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Original Research

Individualization of Donor Nerve Selection With Intraoperative Nerve Monitoring in Axillary Nerve Neurotization

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A R T I C L E I N F O

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Purpose: This study aimed to evaluate the use of intraoperative nerve conduction studies in radial to axillary nerve transfers using the motor branches to the triceps. We hypothesized that morphological characteristics might not fully express a donor nerve's suitability for transfer and that choosing the donor branch based on nerve action potential (NAP) amplitudes would lead to better functional outcomes.
Methods: This retrospective analysis included 17 patients who underwent radial to axillary nerve transfer. The specific triceps motor branch used as donor and the site of neurorrhaphy were chosen based on intraoperative NAP amplitudes independently of morphological criteria, such as size matching or arc of rotation.
Results: We found a moderate correlation between the NAP amplitude of the transferred branch and shoulder abduction strength at the end of the follow-up. The branch to the lateral head of the triceps was the most often selected as a donor. Outcomes were satisfactory in 14 out of 17 patients.
Conclusions: The findings suggest that reinnervation is enhanced when the choice of the donor branch is individualized and based on functional metrics like NAP, instead of anatomical characteristics. The study supports the role of intraoperative nerve monitoring as an objective and predictable method to refine donor branch selection in radial to axillary nerve transfer.
Type of study/level of evidence: Therapeutic IV.

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In radial to axillary nerve transfers for the restoration of deltoid function, there is controversy about which of the motor branches to the triceps is best to use as a donor. In 2003, Witoonchart et al[1] published an anatomical feasibility study for the technique based on the branch to the long head of the triceps. In the same year, Leechavengvongs et al[2] published a short series of seven cases with good results using this choice. In 2006, Colbert and Mackinnon[3] published their results using the branch for the medial head of the triceps. In 2007, Bertelli et al[4] published another series of three cases, using either the branch to the long head of the triceps, as described in the original technique, or a double transfer using the branches to the long and medial heads. Cited reasons for choosing one branch over the others are proximity to the target muscle (meaning shorter reinnervation times), arc of rotation, ease of dissection, and size similarities. These technical aspects are partially affected by the point along the axillary nerve where neurorrhaphy is performed, as nerve branches can be transferred

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proximally to the axillary nerve's main trunk, which has a larger section area, or more distally onto one of its terminal divisions. Wasteful regeneration of axons into functionally unrelated branches (to the teres minor and the superior lateral cutaneous nerve) is a concern in excessively proximal nerve transfers, especially if the axonal load of the donor branch is insufficient. The possibility of missing an injury distal to the coaptation site is also a hazard, as it effectively means transferred axons will regenerate into a dead end instead of reinnervating the target muscle.

It is possible that morphological characteristics, although important, might not fully reflect a nerve's conductive properties and suitability for transfer. Consequently, it makes sense that the choice of donor branch should be at least partially based on measurable neurophysiological variables, such as those provided by intraoperative nerve monitoring.

The aim of our study was to assess the use of intraoperative electroneurography in radial to axillary nerve transfers. We hypothesized that better results could be achieved by basing the choice of donor branch on the nerve action potential (NAP) of candidate donor nerves. As the sum of the potential carried by each individual fiber, NAP correlates to the existing number of functional axons in a branch, thus helping evaluate its prospects for supplying the receptor nerve. Thus, we set out to determine if NAP amplitude predicts a better neurotization result, as its absence in the context of injury predicts poor reinnervation outcomes.[5,6]

Methods

A retrospective study including patients from 2014 to 2021 was undertaken to analyze if radial to axillary nerve transfer assisted by intraoperative nerve monitoring achieves satisfactory results in axillary nerve injuries of diverse etiology. Of the 50 consecutive cases that were intervened surgically for brachial plexus injuries involving the axillary nerve, 17 patients were included in the analysis. The other 33 patients were excluded because of either having incomplete clinical records (12 cases), a nonstandardized intraoperative nerve monitoring protocol (12), an end-to-end radial to axillary nerve transfer ultimately not being performed (8), or because they were lost to follow-up (1). Specifically, the decision not to perform an end-to-end transfer was taken in accordance with intraoperative findings such as the presence of residual conduction in the axillary nerve, which advised neurolysis or a supercharge type intervention instead. Both surgery and clinical follow-up were performed by the same lead surgeon in the facilities of two different hospitals. The lead surgeon was an expert specialist, corresponding to level 5 of Tang and Giddins' criteria.[7] Neurophysiologists, anesthesiologists, assistant surgeons, and other personnel involved in the procedures varied between interventions.

