER FOR RECONSTRUCTION AND FUNCTIONAL RESTORATION OF THE THENAR BRANCH IN A HIGH MEDIAN NERVE LESION

**Pejkova Sofija[1], Georgieva Gordana[1], Gstöttner Clemens[2,3], Srbov Blagoj[1], Tusheva Sofija[1], Aszmann C. Oskar[2,3]**

[1]University Clinic for Plastic and Reconstructive Surgery, Faculty of Medicine, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia
[2]Department of Plastic and Reconstructive Surgery, Medical University of Vienna, Austria
[3]Center for Extremity Reconstruction and Rehabilitation, Medical University of Vienna, Austria
*e-mail:* pejkova@gmail.com

## Abstract

Timely and specific repair is critical for optimal recovery of thenar muscle function in high median nerve lesions. While many nerve transfers have been developed for such injuries, limited literature exists for thenar muscles. This article illustrates reinnervation of thenar muscles following high median nerve injury using fascicles from the deep branch of the ulnar nerve. We present a 30-year-old male with a history of open humeral fracture, soft tissue defect and total division of the median nerve. Six months after bone and soft tissue reconstruction, the median nerve was reconstructed at midarm level with sural nerve cable grafts. Immediate restoration of FPL and index finger FDP function was achieved using brachioradialis tendon transfer and side-to-side tenorrhaphy to the ring finger FDP. The thenar branch of the median nerve was reconstructed with 2.5 cm nerve graft using fascicle group from abductor digiti minimi. Pre- and postoperative nerve function was evaluated electroneurographically, with quantitative sensory-motor testing, photo- and video-documentation. Modified Bishop Rating Scale was used for endpoint analysis 18 months postoperatively. Early electroneurographic evaluations revealed clear evidence of innervation of thenar muscle targets by ulnar nerve axons. The abductor digiti minimi showed signs of chronic denervation. At 18-months, two-point discrimination was 4 mm for the little finger and 8 mm for the index and thumb, the middle finger not regaining this capacity. Pinch- and power grip strength reached mean values of 64% and 38%, respectively, compared to the unaffected hand. This procedure addresses the daunting issue of irreversible atrophy in thenar and intrinsic musculature following high or delayed median nerve injuries. The presented data validates that fascicles from the deep branch of the ulnar nerve provide sufficient axonal power for challenging median nerve targets at early post-reconstruction, offering valuable window of opportunity in high or late median nerve reconstruction.

**Keywords:** distal nerve transfer, thenar muscle reinnervation, high median nerve injury, nerve transfer, peripheral nerve reconstruction, hand function restoration

## Introduction

Restoration of thenar musculature after high median nerve lesions remains a challenge for reconstructive surgeons. Irrespective of etiology of median nerve injury, both late reconstruction and long regeneration distance account for prolonged denervation time, resulting in irreversible target muscle atrophy[1-3]. Furthermore, given the paucity of motor fibers (<500 axons) responsible for the thenar muscles, make it statistically almost impossible that these actually will find the thenar branch in the regeneration process[4]. The reconstructive goal after high median nerve lesions thus has traditionally been sensation of the median fingers and strong flexion of the thumb and index finger. Restoring thumb opposition was prioritized as this function has a paramount role in the hand for a wide range of intricate tasks.

In an attempt to diminish atrophy of the thenar muscles and restore hand function, the anterior interosseous nerve (AIN) transfer to the recurrent motor branch of the median nerve at the level of the wrist has been described[5,6]. This concept aimed at early reinnervation and provided a pure motor donor source. However, in high median nerve lesions this concept obviously will not work and other solutions must be investigated.

Anatomically three levels of exchange of motor fibers between median and ulnar nerve are described: median-to-ulnar nerve in the forearm or Martin-Gruber anastomosis (MGA), ulnar-to-median nerve in the forearm or Marinacci communication, the Riché-Cannieu anastomosis (RCA - described in 1896 by Cannieu and in 1897 by Riché) in the hand, between the recurrent motor branch of the median nerve and the deep motor branch of the ulnar nerve at the thenar.