Data obtained from clinical records included age, sex, injured side, etiology, nerve injury type with regard to Sunderland's classification (when applicable, ie, in all cases of traumatic etiology), and days passed between injury and surgery. Preoperative needle EMG findings on the deltoid and triceps muscles were also recorded to assess preoperative function and obtain baseline values that would help detect donor site morbidity in case it became apparent.

Outcomes were measured clinically in terms of strength on abduction in the plane of the scapula at the end of follow-up. The end of follow-up was defined as the moment at which no further progress was achieved by the patient in subsequent visits, provided a minimal reinnervation time of 12 months had passed. To better isolate the deltoid from rotator cuff contributions when assessing motor recovery, EMG examinations targeting the deltoid were also performed during follow-up, supplementing clinical information. The neurophysiological result of the surgical intervention was evaluated based on the decrease in deltoid fibrillation at the end of the follow-up. It should be noted that postoperative decrease in muscle fibrillation is not a valid assessment of recovery by itself, as failure to reinnervate will, in time, also lead to a silent EMG record when muscle fibers undergo fibrosis and fatty replacement. A notable decrease in fibrillation in the presence of observable, active muscle function, however, is a positive indicator of neuromuscular restoration. In other words, postoperative EMG variables were never considered in isolation but only in the context of clinically verifiable muscle contraction.

Fibrillation was described by an ordinal scale, which categorized muscle fibrillation as absent, occasional, moderate, or abundant, following the consensus described by the 2019 updated standards of the International Congress of Clinical Neurophysiology.[8] The Medical Research Council (MRC) scale, in its version modified by Paternostro-Sluga, was used to describe muscle function instead of quantitative measurements such as raw force measurements or active range of motion, as we consider it more representative of a patient's ability to interact with the environment. Furthermore, the modified MRC integrates range of motion information, which was considered an advantage as many of our patients experienced sequelae from concomitant injuries (rotator cuff tears, fractures, etc) that would have altered other outcome variables.[9,10]

Surgery was performed through a posterior approach, in lateral decubitus, and with the injured extremity pointing upward and flexed at the elbow. The axillary nerve was identified in the quadrangular space and the radial nerve in the innominate space, beneath the teres major tendon. When both nerves were localized and their different branches individualized, intraoperative neurophysiological recording was performed.

All intraoperative neurophysiological studies were performed using the three-channel Nicolet EDXEMG/NCS/EP/IOM system. Through a bipolar or tripolar (two cathodes and one anode) stimulator, intraoperative neurophysiological studies were performed. Intensity of stimulation ranged from 0.1 to 25 mA. The duration of stimuli was 200 ms, and the stimulation rate was 1 Hz. For recording, a bipolar hook electrode was used. Epoch length was fixed at 20–30 ms, and a 2000-5 Hz filter was applied.

The axillary nerve was studied along its course to detect sharp, localized decreases in potential, with the intention of identifying and marking the specific injury site at which conduction stopped. Regarding candidate donor radial nerve branches, the one with the highest NAP amplitude was selected, regardless of other considerations such as branch length or girth. After choosing a branch, the transfer was performed under microscopic view with a 9–0 nonabsorbable thread and fibrin glue. The chosen branch was transferred to either the axillary nerve itself or to its anterior division, verifying that coaptation was always performed distally to any local alterations in the axillary nerve's conductivity. After neurorrhaphy, the approach was then closed layer by layer, and a soft bandage and sling were put in place for 3 weeks after discharge.

A Shapiro-Wilk test was initially performed to evaluate normality in the variables of interest: age, surgical delay, preoperative and postoperative deltoid fibrillation, NAP amplitude at the transferred branch, and abduction strength at the end of follow-up. All variables examined followed nonnormal distributions except for age.