Our aim with this case report was to present an artificial communication between the ulnar and the median nerve similar to Riché-Cannieu anastomosis (RCA) in a patient with a high median nerve palsy.

**Case description**

We present a case of a 30-year-old male with a 6 months’ history of left humeral shaft trauma. The patient suffered a high-energy polytrauma with an open left humeral shaft fracture, traumatic transection of the brachial artery and a segmental loss of the median nerve. Additionally, his left scapula, left clavicle, 6th and 7th left ribs, left radius fracture, left tibial plateau and left calcaneus were fractured. After initial stabilization, the primary surgical treatment was external fixation of the multifragmentary humeral shaft and end-to-end repair of the brachial artery. Median nerve reconstruction was postponed due to serious soft-tissue loss and severe wound contamination.

Six months later the patient was referred to our University Clinic for Plastic and Reconstructive Surgery with a complete high median nerve palsy for further management. Clinical examination revealed a complete loss of sensation in the autonomous area of the median nerve at the hand and forearm with obvious signs of thenar wasting and trophic loss.

The inactive thumb was in adduction, without the ability for opposition and loss of palmar abduction. Atrophy of the thenar muscles was evident. Furthermore, no active thumb and index finger flexion was possible. The wrist was in a position of ulnar deviation. and evidently weakened pronation of the forearm compensated by shoulder rotation was also recognizable. Muscle strength was assessed according to the British Medical Research Council (BMRC) grading system, with grade 0 for median nerve innervated muscles and 5 for muscles innervated by radial and ulnar nerves. More proximally a large scar on the medial aspect of the arm was visible. ENG studies indicated a high median nerve palsy and CT angiography revealed adequate and unobstructed brachial artery and stable humeral bone axis with callus in remodeling.

*Surgery*

The operation was performed under general anesthesia using short-term muscle relaxant, the arm resting on a separate table. The operation was performed under 3.5x magnification using loupes. After prepping and draping the whole left upper extremity and left leg, a tourniquet was placed at arm level at 250 mmHg. Following scar excision on the medial part of the arm, two large incisions in zig-zag style running from the proximal third of the arm all the way to the distal palmar crease were made. The median nerve was identified at upper arm level and marked with a vessel loop together with the exposure of ulnar nerve and brachial artery. The median nerve was then followed to the proximal neuroma and distally identified just proximal to the pronator canal. After resection of the proximal neuroma and distal glioma, a defect of 15 cm was present. This defect was grafted with two sural nerve cables (Figure 1).

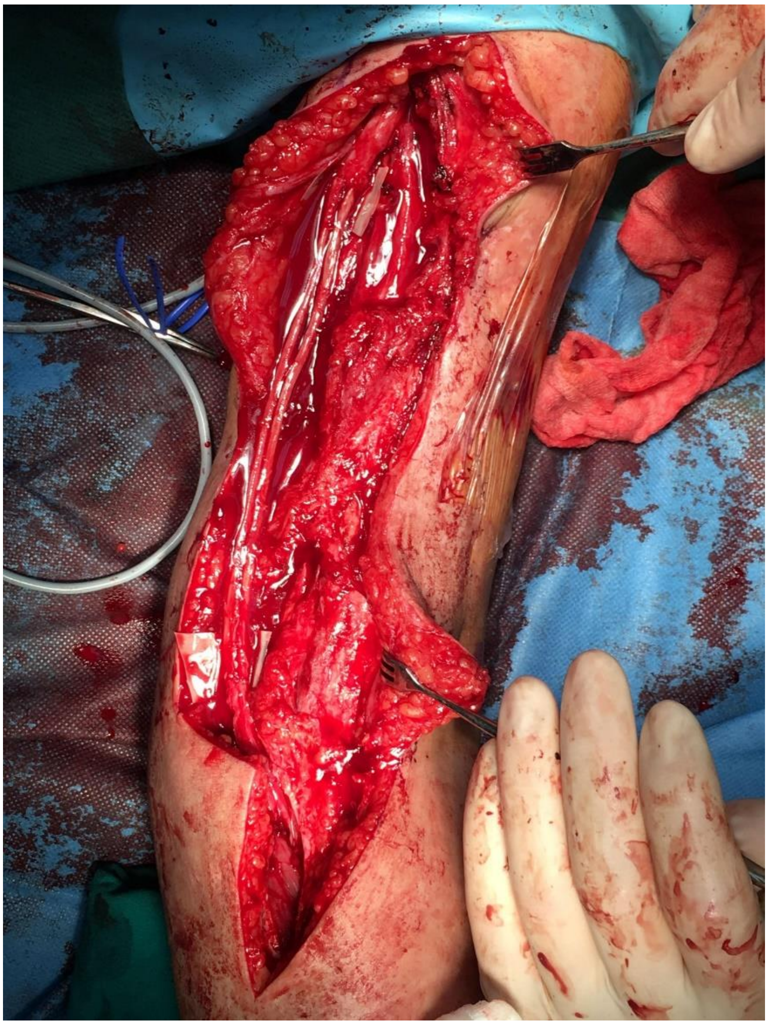

**Fig. 1.** Intraoperative site: post-resection defect grafted with two sural nerve cables.

The flexor pollicis longus (FPL) was reanimated with a classic tendon transfer using the brachioradialis (BR) muscle in a side-to-side fashion. The deep flexor tendon of the index finger was restored with a side-to-side tenorrhaphy to the FDP tendons of the ring finger and little finger at forearm level using 2-0 polyethylene terephthalate non-absorbable braided suture.

Finally, the carpal tunnel was opened to provide enough space once the axoplasm of the regenerating nerve fibers of the median nerve arrived at that level. Through the same incision, the ulnar nerve was explored at Guyon's canal. Here, the deep motor branch and the superficial sensory branch of the ulnar nerve were identified. Using a nerve stimulator NT 2 (Erbe Elektromedizin, Tübingen, Germany) the fascicle for abductor digiti minimi (ADM) muscle was isolated and marked with a vessel loop. Subsequently, the recurrent motor branch of the median nerve was looped and prepared for the nerve transfer. A 5 cm sural nerve interposition graft was prepared and coapted in an end-to-end fashion to the motor fascicle of the ADM and in an end-to-side fashion to the recurrent motor branch using epineural 9-0 nylon sutures (Figure 2).

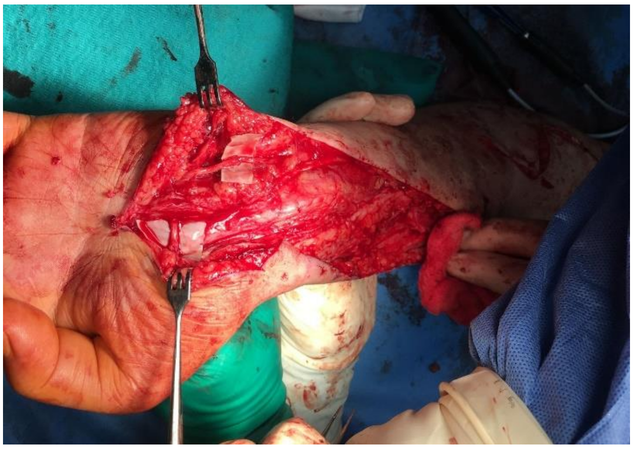

**Fig. 2.** Intraoperative site; interposition of a sensory cable graft, coapted to the motor branch of the ADM to the thenar branch of the median nerve.

A schematic demonstration of the position and installation of the artificial Riche-Cannieu anastomosis is shown in Figure 3. This was done with the purpose of fast reanimation of the thenar muscles that otherwise would have been lost.