The relationship between intraoperative NAP amplitude at the transferred radial branch and abduction strength at the end of follow-up was analyzed by calculating Spearman's rank correlation coefficient between both variables. Because of the ordinal

Table 1
Detailed Demographics of the Studied Sample, Including Nerve Injury Type According to Sunderland's Classification, the Injury Pattern (Axillary Nerve or Upper-Brachial Plexus), the NAP Found at the Transferred Branch in Microvolts, the Donor and Receptor Nerves Involved in the Transfer, and Abduction Strength Before and After Surgery According to the mMRC Scale

Case	Sex	Age (Y)	Injury Pattern	Class (Sunderland)	NAP (μV)	Transfer Performed	Preoperative Strength (mMRC)	Postoperative Strength (mMRC)
1	M	37	Upper brachial plexus	V	50	Lateral to common trunk	0	0
2	F	19	Axillary nerve	V	400	Lateral to anterior division	0	3
3	M	27	Upper brachial plexus	IV	200	Lateral to anterior division	0	4
4	M	51	Axillary nerve	V	125	Lateral to common trunk	0	4
5	M	52	Axillary nerve	IV	150	Lateral to anterior division	0	3
6	M	52	Upper brachial plexus	IV	500	Medial to common trunk	0	4
7	M	52	Upper brachial plexus	Not applicable*	850	Lateral to common trunk	0	4
8	M	35	Axillary nerve	IV	240	Lateral to anterior division	0	5
9	M	21	Axillary nerve	IV	800	Lateral to anterior division	0	5
10	M	72	Upper brachial plexus	V	100	Lateral to anterior division	0	4
11	F	25	Upper brachial plexus	Not applicable*	45	Lateral to common trunk	0	1
12	M	18	Upper brachial plexus	IV	200	Lateral to common trunk	0	5
13	M	46	Upper brachial plexus	IV	500	Lateral to common trunk	0	4
14	M	57	Upper brachial plexus	V	60	Lateral to common trunk	0	4
15	M	21	Upper brachial plexus	IV	75	Lateral to common trunk	1	2
16	M	40	Upper brachial plexus	V	138	Long to common trunk	0	4
17	M	20	Upper brachial plexus	IV	150	Lateral to common trunk	0	4

* Patients with nontraumatic denervation caused by Parsonage-Turner syndrome.

nature of the MRC score, Kendall's tau test was also performed to offer additional robustness to this analysis.

We performed a paired Wilcoxon test between preoperative and postoperative fibrillation scores to provide objective reinnervation data that supported clinical observations.

Age (years), time between injury and surgery, and injury classification (according to Sunderland's system) were considered potential confounders. An ordinal logistic regression analysis was initially considered but rejected because of the small sample size and imbalanced distribution of abduction values, leading to overfitting and an unreliable result. Instead, Spearman's correlation was used to explore the possibility of abduction strength being influenced by age or delay of the intervention. Following the same reasoning, Kruskal-Wallis' test was used to assess a possible relationship between injury classification and final abduction strength.

Written informed consent was obtained from the patients for their anonymized information to be published in this article. Ethical approval for this study was obtained from the University of Barcelona Bioethics Committee (IRB00003099). The authors adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines in the elaboration of the manuscript.

Results

The mean age of the 17 participants was 38 years (range: 18−72). Most cases (13 out of 17) had experienced injury to their right shoulder. The mean delay between the date of injury and the date of surgery was 409 days, with a median of 317 days (range: 110−1485, interquartile range: 274−346). Table 1 summarizes in more detail the demographics of the sample.

Our study included patients with isolated axillary nerve injuries and more complex injuries affecting the upper trunk of the brachial plexus. In patients with upper-brachial plexus injuries, other nerve transfers were sometimes performed: one patient underwent a spinal to suprascapular nerve transfer, three patients underwent an Oberlin transfer, and five patients underwent both procedures. The cause of injury varied; high-energy trauma accounted for 12 cases (11 motor vehicle collisions and one paragliding accident), whereas other etiologies included low-energy trauma leading to shoulder dislocation (1 case), Parsonage-Turner Syndrome (2 cases), and iatrogenic nerve damage (2 cases, in the context of unrelated shoulder surgeries).

The radial nerve branch chosen for transfer varied among the participants, with the branch to the lateral head being chosen most often (15 cases). In contrast, both the branches to the medial and the long heads were selected in one case, respectively. The NAP amplitude of the transferred branch had a mean value of 267 μV (range: 45−850, interquartile range: 100−400). The median abduction strength after surgery was an MRC of 4, with a mean value of 3.529. No postoperative complications or donor site morbidity occurred in any of our patients.