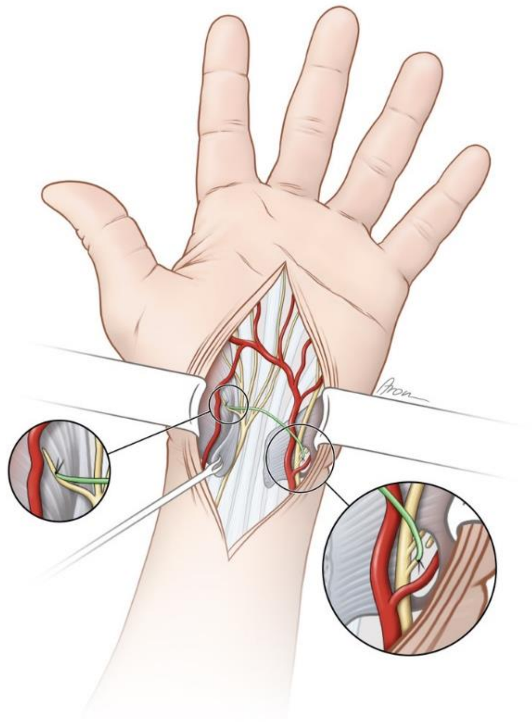

**Fig. 3.** Schematic demonstration of the position and installation of artificial Riche-Cannieu anastomosis.

Postoperatively the patient immediately followed an early active mobilization protocol to prevent adhesion of tendon transfers consisting of passive and active range of motion exercises.

*Electroneurography*

Electroneurography (ENG) was performed prior to surgery for the median and ulnar nerve in order to evaluate and complete the clinical indication for surgical treatment. Postoperative ENG was recorded in 3-month-intervals with a maximum follow-up at 18 months.

In order to gain evidence for median nerve axons sprouting along the artificially installed nerve graft into the recurrent motor branch of the median nerve, compound muscle action potentials (CMAP) and distal latency were determined from the abductor pollicis brevis and the 1$^{st}$ dorsal interosseous muscle after stimulation of the ulnar nerve. All ENG recordings were done at supramaximal stimulation of the corresponding nerves.

*Quantitative Sensorimotor Testing*

At follow-up evaluation, classic two-point discrimination (2PD) was measured in millimeters of distance at which two points can be distinguished, and for which the pressure of application was not specifically defined. One or two points were applied perpendicularly to the little finger pulp using a Disk-Criminator, with progressively decreasing distances until seven out of ten correct identifications of the stimulus was achieved by the patient. Pinch and Grip strength were measured in kilograms with a Dynomanometer [Electronic / hydraulic hand dynamometer MAP K1 40 130 Kg series KERN & SOHN Balingen, Baden-Württemberg]. Again 5 trials were recorded, the highest and lowest readings discarded and the remaining three averaged.

*Outcome Analysis*

Grip strength, pinch, two-point discrimination, residual symptoms, work status, and overall improvement was rated according to the modified Bishop rating scale (Table 1). Pre- and postoperative sensory and motor values were graded by the Highet-Zachary scale with regard to overall return of sensibility and motor recovery using the modification of Mackinnon and Dellon[16]. Final evaluation was performed 18 months post-surgery.

**Table 1.** Modified Bishop Rating Scale

| Parameter | Score |
|---|---|
| **Severity of Residual Symptoms** | |
| Symptomatic | 3 |
| Mild - occasional | 2 |
| Moderate | 1 |
| Severe | 0 |
| **Improvement** | |
| Better | 2 |
| Unchanged | 1 |
| Worse | 0 |
| **Work Status** | |
| Working previous job | 2 |
| Working other job | 1 |
| Not working | 0 |
| **Strength** | |
| Grip ≥ 80 % of other hand | 1 |
| Grip < 80 % | 0 |
| **Sensibility** | |
| ≤ 5 mm | 1 |
| > 5 mm | 0 |
| **Maximum Total** | 9 |

Total of 8-9: excellent, 5-7: good, 3-4 fair, 0-2 poor

**Results**

Preoperative CMAP was 0 mV for the median nerve at the thenar eminence, which corresponded very well with the clinical presentation of thenar wasting and MRC 0. (de Carvalho and Swash 2000). Postoperatively, the median nerve CMAP increased, which corresponded to an equivalent of MRC grade 4+. Although APB activity was not recorded preoperatively, postoperatively contributions were recorded from the ulnar nerve, confirming that the nerve transfer was functioning and muscular activity was restored.

Final examination of thenar muscle function was tested by pinch- and grip strength in percent of the contralateral hand recorded values of 64% and 38%, respectively. Functional sensory recovery testing performed at the index and thumb pulp achieved values of 8 mm. The results of the endpoint analysis proved an excellent outcome. Photo-documentation of the patient’s hand function is shown in Figure 4, clinically showing unimpaired thenar muscle function.

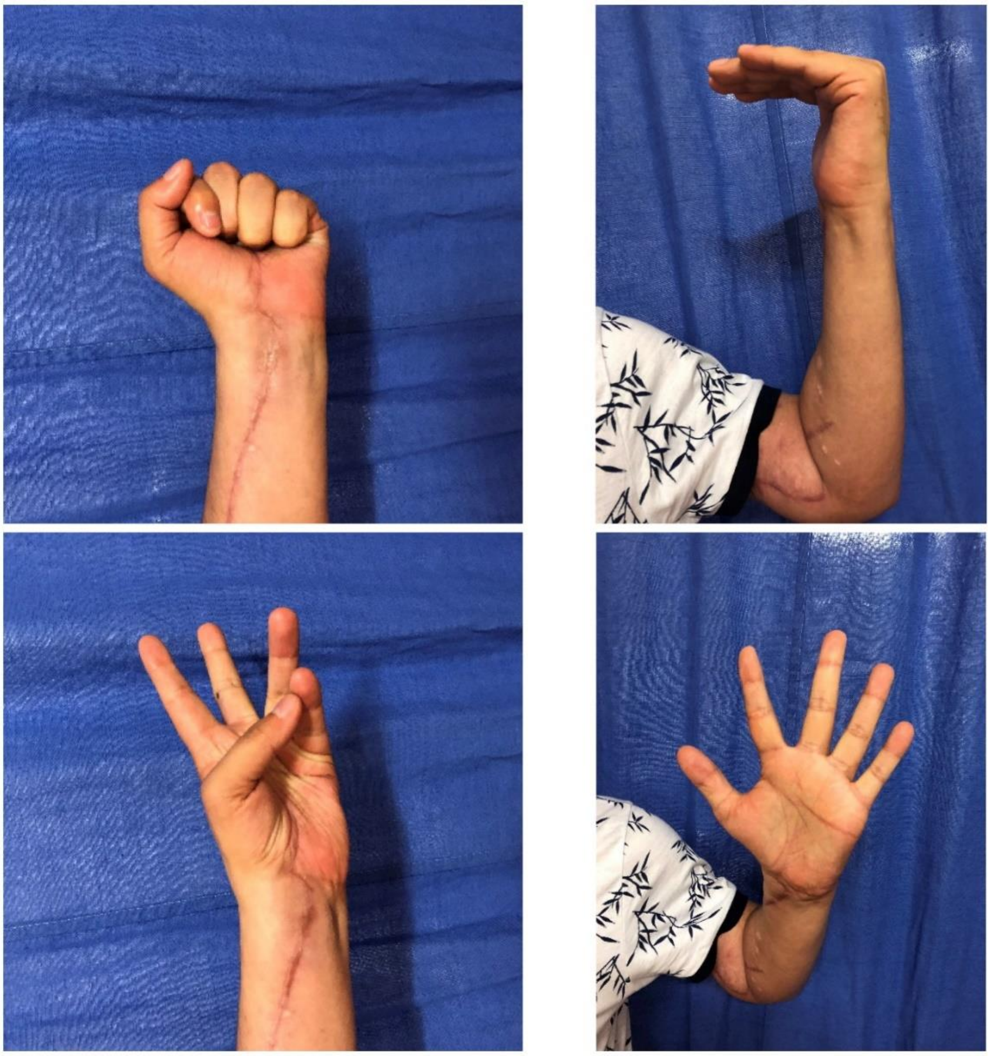

**Fig. 4.** Photo-documentation showing excellent thenar muscle function including full opposition. FPL and FDP II function was restored with tendon transfers (BR->FPL, FDP IV and FDP V>FDP II.