The estimated Spearman correlation coefficient (ρ) between intraoperative NAP amplitude found at the transferred radial branch and abduction strength at the end of follow-up was found to be 0.577, indicating a moderate positive correlation between both variables with a P value of .0152. Kendall's tau correlation between transferred branch NAP and abduction strength also showed a statistically significant, moderate positive relationship ($\tau = 0.4530$; P value = .021). Figure 1 shows a scatter plot summarizing these results. The paired Wilcoxon signed-rank test used to evaluate changes in fibrillation scores showed a statistically significant decrease after surgery ($V = 70$, $P = .014$).

We used Spearman's rank correlation to evaluate the relationships between patient age, the number of days before surgery, and the final abduction outcome. Both age ($\rho = -0.039$, $P = .883$) and surgical delay ($\rho = 0.041$, $P = .875$) showed negligible and nonsignificant correlations with abduction, indicating no meaningful association. Additionally, the Kruskal-Wallis test ($H = 2.473$, $P = .290$) revealed no significant differences in abduction outcomes across Sunderland classifications. These findings suggest that patient age, timing of surgery, and the type of nerve injury (as classified by Sunderland) did not significantly influence the outcome in the analyzed sample.

Discussion

This study sought to make nerve transfers more objective and predictable by basing donor branch selection on measurable electrophysiological variables, instead of relying on morphology.

We found a moderate correlation between NAP amplitude at the transferred branch and abduction strength. The effect of the intervention was further demonstrated by improved deltoid function with concomitant decreases in deltoid fibrillation. In

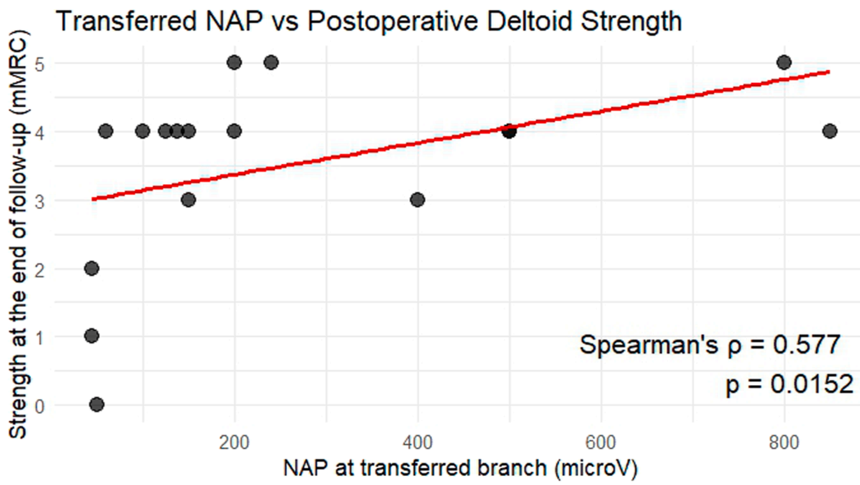

Figure 1. A scatter plot showing the Spearman correlation between NAP in microvolts found intraoperatively at the transferred branch and the abduction strength achieved at the end of follow-up in the modified Medical Research Council grading scale (mMRC).

12/17 patients, an abduction strength of ≥M4 was achieved, with the branch for the lateral head of the triceps being the most frequent donor. This was unexpected, as other case series seldom report this choice.

A review by Wells et al[11] defined success as either a postoperative abduction range of ≥40° or postoperative abduction strength of ≥M3. Only the branches to the long and medial heads were used in the reports studied, with a success rate of 16/21 and 2/7, respectively. Another series by Desai et al,[12] uncovered by Wells, reported 17/27 cases attaining ≥M4, with all donor branches represented with comparable results between them, and no specific criteria cited for selection. Four cases were deemed failures with no identifiable cause: notably, none of them occurred when transferring the lateral head branch. In our sample, the three patients not attaining M3 had received lateral head branch transfers with NAPs ranging from 45 to 75 μV (ie, values lower than the 20th percentile).

A possible explanation for our failed transfers is subclinical radial nerve involvement undetected by preoperative needle EMG. Even with careful technique, nerve transfer likely causes the loss of a percentage of nerve fibers, further aggravated by misrouting of budding axons during reinnervation across the coaptation site, as documented in experimental models.[13] In the context of nerves with borderline axonal populations, this insufficiency may become apparent after the attrition caused by transfer and regeneration. Detecting axonal depletion is especially beneficial when donor nerve dysfunction is hard to anticipate location-wise. Traumatic injuries typically follow etiology-related anatomical patterns (avulsive mechanisms, penetrating injuries, etc); this is not the case for patched, random patterns of brachial plexus damage, such as those found in Parsonage-Turner syndrome.