**Discussion**

Next to the ulnar nerve, the most commonly affected nerve in upper extremity nerve injuries is the median nerve[17]. Unfortunately, high-nerve injuries have the most unpredictable and discouraging outcomes[1,3,18]. While sensation may return after even an extensive denervation period[17], motor function is particularly affected with poor regeneration potential. This is for sure also determined by simple statistics, with less than 500 motor axons responsible for the thenar musculature fighting for pathway and target with more than 60.000 sensory axons[4]. In total, it is less than 2000 motor neurons (1.300 deep branch of ulnar and 500 recurrent median) responsible for the entire intrinsic capacity of the hand.

In a retrospective study including 110 patients with ulnar nerve lesions, Vastamaki *et al*. reported patient's age, the level of injury and delay to treatment as three major factors influencing successful outcomes of ulnar nerve lesions18, findings which were corroborated by Ruijs *et al.* [19].

With respect to age, reconstruction of high-level nerve injuries has been observed to have particularly unfavorable outcome in adults compared to patients under the age of 18 years[20]. There was no observed difference in patients with more distal injuries.

The intrinsic muscles of the median and ulnar nerve are furthest in the upper extremity, meaning that proximal level lesions require extensive time for regenerating axons to reestablish target muscle contact in the hand[1,21]. As recovery is time-dependent, an irreparable fibrosis of target muscles must be prevented and it is important that these muscles are reinnervated early, even at low power levels, to allow eventual full recovery[17,22,23].

This is significant, as the intrinsic muscles exhibit the highest innervation densities observed in humans.[7]. These muscles require innervation within a short timeframe to regain fine control and coordinated muscle movement. In order to achieve that goal, the principal step must be the reconstruction of continuity with the original motor source[22].

The procedure presented in this case report is designed for cases of either late reconstruction or high-level lesions. As described previously, the babysitter approach aims to provide valuable motor axons to babysit denervated muscles until native axons finally reach their most distal targets[8].

In our case, the motor branch to the ADM of the ulnar nerve met the requirements. It is a pure motor nerve in topographic and cognitive proximity to the recurrent thenar branch and it normally innervates muscles functionally synergistic to target muscles of the thenar eminence. The motor branch of the ADM has enough axonal power to provide motor input to orphan median nerve targets due to short regeneration distances via the graft. As our results demonstrate, the "denervation clock"[13] can thus be bypassed using the babysitter technique and the intrinsic muscles of the hand are kept functioning over prolonged periods without innervation by the original nerve.

The inspiration for the surgical treatment in our patients arises from a naturally existing ulnar to median nerve communication, the Riche-Cannieu anastomosis (RCA)[24]. The only possible way to create an artificial RCA was by interposition of a sensory nerve graft. This was achieved in an end-to-end fashion to the donor fascicle. The graft was coapted end-to-side into the recurrent median nerve, by creating a perineural window in the side of the nerve through which regenerating axons could grow.

The decision in favor of the perineural windows instead of epineural end-to-side coaptation was made to offer a barrier-free environment for sprouting axons. The repeated ENG tests suggest that early reinnervation starts at three months and continues to improve over time. Polyphasic action potentials subsided in the final evaluation suggesting healthy, well reinnervated thenar muscles. The clinical outcome also reflects this (Figure 4). This observation is in accordance with other authors demonstrating the usefulness of this type of nerve reconstruction[17,25-31]. Siemionow and Brzezicki comment that "the advantage of end-to-side repair is the recovery of function of an injured nerve without compromising the function of the donor nerve"[17].

**Clinical significance**

The goal of the artificial "Riche-Cannieu anastomosis" is to extend the concept of distal nerve transfers, as has been described with the AIN transfer for high-median nerve lesions where this option is no longer possible. Our findings suggest that even this small amount of pure motor axons coming from the ADM motor branch suffices to reanimate the thenar muscles at an early time point. The strength has improved over time and appeared almost normal at 18 months follow-up. The repeated ENG tests suggest that early reinnervation starts at three months and continues to improve over time. Polyphasic action potentials subsided in the final evaluation suggesting healthy, well reinnervated thenar muscles. Since preoperative median nerve performance was rated as non-existent, this excellent result encourages for a further application of this procedure in patients presenting with extensively delayed repair or with lesion far away from target organs.