Strength after peripheral nerve surgery decreases with age and surgical delay.[14,15] Nonetheless, we believe in attempting surgery if preoperative EMG studies show fibrillation potentials and positive sharp waves, meaning muscle fibers are still responsive to electrical stimulation and yet to undergo fibroadipose metaplasia. This was the case in all our patients; hence, the negative effects of age and delay might have been minimized. This is exemplified by cases 11 and 14, whose delays far exceeded the conventional therapeutic window for nerve transfer (1,485 and 1,172 days, respectively). In any case, we indicated surgery whenever patients showed a lack of clinical progression in subsequent visits and EMG studies, which combined suggested a high-grade injury warranting surgical exploration.[16]

Regarding assessment of neuromuscular function before nerve transfer, Schreiber et al[15] used compound muscle action potentials (CMAP) for preoperative evaluation of donor nerves, finding better outcomes in patients with unaltered EMGs. Bhandari et al[17] published in 2009 a case-control study of patients undergoing the Oberlin procedure, in which donor fascicles were either chosen with the aid of a handheld nerve stimulator or selected based on ease of dissection. They found the use of the nerve stimulator unnecessary when its application was only qualitative and based on the observable muscle contraction obtained by stimulating potential donors. In a case series by Suzuki et al,[18] donor fascicle selection for biceps neurotization was based on quantitative intraoperative CMAPs; higher-amplitude CMAPs showed correlation with a stronger elbow flexion after surgery. We prefer NAP to CMAP because evoked potentials recorded from muscles are sensitive to anesthetic paralytic agents and because electrical potentials generated by nearby muscles can be mistaken for the target CMAP.

We consider size matching a poor predictor of success, as a nerve's section area depends on both axonal load and nonneural components, including a variable amount of inter- and intrafascicular connective tissue. Regarding fiber counts, Khair et al[19] described the axonal loads of radial nerve branches, finding that the branches to the medial, long, and lateral heads of the triceps had donor-to-recipient ratios of 54%, 57%, and 36%, respectively, compared with the axillary nerve. Their conclusion was that the branch to the medial head was the superior choice because of its large axon count and good swing distance. The role of fascicular topography, however, plays an underexplored role in this regard. As reinnervation requires axons to navigate the coaptation site, it is conceivable that a complex intraneural architecture with numerous fascicles and connective tissue barriers is an obstacle to reinnervation. Further microanatomical studies are needed in this direction.

We acknowledge that the functional diversity (ie, motor vs sensitive) of the nerve fibers themselves cannot be assessed by NAP, as the signal obtained by stimulation represents the summed potentials of orthodromic motor conduction and antidromic sensory conduction.[20] This is an important limitation, considering that "pure motor" nerves may be carrying a nonnegligible proportion of sensory fibers for proprioceptive and sensory functions.[21] The theoretical assumption that the proportion of sensory fibers is similar in all candidate donors must be addressed in further research, as motor axon stumps are known in experimental models to preferentially grow into motor pathways after transection.[22]

As a case series, our study has several limitations. Although the transferred branch was always the one with the highest NAP amplitude, the recordings for the unchosen branches were often missing from surgical reports. The branches for the medial and long heads were only chosen once, impeding the obtention of representative samples of each. Consequently, our analysis did not generate evidence of any branch's general superiority in neurophysiological terms. Nonetheless, this outcome is indirect evidence of the utility of intraoperative nerve monitoring, as we can speculate that the choice might have been different if based on published anatomical evidence. Our lack of a control group and the heterogeneity of other published case series preclude direct comparison with such a cohort. Finally, it should be noted that we did not consider the personnel and equipment implications of our approach, which is another limitation requiring further inquiry.

In any case, these findings support the idea that donor branch selection should be based on functional, measurable parameters. Our results suggest that NAP of around 100−150 μV can restore satisfactory (≥M4) function, whereas the threshold for achieving ≥M3 lies closer to around 50 μV.

Conflicts of interest

No benefits in any form have been received or will be received related directly to this article.