***Acknowledgement:*** We thank Aron Cserveny for his excellent illustrations of the technique we present in this paper. We thank Petra Gettinger PT, for her tremendous work with the patient during the follow-up.

*Conflict of interest statement*. None declared.

**References**

1. Pfaeffle HJ, Waitayawinyu T, Trumble TE. Ulnar nerve laceration and repair. *Hand Clin* 2007; 23(3): 291-299. doi: 10.1016/j.hcl.2007.06.003.
2. Secer HI, Daneyemez M, Gonul E, Izci Y. Surgical repair of ulnar nerve lesions caused by gunshot and shrapnel: results in 407 lesions. *J Neurosurg* 2007; 107(4): 776-783. doi: 10.3171/JNS-07/10/0776.
3. Terzis JK, Kokkalis ZT. Outcomes of secondary reconstruction of ulnar nerve lesions: our experience. *Plast Reconstr Surg* 2008; 122(4): 1100-1110. doi: 10.1097/PRS. 0b013e3181858f67.
4. Gesslbauer B, Hruby LA, Roche AD, Farina D, Blumer R, Aszmann OC. Axonal components of nerves innervating the human arm. *Ann Neurol* 2017; 82(3): 396-408. doi: 10.1002/ana.25018.
5. Vernadakis AJ, Humphreys DB, Mackinnon SE. Distal anterior interosseous nerve in the recurrent motor branch graft for reconstruction of a median nerve neuroma-in-continuity. *J ReconstrMicrosurg* 2004; 20(1): 7-11. doi: 10.1055/s-2004-818043.
6. Frank K, Englbrecht M, Koban KC, Cotofana SC, Stewart JK, Giunta RE, *et al*. Nerve transfer of the anterior interosseous nerve to the thenar branch of the median nerve - an anatomical and histological analysis. *J PlastReconstrAesthet Surg* 2019; 72(5): 751-758. doi: 10.1016/j.bjps.2018.12.017.
7. Feinstein B, Lindegard B, Nyman E, Wohlfart G. Morphologic studies of motor units in normal human muscles. *ActaAnat (Basel)* 1955; 23(2): 127-142. doi: 10.1159/ 000140989.
8. Terzis JK, Tzafetta K. "Babysitter" procedure with concomitant muscle transfer in facial paralysis. *PlastReconstr Surg* 2009; 124(4): 1142-1156. doi: 10.1097/PRS. 0b013e3181b2b8bc.
9. DeSmet L. Anterior interosseous nerve transfer to the motor branch of the ulnar nerve: a case report. *Eur J PlastSurg* 2005; 28(8): 523-524. Available from: http://link.springer.com/10.1007/s00238-005-0010-5.
10. Haase SC, Chung KC. Anterior interosseous nerve transfer to the motor branch of the ulnar nerve for high ulnar nerve injuries. *Ann PlastSurg* 2002; 49(3): 285-290. doi: 10.1097/00000637-200209000-00008.