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References

1. Witoonchart K, Leechavengvongs S, Uerpairojkit C, Thuvasethakul P, Wongnopsuwan V. Nerve transfer to deltoid muscle using the nerve to the long head of the triceps, part I: an anatomic feasibility study. *J Hand Surg Am*. 2003;28(4):628−632.
2. Leechavengvongs S, Witoonchart K, Uerpairojkit C, Thuvasethakul P. Nerve transfer to deltoid muscle using the nerve to the long head of the triceps, part II: a report of 7 cases. *J Hand Surg Am*. 2003;28(4):633−638.
3. Colbert SH, Mackinnon S. Posterior approach for double nerve transfer for restoration of shoulder function in upper brachial plexus palsy. *Hand (N Y)*. 2006;1(2):71−77.
4. Bertelli JA, Kechele PR, Santos MA, Duarte H, Ghizoni MF. Axillary nerve repair by triceps motor branch transfer through an axillary access: anatomical basis and clinical results. *J Neurosurg*. 2007;107(2):370−377.
5. Tiel RL, Happel LT, Kline DG. Nerve action potential recording method and equipment. *Neurosurgery*. 1996;39(1):103−108; discussion 108.
6. Zelenski NA, Oishi T, Shin AY. Intraoperative neuromonitoring for peripheral nerve surgery. *J Hand Surg Am*. 2023;48(4):396−401.
7. Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. *J Hand Surg Eur Vol*. 2016;41(4):365−366.
8. Stålberg E, van Dijk H, Falck B, et al. Standards for quantification of EMG and neurography. *Clin Neurophysiol*. 2019;130(9):1688−1729.
9. Paternostro-Sluga T, Grim-Stieger M, Posch M, et al. Reliability and validity of the Medical Research Council (MRC) scale and a modified scale for testing muscle strength in patients with radial palsy. *J Rehabil Med*. 2008;40(8):665−671.
10. Wang Y, Sunitha M, Chung KC. How to measure outcomes of peripheral nerve surgery. *Hand Clin*. 2013;29(3):349.
11. Wells ME, Gonzalez GA, Childs BR, Williams MR, Nesti LJ, Dunn JC. Radial to axillary nerve transfer outcomes in shoulder abduction: a systematic review. *Plast Reconstr Surg Glob Open*. 2020;8(9):e3096.
12. Desai MJ, Daly CA, Seiler JG, Wray WH, Ruch DS, Leversedge FJ. Radial to axillary nerve transfers: a combined case series. *J Hand Surg Am*. 2016;41(12):1128−1134.
13. De Ruiter GCW, Spinner RJ, Verhaagen J, Malessy MJA. Misdirection and guidance of regenerating axons after experimental nerve injury and repair. *J Neurosurg*. 2014;120(2):493−501.
14. Bonnard C, Anastakis DJ, Van Melle G, Narakas AO. Isolated and combined lesions of the axillary nerve. A review of 146 cases. *J Bone Joint Surg Br*. 1999;81(2):212−217.
15. Schreiber JJ, Feinberg JH, Byun DJ, Lee SK, Wolfe SW. Preoperative donor nerve electromyography as a predictor of nerve transfer outcomes. *J Hand Surg Am*. 2014;39(1):42−49.
16. MacKinnon SE, Novak CB. Nerve transfers. New options for reconstruction following nerve injury. *Hand Clin*. 1999;15(4):643−666, ix.
17. Bhandari PS, Deb P. Fascicular selection for nerve transfers: the role of the nerve stimulator when restoring elbow flexion in brachial plexus injuries. *J Hand Surg Am*. 2011;36(12):2002−2009.
18. Suzuki O, Sunagawa T, Yokota K, et al. Use of quantitative intra-operative electrodiagnosis during partial ulnar nerve transfer to restore elbow flexion. *J Bone Joint Surg Br*. 2011;93(B):364−369.
19. Khair MM, Schreiber JJ, Rosenblatt L, Byun DJ, Lee SK, Wolfe SW. Axon counts yield multiple options for triceps fascicular nerve to axillary nerve transfer. *J Hand Surg Am*. 2016;41(11):e405−e410.
20. Bączyk M, Manuel M, Roselli F, Zytnicki D. Diversity of mammalian motoneurons and motor units. *Adv Neurobiol*. 2022;28:131−150.
21. Mioton LM, Dumanian GA, De la Garza M, Ko JH. Histologic analysis of sensory and motor axons in branches of the human brachial plexus. *Plast Reconstr Surg*. 2019;144(6):1359−1368.
22. Brushart TME. Motor axons preferentially reinnervate motor pathways. *J Neurosci*. 1993;13(6):2730−2738.