11. Battiston B, Lanzetta M. Reconstruction of high ulnar nerve lesions by distal double median to ulnar nerve transfer. *J Hand Surg Am* 1999; 24(6): 1185-1191. doi: 10.1053/jhsu.1999.1185.
12. Wood MB, Murray PM. Heterotopic nerve transfers: recent trends with expanding indication. *J Hand Surg Am* 2007; 32(3): 397-408. doi: 10.1016/j.jhsa.2006.12.012.
13. Mersa B, Tiangco DA, Terzis JK. Efficacy of the “baby-sitter” procedure after prolonged denervation. *J ReconstrMicrosurg* 2000; 16(1):27-35. doi: 10.1055/s-2000-7538.
14. Hadlock T, Sheahan T, Heaton J, Sundback C, Mackinnon S, Cheney M. Baiting the cross-face nerve graft with temporary hypoglossal hookup. *Arch Facial PlastSurg* 2004; 6(4): 228-233. doi: 10.1001/archfaci.6.4.228.
15. Lee EI, Hurvitz KA, Evans GRD, Wirth GA. Cross-facial nerve graft: past and present. *J Plast Reconstr Aesthet Surg* 2008; 61(3): 250-256. doi: 10.1016/j.bjps.2007.05.016.
16. Mackinnon S, Dellon A. Surgery of the peripheral nerve. 1st ed. New York: Thieme Medical Publishers; 1988.
17. Siemionow M, Brzezicki G. Chapter 8: Current techniques and concepts in peripheral nerve repair. *Int Rev Neurobiol* 2009; 87: 141-172. doi: 10.1016/S0074-7742(09)87008-6.
18. Vastamäki M, Kallio PK, Solonen KA. The results of secondary microsurgical repair of ulnar nerve injury. *J Hand Surg Br* 1993; 18(3): 323-326. doi: 10.1016/0266-7681(93)90053-i.
19. Ruijs ACJ, Jaquet J-B, Kalmijn S, Giele H, Hovius SER. Median and ulnar nerve injuries: a meta-analysis of predictors of motor and sensory recovery after modern microsurgical nerve repair. *PlastReconstrSurg* 2005; 116(2): 484-494; discussion 495-496. doi: 10.1097/01.prs.0000172896.86594.07.
20. Gaul JS. Intrinsic motor recovery-a long-term study of ulnar nerve repair. *J Hand Surg Am* 1982; 7(5): 502-508. doi: 10.1016/s0363-5023(82)80048-8.
21. Brown JM, Mackinnon SE. Nerve transfers in the forearm and hand. *Hand Clin* 2008; 24(4): 319-340. doi: 10.1016/j.hcl.2008.08.002.
22. Mackinnon SE, Colbert SH. Nerve transfers in the hand and upper extremity surgery. *Tech Hand Up ExtremSurg* 2008; 12(1): 20-33. doi: 10.1097/BTH.0b013e31812714f3.
23. Papakonstantinou KC, Kamin E, Terzis JK. Muscle preservation by prolonged sensory protection. J ReconstrMicrosurg; 18(3): 173-182; discussion 183-184. doi: 10.1055/s-2002-28469.
24. Bölükbası, O., Turgut, M. & Akyol, A. Ulnar to median nerve anastomosis in the palm (Riches-Cannieu anastomosis). *Neurosurg Rev* **22**, 138–139 (1999). https://doi.org/10.1007/s101430050049
25. Ray WZ, Mackinnon SE. Management of nerve gaps: Autografts, allografts, nerve transfers, and end-to-side neurorrhaphy. *ExpNeurol* 2010; 223(1): 77-85. doi: 10.1016/j.expneurol.2009.03.031.
26. Beris AE, Lykissas MG. Chapter 13: Experimental results in end-to-side neurorrhaphy. *Int Rev Neurobiol* 2009; 87: 269-279. doi: 10.1016/S0074-7742(09)87013-X.
27. Bontioti E, Dahlin LB. Chapter 12: Mechanisms underlying the end-to-side nerve regeneration. *Int Rev Neurobiol* 2009; 87: 251-268. doi: 10.1016/S0074-7742(09)87012-8.
28. Geuna S, Papalia I, Tos P. End-to-side (terminolateral) nerve regeneration: a challenge for neuroscientists coming from an intriguing nerve repair concept. *Brain Res Rev* 2006; 52(2): 381-388. doi: 10.1016/j.brainresrev.2006.05.002.

29. Tos P, Artiaco S, Papalia I, Marcoccio I, Geuna S, Battiston B. Chapter 14: End-to-side nerve regeneration: from the laboratory bench to clinical applications. *Int Rev Neurobiol* 2009; 87: 281-294. doi: 10.1016/S0074-7742(09)87014-1.
30. Brenner MJ, Dvali L, Hunter DA, Myckatyn TM, Mackinnon SE. Motor neuron regeneration through end-to-side repairs is a function of donor nerve axotomy. *PlastReconstrSurg* 2007; 120(1): 215-223. doi: 10.1097/01.prs.0000264094.06272.67.
31. Pannucci C, Myckatyn TM, Mackinnon SE, Hayashi A. End-to-side nerve repair: review of the literature. *RestorNeurolNeurosci* 2007; 25(1): 45-63. PMID: 17473395. http://www.ncbi.nlm.nih.gov/pubmed/17473395.